EN

Horizon Europe

Work programme 2021-2022

4. Digital, Industry and Space

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[Decision reference after adoption]

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Introduction

Progress in digital and industrial technologies, including in space, shape all sectors of the economy and society. They transform the way industry develops, produces new products and services, and are central to any sustainable future. The COVID-19 crisis of 2020 has shown the necessity to strengthen Europe’s industrial base, enhancing its resilience and flexibility both in terms of technologies and supply chains to reduce EU dependencies on third countries. It has also created a new urgency around addressing key societal challenges like sustainability or inclusiveness. In a globalised world of heightened uncertainties and volatile geopolitical interests, what is at stake is not only Europe’s prosperity and economic competitiveness, but also its ability to autonomously source and provide crucial raw materials, technologies and services that are safe and secure for industry as a whole. This is not about protectionism. This is about upholding EU’s strategic interests.

As Europe gears up for a more resilient, green, and digital recovery, the EU needs to maintain a strong industrial and technology presence in key parts of digital and other supply chains, in industrial ecosystems while safeguarding its ability to access and operate safely in space. This is critical not only to be able to compete globally, but also to protect its citizens, deliver services and products of the highest quality, and preserve its values and socio-economic model. To come out of the crisis faster, it will not only need to develop, but also deploy technologies and reshape its industries and services towards a new reality, ensuring that industry can become the accelerator and enabler of this change, as stated in the European Commission’s ‘New Industrial Strategy for Europe’ supporting the Green Deal and announcing the Circular Economy Action Plan, digital strategies ‘Shaping Europe’s Digital Future’, ‘Data’ ‘Artificial Intelligence White Paper and ‘Space Strategy for Europe’ . To deliver on a green and digital transformation according to European values, Europe must master digital, space and key enabling technologies and reintegrate some of its supply chains into the EU. Increased adaptability and resilience to improve production response, recovery and preparedness will also include continuous investments in upskilling and reskilling of the work force.

The green transition and digital transformation are just at their beginning. Major opportunities lie ahead to position Europe as a technology and industrial leader of this transition. The overarching vision behind the proposed investments under Cluster 4 is that of Europe shaping competitive and trusted technologies for a European industry with global leadership in key areas, enabling production and consumption to respect the boundaries of our planet, and maximising the benefits for all parts of society in the variety of social, economic and territorial contexts in Europe.

Actions under this cluster will support key enabling technologies that are strategically important for Europe’s industrial future, and deliver on the following six expected impacts in the Strategic Plan, through matching destinations in this Work Programme:

- Global leadership in clean and climate-neutral industrial value chains, circular economy and climate-neutral digital systems and infrastructures (networks, data centres), through innovative production and manufacturing processes and their digitisation, new business models, sustainable-by-design advanced materials and technologies enabling the switch to decarbonisation in all major emitting industrial sectors, including green digital technologies.

- Industrial leadership and increased autonomy in key strategic value chains with security of supply in raw materials, achieved through breakthrough technologies in areas of industrial alliances, dynamic industrial innovation ecosystems and advanced solutions for substitution, resource and energy efficiency, effective reuse and recycling and clean primary production of raw materials, including critical raw materials.

- Sovereignty in digital technologies and in future emerging enabling technologies by strengthening European capacities in key parts of digital and future supply chains, allowing agile responses to urgent needs, and by investing in early discovery and industrial uptake of new technologies.

- Globally attractive, secure and dynamic data-agile economy by developing and enabling the uptake of the next-generation computing and data technologies and infrastructures (including space infrastructure and data), enabling the European single market for data with the corresponding data spaces and a trustworthy artificial intelligence ecosystem.

- Strategic autonomy in conceiving, developing, deploying and using global space-based infrastructures, services, applications and data, including by reinforcing the EU's independent capacity to access space, securing the autonomy of supply for critical technologies and equipment, and fostering the EU's space sector competitiveness.

- A human-centred and ethical development of digital and industrial technologies, through a two-way engagement in the development of technologies, empowering end-users and workers, and supporting social innovation.

DESTINATION 1 – Climate neutral, circular and digitised production TWIN-TRANSITION-2021-2022

This Destination foucuses on the twin green and digital transition in the Union's manufacturing, construction and process industries.

Manufacturing and Construction Industries:

The gross added value of the European manufacturing sector is EUR 2,076 billion (2019). The sector employs more than 30 million people in the Union and represents 22% of the world's manufacturing output. The Union's trade surplus in manufactured goods is EUR 421 billion (2019). Similarly, the construction sector (driven mainly by SMEs) offers 18 million jobs and contributes to 9% of the Union's GDP.

However, the manufacturing and construction sectors must significantly reduce their pollution and waste, and increase their recycling. Moreover, the potential of digital technologies is underused in manufacturing industry, e.g. 12% of EU enterprises use big data technologies and only 1 out of 5 SMEs is highly digitised. Construction in particular remains one of the least digitised sectors, with a notable underinvestment in R&D. A key issue for the manufacturing sector is that its complex supply and value chains are heavily affected by the current pandemic crisis, and the sector needs to further develop resilience against financial and technical disruptions.

This destination will therefore support the Union's manufacturing and construction sectors in the twin green and digital transition. It will help these sectors increase productivity, innovation capacity, resilience and global competitiveness. It will lead to flexible, responsive and resilient factories and value chains, enabled by digitisation, AI, data sharing, advanced robotics and modular manufacturing. At the same time it will help reduce CO2 emissions and waste in these sectors, and enhance the durability, reparability and re-cycling of products/components – that is, circular economy approach at the design phase. A further, crucial objective is to make the jobs of the humans working in the manufacturing and construction sectors more attractive and safer, and point the way to opportunities for upskilling.

Process Industries:

The Union's process industry is hugely important to its economy, its resilience and its environmental credentials, but faces two key challenges: a strong global pressure (e.g. China, USA), and an environmental challenge. Process industries are by nature resource intensive, using huge amounts of raw materials, often imported fossil based ones. In their operations, they generate large amounts of waste, greenhouse gases (GHG) and pollutats. The sector needs to transform itself to decrease GHG and pollutant emissions, its resource utilisation and its overall environmental impact. It will have to achieve climate neutrality, near zero waste, zero pollution and zero landfill by 2050 at the latest.

As with the manufacturing and construction sectors, this destination will support the Union's process industry in its twin green and digital transition. Key developments to be pursued are

- Hubs for circularity, as a stepping stone towards climate neutrality and circularity in industry (in particular, at least 10 new hubs for circularity by 2025, providing large scale demonstration platforms at TRL 7 and above);

- A circular utilisation of waste streams and CO2/CO streams, turning waste into a resource and giving access to alternative feedstocks to replace fossil based raw materials. To make process industries more sustainable, it is critical to reduce resource utilisation as well as waste and emissions generation; and

- Electrification and a switch to renewable energy systems.

This destination will directly support the following Key Strategic Orientations, as outlined in the Strategic Plan:

- A, '**Promoting an open strategic autonomy by leading the development of key digital, enabling and emerging technologies, sectors and value chains** to accelerate and steer the digital and green transitions through human-centred technologies and innovations.'

- C, '**Making Europe the first digitally led circular, climate-neutral and sustainable economy** through the transformation of its mobility, energy, construction and production systems.'

Proposals for topics under this Destination should set out a credible pathway to contributing to the following expected impact:

> **Global leadership in clean and climate-neutral industrial value chains, circular economy and climate-neutral digital systems and infrastructures (networks, data centres),** through innovative production and manufacturing processes and their digitisation, new business models, sustainable-by-design advanced materials and technologies enabling the switch to decarbonisation in all major emitting industrial sectors, including green digital technologies.

This Destination is structured into the following sections:

- Green, flexible and advanced manufacturing
- Advanced digital technologies for manufacturing
- A new way to build, accelerating disruptive change in construction
- Hubs for circularity, a stepping stone towards climate neutrality and circularity in industry
- Enabling circularity of resources in the process industries, including waste, water and CO2/CO
- Integration of Renewables and Electrification in process industry

The following call(s) in this Work Programme contribute to this Destination:

The Destination structure and the allocation of topics to calls and year will be decided at a later stage.

Section: Green, flexible and advanced manufacturing

[Expected impacts addressed: #15 (Green), #20 (Human-centred)

Objectives for 2030: Increase resilience and global competitiveness of European manufacturing companies, through more efficient, versatile, effective and participatory production processes, while reducing CO2 emissions and waste ending up in landfills, and material use by increasing durability, re-use/repair/re-manufacturing/recycling of products/components.

Current status:

- The added value of the European manufacturing sector is EUR 2076 billion (2019), and employs directly more than 30 million people in Europe. Surplus in trade of manufactured products is 286 billion euro (2018).
- Its complex supply and value chains are heavily affected by the current pandemic crisis, and need to further develop resilience against financial and technical disruptions and restraints to trade.
- Furthermore, the sector has the potential to significantly reduce its pollution and production of by-products and waste material. Currently, the sector emits 0.45 Gt (million tonnes, 2017) and 0.71 Gt (billion tonnes, 2017) ends up in landfills. Roughly 9% of material processed by European industry is recycled material (0.72 out of 7.98 Gt, 2017).
- A growing but still small portion of the products are remanufactured or upgraded. There is a huge potential to increase European competitiveness and at the same time heavily reduce environmental impact by regaining the functions of the products with circular remanufacturing approaches.

Achievements sought / targets:

- Developing zero-defect and zero-downtime high-precision manufacturing technologies, realised by new AI-assisted predictive maintenance, quality control and non-destructive inspection methods;
- Realising flexible, responsive and resilient factories, enabled by advanced robotics and mechatronics, modular manufacturing, laser-based and other advanced production processes, application of new Artificial Intelligence technologies, and correct and reliable context-dependent data collection;
- Achieving more efficient, sustainable, resilient and responsive supply chains, including flexible processes and supply networks, by fostering traceability of supply chains in order to enable quality assurance and control;
- Sustainable-by-design, through reduction of material use, facilitated repair, remanufacturing, easy and efficient dismantling of elements, replacement of scarce or hazardous materials by advanced materials, and use of alternative, bio-friendly materials including biopolymers and other biobased materials like fiber-based materilas (e.g. cellulose-based components);
- Adopting circular economy practices through a systemic approach. At the design phase, products have to be manufactured in a way that minimise consumption of resources (energy, materials, water, etc.) during their manufacturing but also during their use. They should also be designed so as to lead to increased re-use/repair/remanufacturing/recycling of products/components, enabled

by solutions for new methods for reverse logistics and waste sorting, and technology development for product tracing throughout supply chains. The use of the environmental footprint method with its related economic/social impact is further expanded.

Means/links: This 'orientation for topics' will be largely implemented through the co-programmed partnership Made in Europe.

There are links with other partnerships, such as AI, Data, and Robotics, Key Digital Technologies, and Photonics, with the EIT Manufacturing and EIT Digital KICs, with the Manu*future* European Technology Platform, with the Digital Europe Programme, e.g. related to manufacturing data spaces and AI testing and experimentation facilities for smart manufacturing, and with the thematic smart specialisation platform on Industrial Modernisation.

Means/links: This 'orientation for topics' will be largely implemented through the co-programmed partnership Made in Europe.]

Proposals are invited against the following topic(s):

TWIN-TRANSITION-01-2021: Circular by design manufacturing (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Demonstrate viability of circular production models by
  - manufacturing added-value products with fewer resources
  - developing innovative product recovery approaches
  - advancing reuse and re-manufacturing methods and technologies
  - addressing the whole supply chain and life-time of products
  - introduce new business models where necessary
- Reduce the environmental impact of products thanks to advances in energy and resources efficient manufacturing and dismantling strategies. This should be supported by integrated tracking and tracing systems allowing to recognize the circular by design approach at the level of recycling at the EOL.
- Widen adoption of circular approaches to production throughout the manufacturing industry by establishing links and cooperation across projects, networks and platforms

Scope: One of the top priorities of the European Commission is the Green Deal, which aims at transforming Europe in a climate-neutral continent by 2050. The development of a true circular economy is a fundamental enabler to achieve this goal.

Europe's Circular Economy Action Plan aims at making sustainable products the norm in the EU, with a special focus on the sectors that use most resources and where the potential for circularity is high such as: electronics and ICT; batteries and vehicles; packaging; plastics; textiles; construction and buildings; food; water and nutrients.

Up to 80% of products' environmental impacts are determined at the design phase. To face sustainability and flexibility challenges the current linear pattern of "take-make-use-dispose" is no longer feasible: products need to be conceived, designed and manufactured in a modular way to enable circular economy.

Research activities should be multi-disciplinary, address all of the following areas and demonstrate the targeted benefits in at least three use cases:

- Methodologies to design products and components fit for a circular economy through iterative machine-learning-assisted design processes that allow for rapid prototyping and testing.
- Solutions to optimise the design process experiences from existing products and running production processes should be taken into account,
- Machine learning techniques to analyse Big Data coming from existing products and processes with a view to reuse resources as well as semantic techniques to integrate human experiences or combination of both should be investigated.
- Advancement of production solutions exploiting latest results from underlying technologies (e.g. laser-based production, additive manufacturing, non-destructive inspection and classification methods, machine learning for predictive quality, robotics) to
    - minimize waste during production
    - enable fast manufacturing, modular assembly and configuration
    - establish effective disassembly/separation of used products and recovery of materials
- Generation and validation of new business models to improve economic viability of closed-loop life cycles, which make use of the systemic approaches for product life-cycle management involving all relevant actors in the supply chain.

Proposals submitted under this topic should include actions designed to facilitate cooperation with other projects; to enhance user involvement; and to ensure the accessibility and reusability of data produced in the course of the project.

TWIN-TRANSITION-02-2021: AI enhanced robotics system for smart manufacturing (IA)

<u>Expected outcomes</u>: Projects are expected to contribute to the following outcomes:

- Demonstrate, through at least three large-scale pilots, significant improvements towards a meaningful and seamless collaboration between human workers and autonomous agents and between robots by exploiting latest advancements in robotics, in particular advanced cognitive and physical capabilities.
- Provide solutions highly flexible, reconfigurable and modular, allowing fast response to changes in production requirements.
- Create a network of open-access pilots to allow new users, especially start-ups and SMEs, to experiment new technologies and to enable knowledge sharing through the European industrial ecosystem.

Scope: Europe needs to strengthen its capacity to manufacture goods in a sustainable and competitive way. The recent crisis has also shown the importance of resilient, flexible, reconfigurable and responsive manufacturing lines that can switch production within a matter of hours.

Projects should seize the opportunities arising from AI and robotics latest developments to deploy intelligent and autonomous systems for flexible production.

Research activities should be multi-disciplinary and address all of the following areas:

- Implement and integrate the latest research findings on technologies such as AI, sensors, actuators, control, edge computing, haptic technologies and robotics to enhance collaborative robotics systems to develop advanced smart manufacturing collaborative systems ensuring safe physical and social interactions and efficient collaboration with human workers.
- Demonstrate complex, safe and efficient interactions between multiple agents simultaneously, e.g. humans, industrial machinery, AGVs and cobots.
- Social Sciences and Humanities (SSH) should provide a human-centric approach to increase user experience, comfort, trust, safety of workers in the highly automated industrial environment. A plan for up-skilling, training workers is essential to increase acceptance.
- Demonstrate results in at least 3 industrial use-cases, targeting sectors and tasks typically difficult to automate.
- Projects are encouraged to seek collaboration with regional and national initiatives (e.g. DIHs, S3P) to extend impact beyond their life.

Proposals submitted under this topic should include actions designed to facilitate cooperation with other projects; to enhance user involvement; and to ensure the accessibility and reusability of data produced in the course of the project.

TWIN-TRANSITION-03-2021: Zero-defect manufacturing towards zero-waste (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Demonstrate a significant increase of sustainable production and non-destructive inspection methods.
- Methodologies and tools shall be developed to prevent the generation of defects at component level and its propagation to the system level.

Scope: The projects must address the full system with the aim of reducing defects. The defect reduction and the overall quality control should be centred on such defects that reduce the yield, acceptance, or qualification of the final product, and enable a “first-time-right” production process.

Projects should target types of waste or discarded material from identified defective products or components that cannot be easily reworked or recycled without significant effort. This implies a demonstrable transition to a sustainable production, and can include additional elements such as life-cycle analyses and environmental assessments.

The system improvements should also contain two main elements:

- The integration of in-line non-destructive inspection methods that enable for rapid feedback control
- The use of large data sets, stemming from all sorts of production process and material data, for the creation of comprehensive machine learning algorithms

Finally, the projects should provide solutions for transfer of the developed technologies to other industrial applications and areas, as well as contributions to standardisation.

TWIN-TRANSITION-04-2021: Laser-based technologies for green manufacturing (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Reinforcing European industry as leader in agile, green manufacturing through the application of laser-based technologies;
- improving the agility of industrial production by making processes more versatile, simpler to reconfigure and more efficient to control through data exchange;
- improving the environmental sustainability of industrial production towards 'first-time right' processes with 30% lower consumption of resources compared to the state of the art.

Scope: Machine tools include various laser-based technologies such as milling, turning, grinding, laser processing, surface treatment, forming and additive manufacturing. Projects funded under this topic should integrate state-of-the-art high-power lasers and tailored beams together with quality sensors and real time monitoring systems into advanced manufacturing and re-manufacturing tools.

Known research challenges are amongst others the transmission of very high average and peak power laser radiation without loss or distortion including in the ultraviolet, mid and far infrared spectral range, powerful optical fibres, programmable beam guidance, maximum positional flexibility, free choice of energy distribution, rapid quantitative feedback and beam distribution systems with sub-micrometre resolution and high performance. A further research challenge is the integration of quality sensors in laser-based manufacturing. These produce a vast amount of data with a need for dedicated signal processing. Edge devices with self-learning algorithms should be developed that can handle the computing requirements.

Project consortia should comprise research institutes, technology suppliers and users. They should demonstrate the benefits to the targeted technologies in at least three use cases.

TWIN-TRANSITION-05-2021: Industrial Internet for distributed control and modular manufacturing (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- establishing European industry as leader in sustainable manufacturing and process industries through efficient data processing within and across the supply chain;
- improving the environmental, economic and social sustainability of industrial production;
- Achieving more efficient and responsive supply chains, and improving the agility of European industry and its resiliency to external shocks;
- integrating state-of-the-art industrial internet technologies with advanced manufacturing and re-manufacturing technologies and systems, exploiting their potential across the entire product lifecycle.

Scope: Factory automation and logistics approaches – in synergy with the role of humans in the factory – are evolving rapidly, not least through advances in connectivity, data analytics and cognitive approaches. Succesful digital transformation depends on the ability to systemically integrate and upgrade operational technology to the innovative developments in (self-) configuration, such as the administrative shell, simulation and modelling (digital twins), real time monitoring, data processing, decision-making, therefore building a flexible industrial Internet for distributed control and modular manufacturing while keeping the high-level of reliability and safety required by the manufacturing sector. Projects in this topic will develop modular systems and technologies for flexible and distributed control, to be integrated in a systemic approach and deployed from machine level up to supply chain level.

TWIN-TRANSITION-06-2021: Engineering support tools for sustainable production (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Provide a range of support solutions for engineers, technicians and operators on the factory floor, in order to build an agile and responsive production environment.
- Increase the productivity of a production line while maintaining a transition towards a more sustainable production model in line with green policy goals.
- Reduce the skills and knowledge gap for the actors involved.

Scope: The transition towards a responsible and sustainable production requires a holistic and full system overview of the entire production line. In order to respond to changes in business models and reorganisation of production lines, new support tools will be needed to help actors, such as engineers, technicians and operators, to make decisions related to the conception, control, and verification of the production operation.

Another challenge that falls within this scope is the human dimension. The support tools need to work with the user, and training, knowledge transfer, cognitive interfaces, as well as acceptance and uptake will be vital in the solutions proposed.

The project should cover all of the following aspects:

- The development of completely new support tools for decision making and control, including elements such as human-machine interfaces and cyber-physical systems
- The inclusion and handling of real-time production data in analysis software and tools
- Demonstration of the support tools in a production environment with a clear target of improving quality and sustainability
- Training and qualification for the users, which need to include a strategy for acceptance and uptake of the tools in a relevant environment.

TWIN-TRANSITION-07-2021: Biomaterial-based manufacturing (RIA)

<u>Expected outcomes</u>: Projects are expected to contribute to the following outcomes:

- Demonstrate large-scale production of innovative bio-based products to substitute traditional materials with high environmental footprint. Products should have similar or better mechanical, physical and chemical properties, while being non-toxic, biocompostable and biodegradable in an environmentally friendly and resource-saving way.
- Demonstrate disruptive innovation of biomaterial-based manufacturing in three manufacturing sectors

<u>Scope:</u> Europe's Circular Economy Action Plan aims at making sustainable products the norm in the EU. Twenty-first century manufacturing requires new materials and new techniques to produce them. Rapid progress in biomanufacturing is one of the drivers of this trend. This new frontier of science is a multidisciplinary research field combining engineering, biology, genetics, material science, which allow the production of biobased products starting from cells**,** molecules or extracellular matrices. Particularly interesting with respect to the green transition of the economy are biodiesel, bioplastics, extracellular polymeric substance, biosurfactants and other value added bioproducts produced exploiting CO_2 sequestration mechanism in bacteria.

These technologies provide a valid alternative to synthetic materials with a substantially lower environmental impact with a range of applications for example in construction, food and fashion industries. However, the use of compostable, biodegradable materials should increase substantially in order to build a truly sustainable manufacturing industry.

Research activities should address the following areas:

- Optimisation and improvement of smart manufacturing processes, e.g. additive manufacturing, to unlock the full potential of bio-based materials, such as carbon-positive bioplastics, biopolymers and other fiber-based materials (e.g. cellulose-based components and marine-based components);
- Use of carbon positive bio-based materials, such as composite, rubber, plastics, in different products to achieve high technical properties while lowering the environmental footprint.

TWIN-TRANSITION-08-2022: Rapid reconfigurable production process chains (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Demonstrate multiple reconfigurable manufacturing processes in one or more production lines that are running medium to high volume manufacturing.
- Achieve a reconfiguration time, which includes all steps between stopping a production, reconfiguration of the individual production steps, requalification, and ramping up to a full production speed, below 48 hours.
- Present protocols for best practices in rapid reconfiguration applicable not only for the products and sectors present in the project, but also transferable to other sectors and application areas.

Scope: In times of disrupted supply chains or rapidly changing customer demands, production lines will need be built flexible enough to be able to handle these variations. Rapid reconfiguration technologies, below 48 hours, will enable industries with many production process steps to maintain a resilience against sudden shocks in ordering and/or supplies.

The projects should address reconfiguration of production lines in which the lines are running at medium or high volume manufacturing rates (MVM and HVM respectively), and include a variety of production steps, such as cleaning, forming, thermal treatments, cutting, joining, painting, assembly, etc.

The reconfiguration should be ambitious to the extent that the change addresses a new customer base, or drastically changes the original supply chain.

Projects should also include protocols for the reconfiguration that can be applicable also outside the sectors active in the project, which would include taking into account any sector specific qualification requirements (such as clean room levels or certifications for sectors such as medical and food). These protocols as well as the projects should include a worker’s perspective, including skills requirements and training.

TWIN-TRANSITION-09-2022: Products with complex functional surfaces (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- More efficient manufacturing processes for products with functional surfaces
- Significant reduction of the environmental footprint for surface treatments
- Market share increase for sustainable production processes focussed on complex, functional surfaces
- Uptake of treatment technologies in applications for a sustainable society, targeting reductions in energy use and environmental footprint

Scope: Surface treatments are an integral part of any manufacturing process. Surface treatments include many disciplines, such as painting (spray, powder, etc.), plating (electroplating, vacuum plating, etc.), thermal treatments (annealing, thermo-chemical processes, etc.), laser-based treatments (annealing, texturing, etc.), etching (wet etching, plasma/dry etching, also for texturing).

While the integration of these treatment technologies into a manufacturing line has been well reported, the technologies still need to be adapted for each particular profile. In addition, with progressively more complex and customised requirements on shape, material and functionality, the demands on efficient surface treatments are increasing. In a transition towards a sustainable production, with a lower environmental footprint, the demands are even higher.

The projects under this topic should address the following:

- Develop new surface treatments specifically targeting and enabling end-products with the purpose of reducing the end-products' energy usage and/or environmental footprint.
- Integrate the new surface treatments in a manufacturing line for profiles with complex shape or multimaterial content, with clear metrics on its efficiency during operation
- Develop new business models and strategies for the uptake of these new technologies and with clear objectives on how to expand the uptake to other sectors and other applications.

TWIN-TRANSITION-10-2022: Smart sustainable production of complex products (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Manufacturing products with complex geometries, structure and materials reducing material waste, energy consumption and defects.

- Increase of productivity of complex products manufacturing while ensuring high quality and minimising need of reworking
- Demonstration of significant improvement in several processes for manufacturing complex products, such as joining, cutting/forming, assembly and finishing.

Scope: Products are increasingly complex, e.g. geometries, structures, embedded electronics, micro-features, advanced multi-materials. Moreover, newer constraints are coming from requirements of sustainability in production processes (resource and energy efficiency).

To enable the viable and sustainable manufacturing of these high-tech products, innovative advanced manufacturing processes should be developed. Digital models make development, production, and operation of complex products manageable.

Proposal should cover research activities in the following areas:

- Advancement of smart production technologies such as additive manufacturing and laser-based manufacturing, intelligent and autonomous handling, shaping, assembly technologies.
- Functional printing to manufacture complex products, such as in-mold electronics and printed electronics (e.g 3D printed, screen printed, etc) as a mechanism of adding value to the mechanical components.
- Use of novel sustainable and smart materials to achieve same or higher technical features in products while reducing environmental impact.
- Parallel product and manufacturing engineering, developing cyber physical systems, e.g. digital twins, to manage complex productions.

TWIN-TRANSITION-11-2022: Excellence in distributed control and modular manufacturing (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Significant advance in modular technologies for flexible manufacturing operations, which respond to disrupted supply chains, or rapid changes in customer and societal demands.

- Transition of modular technology to sustainable production for varying batch sizes, including single lots, with a clear integration of control strategies at different levels.

- Improved understanding of how to handle agile manufacturing systems with modular interfaces, including quality assessments, environmental impact, energy use, and business models.

Scope: Modularity of a production system is crucial for flexibility and allow for varying the production according to needs and circumstances by introducing, changing, and removing different process steps. While the concept of modularity is not new, there are still a vast range of production steps that cannot be considered modular, and the ones that can be considered as such are not necessarily apt for current demands nor to be considered as a part of sustainable production regimes.

The projects under this topic need to address the following aspects:

- Propose and develop new production modules that cover processes that are not currently readily available on the market.
- Create interfaces based on open-source protocols that allow for easily integration of modules in existing lines and with other modules or production elements.
- Introduce strategies on how to use modularity to reduce energy consumption and environmental footprint, and demonstrate it in a relevant environment.
- Explore business models that demonstrate the potential of the modular technologies to be transferred from one specific manufacturing sector to several others.

TWIN-TRANSITION-12-2022: Intelligent work piece handling in a full production line (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Advanced handling control systems of complex products in terms of shape, size, material and stiffness
- Develop highly flexible production lines able to handle a variety of different products and materials with high precision
- Increase productivity by enabling fast and accurate movement of work pieces through the production line, ensuring just-in-time delivery and reducing downtime.

Scope: The trends towards product customization have increased production complexity. To maintain global leadership and competitiveness of European manufacturing industry, there is need for flexible, reconfigurable and agile factories.

Products and component handling is an integral part of the manufacturing industry and its optimization increases productivity while minimizing production costs and time. However, today the number and type of objects that businesses have to work with is increasing, pushing the demand for innovative smart automated handling systems

Research activities should cover:

- Development of innovative, storage, retrieval, conveying and pick-and-place systems using a multi-disciplinary approach combining technologies such as collaborative/autonomous assembly and logistics, smart conveyor belts, advanced robotics, flexible and versatile grippers, IoT, mechanical and optical sensors, image processing, simulation, modelling, data acquisition, data analytics and machine learning.

- Achieve a large degree of flexibility and reconfigurability by ensuring interoperability and user-friendliness of both hardware and software. The solutions proposed should be able to handle different types of objects with a significant variety of shape, size and material properties.

TWIN-TRANSITION-13-2022: Sustainable manufacturing close to the consumer (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Design, develop and deploy symbiotic and sustainable factories that are fully integrated in three densely populated urban districts.
- Such districts should have public shared spaces and a public facade that offer increased value for the larger community.
- Holistic approach of spatial/physical planning in terms of energy, logistics and transport services.
- Reduction of noise, waste and pollution due to industrial activities integrated in the urban tissue.
- Reduction of urban spawl and enhanced land management.

Scope: Cities cover about 3% of the Earth’s land, yet they produce around 72% of its greenhouse gas emissions. On top of that, cities are growing fast. In Europe, it is estimated that by 2050 almost 85% of Europeans will be living in urban areas.

Hand-in-hand with the green and digital transformation of the economy, cities need to shift towards social inclusiveness, higher quality of life, greater levels of citizen action, the pick-up of the circular and shared economy, larger commitments to climate adaptation and more sustainable forms of transport.

Factories are typically located outside cities because of their environmental impact and the disruption of the urban landscape. However, with population growth and urbanization trends, this approach has created massive traffic flow of workers from cities to production locations, thus increasing the pollution generated by mobility and reducing people’s quality of life due to traffic congestion and longer commuting time.

New technologies allow manufacturing activities to be quieter and more discrete. This offer the possibility of implementing manufacturing processes in the city, limiting time to reach the job place for workers, bringing production closer to customers and consumers, promoting a more efficient use of materials and urban resilience.

Research activities should cover:

- Green and digital technologies that allow production in urban contexts with lower environmental impact, noise, waste, energy and space consumption.
- Approaches for the circular economy by closing the material and energy cycles in cities and transforming waste streams into productive resources.
- Activities for developing skills, include unemployed workforce, engage citizens and other stakeholders.

- Planning integration of the factories in their social and urban environment such as urban transport, parking, shopping and entertainment centres and support to families.

Section: Advanced digital technologies for manufacturing

[Expected impacts addressed: #15 (Green)

Objective: to increase productivity and innovation capacity of the manufacturing sector, to contribute to making manufacturing greener, more digital, and more resilient, and to make the jobs of the humans working in the manufacturing sector more attractive and safer, via smart application of digital technologies.

Current status:

- Gross added value of the European manufacturing sector is 2,076 B€ (2019), representing 22% of the world's manufacturing output. EU trade surplus in manufactured goods was 421 B€ (2019).
- Potential of digital technologies is underused in industry, e.g. 12% of EU enterprises use big data technologies, less than 7% use robots, less than 5% use 3D printing, etc. Only 1 out of 5 SMEs is highly digitised. Data sharing among manufacturing companies is limited.

Achievements sought / targets:

- **Increase digitalisation of manufacturing industry**, using the potential of digital technologies to improve innovation and productivity, leading to greener and more resilient production processes. Industrial data is increasingly collected and shared by new sensors, factory-wide communication technologies, data platforms, AI-based analytics, and more. Technologies such as advanced augmented or virtual-reality applications can lead to more productive maintenance and reconfiguration of production machines. New wearable devices can improve workers' safety in dangerous environments. Innovative experiments supported by Digital Innovation Hubs improve the digital maturity of manufacturing SMEs. The target by 2030 is to increase the use of promising digital technologies in industry by 30%.
- **Reinforce European leadership in manufactured goods** via increased labour productivity and an enhanced capacity to innovate, thanks to digital technologies, including digital twins. Advanced modelling and analysis tools support optimisation decisions in the design of products and processes, and in process execution. For instance, advanced modelling, simulation, and analysis tools increase the insights in product characteristics, resource usage, asset features, supply chains, etc. Accompanying optimisation and AI tools improve product durability, resource efficiency, asset utilisation, supply chain resilience, etc. The target by 2030 is to increase EU manufacturing sovereignty in strategic value chains, maintaining a healthy trade surplus in manufactured goods.
- **Contribute to establishing Europe as a global leader in green manufacturing and more resilient supply chains** by smart application of digital technologies. For instance, new methods and technologies are developed to synchronise supply chain activities, realised by new platforms that pool, analyse, and make available data from relevant sources across the chain, including reuse and recycling data. Advanced, easily reconfigurable robots and 3D printing capabilities increase flexibility and resilience of production processes. The target by 2030 is to establish the capabilities to design, control, and operate significantly greener and more resilient key manufacturing processes.
- **Improve human-robot collaboration**, in respect of fundamental rights of the industry workers, including autonomy, privacy and non-discrimination. Develop technology which can be adapted to workers' needs and diversity. Develop technology in parallel to workers' training.

Means/links: This section will be largely implemented through the co-programmed partnership Made In Europe. In addition, there are links with other partnerships, such as AI, Data, and Robotics, Key Digital Technologies, and Photonics, with the EIT Manufacturing and EIT Digital KICs, with the Manu*future* European Technology Platform, with the Digital Europe Programme, e.g. related to manufacturing data spaces and AI testing and experimentation facilities for smart manufacturing, and with the thematic smart specialisation platform on Industrial Modernisation.

There are links with other sections, such as “Green, flexible and advanced manufacturing”, “Data sharing in the common European data space”, “Strengthening Europe’s data analytics capacity”, “Leading European AI based on trust”, “Tomorrow’s deployable Robots: efficient, robust, safe, adaptive and trusted”, “From Cloud to Edge to IoT for European Data”, and “Components and systems for a clean and circular economy”.]

Proposals are invited against the following topic(s):

TWIN-TRANSITION-14-2022: ICT Innovation for Manufacturing Sustainability in SMEs (I4MS2) (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- making European manufacturing companies, especially SMEs and mid-caps more sustainable and resilient through the best use of digital technologies;
- making jobs of humans working in the manufacturing sector safer and more attractive for a diverse population of workers;
- increasing innovation capacity, agility and productivity of the manufacturing sector, in particular for SMEs and mid-caps;
- increasing the competitiveness of SMEs and mid-caps by reducing the entry barriers to the use of advanced digital technologies, and transferring innovative solutions into the wider manufacturing community.

Scope: ICT Innovation for Manufacturing SMEs (I4MS) is a successful European initiative launched in 2013 and financed in 4 phases through the Horizon 2020 programme to support manufacturing SMEs and mid-caps in the widespread use of ICT for their business operations. I4MS2 builds on the past results adding a specific focus on sustainability.

In recent times, the Covid-19 crisis demonstrated the key role of digital technologies in responding quickly to external changes. Digitalisation improves resilience, agility and competitiveness, and enables cost-efficient production in Europe. It will also support a radical reduction of the environmental footprint of the sector. In this context, there is an urgent need for SMEs and mid-caps in the manufacturing sector to experiment with innovative and secure digital technologies in their production processes, products and business models before adopting and investing in these. This will enhance manufacturing companies to successfully manage the twin digital and green transformation of the coming years.

I4MS2 calls for Digital Innovation Hubs projects that will support European SMEs and mid-caps to innovate and make more sustainable their products, production processesses and business models through experimentation and testing. At least 50% of the budget should be allocated to SMEs and mid-caps to participate in the experimentsThe proposals may include financial support to third parties to finance SMEs and mid-caps. Proposals should describe their complementarity to existing initiatives, namely the network of European Digital Innovation Hubs, which is supported through the Digital Europe Programme. They should also indicate how they will collaborate with European Digital Innovation Hubs.

Priority should be given to technologies that can:

- improve the sustainability of processes and products, by reducing or reusing waste and lowering the energy footprint;
- develop new innovative and greener processes for fabrication, quality control and integration;
- make manufacturing jobs more attractive for humans, whichever the age, gender or social and cultural background, through better human-machine interfaces and more intuitive interaction with digital tools;
- make industrial processes more agile, secure and resilient to future changes;
- overcome barriers to manufacturability for new materials;
- bring complex digital technologies within reach of SMEs and mid-caps, though the use of autonomous and self-managing systems.

Examples (non-exhaustive list) of possible technology areas that could be addressed in proposals are the following:

- Industrial Internet of Things;
- Artificial Intelligence applied to manufacturing, including generative design enabled by Artificial Intelligence;
- Innovative secure distributed edge and centralised computing across supply chains;
- Trustworthy sharing of industrial data and its value creation along supply chains
- Advanced interfaces including smart wearables, non-conventional packages of electronic devices, for example in textile, and collaboration within smart working environments such as cobots;

Proposals may cover one or more of the possible technologies, which should be relevant for the manufacturing sector at large; proposers are requested to identify the centre of gravity of their proposed project.

TWIN-TRANSITION-16-2021: Digital tools for Circular Economy (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Innovative digital tools for circularity applied by the European manufacturing sector;
- New concepts to address re-manufacturing, recycling, and reuse of products and components;
- Reduction of the dependency from imported raw materials for the European manufacturing sector;
- Increased data exchange among value chain actors to implement circularity.

Scope: The focus is on developing new concepts, methods, and digital tools to support the industrial processes for recycling, re-manufacturing, refurbishing, and reuse of manufactured products and components. New solutions will enable remanufacturing and high-quality recycling by digitalisation of product and component information throughout the whole product lifecycle, in line with the Circular Economy Action Plan.

Proposals must develop innovative concepts, methods, and tools that track and trace the status of relevant manufactured products and components, such as electronic systems and components as well as machine tools. Where appropriate, proposals need to be able to link up with manufacturing data spaces, so that circular economy data can be shared with a larger set of organisations.

Developed technologies and solutions should be demonstrated in at least two different realistic manufacturing use cases of significant economic value. If applicable, legal obstacles to implementation of the proposed solutions should be identified.

TWIN-TRANSITION-17-2022: Artificial Intelligence for sustainable, agile manufacturing (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- establishing European industry as leader in sustainable manufacturing and process industries through the application of AI technologies;
- improving the environmental, economic and social sustainability of industrial production;
- improving the agility of European industry and its resiliency to external shocks;
- improving human-machine collaboration, enhancing unique human abilities and making manufacturing jobs more attractive;
- integrating state-of-the-art AI technologies with advanced manufacturing and re-manufacturing technologies and systems, exploiting their potential across the entire product lifecycle.

Scope: Artificial Intelligence has already proven to be very effective in specific manufacturing applications e.g. preventive maintenance or quality control. The scope of this topic is to exploit the potential of AI as a transformation tool for the entire manufacturing and process industry, addressing the full lifecycle of products from design to remanufacturing and end of life. AI will be a strategic instrument to improve sustainability, agility and resilience to external shocks, building on the results of the Horizon 2020 topic ICT-38-2020, and in line with the European Green Deal objectives. AI applications will be capable of optimising their actions based on limited human input, thanks to their awareness of the context and of the physical environment delivered by sensors, and will have the long useful lifetime typical of industrial environments. Generative approaches will help designing products and processes improving the sustainability of industrial solutions, and capable of quick evolution whenever the external conditions demand it. The topic will integrate new or existing technologies to make them practically and economically viable in the industrial world.

TWIN-TRANSITION-18-2021: Tools, models, and technologies for industrial ecosystems in promising areas (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Define specifications for data, products, and/or business processes, that have the potential to be agreed and commonly used by many industrial actors, and that have the potential to the emergence of future digital value chains, identify promising industrial areas for industry agreements along the Strategic Value Chains with special focus on circularity and sustainability;

- Innovate and upgrade value-added networks that strengthen Europe's technological autonomy and industrial leadership through increased cooperation and cross-sectoral collaboration, including the ability to deal adequately with IP and competition law - and thus, through their effective implementation, to lead the twin digital and green transitions.

Scope: Europe has everything it needs to take the lead in this new technology race around platforms and hyperscalers. To do so, it must organize its diverse landscape, which is characterized by agile SMEs and midcaps, more efficiently and turn the high numbers into a powerful network that surpasses any single hyperscaler in flexibility. The market is moving towards more cooperative ecosystems (or industry commons), where players of all kinds and across all parts of a particular sector pool their insights and combine their profound customer understanding and relationships, establish industry-specific networks, and highly complementary value chains to create true value-add for their end customers. We want to develop tools, pattern and templates that enable this; co-tools (like co-design and co-create solutions) and organisational models that facilitate cooperation and collaborative product and service design among industry players.

Industrial alliances are new and key instrument to promote this cooperation along strategic value chains, notably with regard to the implementation of large-scale projects of strategic interest that go across borders and beyond the resources of a single company or Member State. In the industry strategy these alliances focus on performing R&D, but can also be seen in the sense of strategic partnering, leading to industry agreements.

We are therefore looking for commonly agreed definitions, specifications, standards and frameworks, which facilitate understandings among industry actors. One element can be data and cloud platforms for the manufacturing sector that will focus on promoting commonly agreed governance rules to facilitate access and use of industrial data.

As promising areas we see platforms that concentrate on the use of process, simulation and maintenance data for predictive and prescriptive maintenance and the use of status, location and external data (like weather data) in supply chain prediction and management. Businesses that largely depend on global supply chains, such as mechanical and plant engineering, automotive, electronics, and retail are being hit much harder by the crisis. Flexibility and agility are becoming the basis of their competitiveness. All parties represented in an industrial ecosystem must rethink their approach and view their sector and its players in a completely new light. Redundancy and near-shoring will play a more important in the steps towards more resilience in the future, here industrial ecosystems and industrial agreements can also be supportive.

Build on the work of the Strategic Forum on IPCEIs and align with the Industrial Forum

TWIN-TRANSITION-19-2022: Digital advances for local and urban manufacturing (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- To develop and demonstrate digitally-enabled solutions that support the local, often urban, manufacturing vision. (local manufacturing is characterised by small, versatile factories, close to customers, where various types of customised products are produced in small series for the cost price of mass-produced products.)
- Significantly improve small-series, customised production costs in local/urban environments as compared to traditional economies-of-scale production sites, thereby contributing significantly to a sustainable manufacturing industry
- Improved access to flexible production capabilities in local/urban environments, esp. for SMEs.

Scope: Local, often urban, manufacturing is characterised by small, universal factories, close to customers (and highly qualified workers), where various types of customised products are produced in small series for the cost price of mass-produced products. Its ambition is to change the economy-of-scale target as in today's mass production sites, into economies achieved by networking.

The challenge is to better understand customer needs, to significantly reduce quotation-delivery lead time, to reduce transaction costs for small series, to better link customer needs, digital design, simulation, and manufacturing, and to smoothly collaborate with different actors. Latest developments of the industrial internet, big data technologies and blockchain enable or promise easier connected digital value chains. It also requires flexible production equipment, such as robots, CNC systems, 3D printers, and fast change-over times.

Proposals are expected to develop digitally-enabled solutions that support the localised/urban manufacturing vision. Possible technology development includes the adoption of artificial intelligence and smart data approaches for local/urban production to control and optimise distributed manufacturing and logistic processes; Internet of Things solutions and big data analysis to reach zero-defect manufacturing processes and zero-surprises predictive maintenance; distributed ledger technologies to reduce transaction costs. Developed technologies should be demonstrated in at least two complementary use cases. Proposals are expected to contribute to the development of standards for reconfigurable, modular and scalable local/urban production facilities.

TWIN-TRANSITION-20-2021: Distributed Industrial Computing (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- establishing European industry as leader in sustainable manufacturing and process industries through efficient data processing within and across the supply chain;
- improving the environmental, economic and social sustainability of industrial production;
- improving the agility of European industry and its resiliency to external shocks;
- integrating state-of-the-art data computing, storage and analytics technologies with advanced manufacturing and re-manufacturing technologies and systems, exploiting their potential across the entire product lifecycle.

Scope: Fully reaching the opportunities of sharing and exploiting industrial data, including deep industrial data, requires to strike the right balance between centrally processing and storing data versus locally, at the edges of industrial network. Such a balance has to take into account not only efficiency (costs of edge computing vs communication to a central node and central processing) but also the real-time and cybersecurity aspects as a whole. These technologies will have to show also flexibility along the industrial value chains and promote the introduction of new business models, based on the availability of deep industrial data, within an agreed data governance, with mutual trust and adequate distribution of the value created by sharing data. Such a distributed industrial computing environment needs to be demonstrated effectively in a minimum of 2 specific manufacturing applications. The topic will integrate new or existing technologies to make them practically and economically viable in the industrial world, and will encompass modern manufacturing technologies such as digital twins.

TWIN-TRANSITION-21-2022: Standardisation and Norms for AI in manufacturing (CSA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- To explore needs for standardisation and qualification of equipment and processes, notably the application of Artificial Intelligence to business processes, in line with guidelines for trustworthy and ethical AI, as put forward by the HLEG on AI.
- Recommendations on standards and certification for AI in machines and industrial goods in the manufacturing sector, including logistics
- Identification of gaps and recommendations for key topics for future standardization and interoperability
- Online observatory of published standards and ongoing standardisation activities in AI worldwide.
- Support to a mechanism for information exchange between international and European Standardization Organizations (ESOs) to increase the transparency of ongoing work at international and European levels.
- Networking of all key players, collection of essential requirements for AI standardization and dissemination of information
- Recommendations on links between standardization and regulation
- Recommendations for research activities supporting standardization

Scope: Given the transformative potential of AI in nearly all application areas, the development of a coherent set of AI standards and certifications for industrial products and processes is essential for the broad adoption of AI in the manufacturing sector, including logistics. This should build on the various AI-related standardization initiatives that have emerged around the world in the past few years.

Standards should guarantee that AI technology in industry brings a high level of trust and safety of operations, and that it respects fundamental values and human rights. Standards should also ensure appropriate governance of AI throughout the system lifecycle and make sure that decision systems are trustworthy by being robust, safe and secure. Standards have the potential to strengthen European competitiveness.

AI standards can be sector specific or horizontal. They may cover diverse aspects of the AI value chain including training data and record-keeping, trustworthiness including explainability and transparency, robustness and accuracy or human oversight. Standards can also provide a common baseline for robustness and safety assessment of AI systems and for virtual testing facilities.

Developing a coherent and broadly accepted set of AI standards requires a minimum level of support to ensure that all essential players are involved and that their voices are heard and in order to disseminate information and collect requirements essential requirements. Support is also needed to coordinate and encourage contributions to standardization activities around the world.

Support to standardisation activities in AI could also include the analysis of the state of play in AI standardisation world-wide, the mapping of possible obligations onto existing activities, the identification of gaps, reflections on best ways to link standardisation and possible regulation and linking standardisation with certification.

An important dimension will be to explore needs for standardisation, interoperability and qualification of equipment and processes, notably the application of Artificial Intelligence to business processes, in line with guidelines for trustworthy and ethical AI, as put forward by the HLEG on AI.

TWIN-TRANSITION-22-2021: 5G Innovation for Manufacturing (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- establishing European industry as leader in energy efficient and realiable industrial networks through the application of AI technologies, improving Europe's autonomy in industrial networks, keeping a strong position in the network supply market and seizing opportunities of integration with new value chains such as edge computing as well as electronic and optical components and devices beyond smartphones;
- improving the agility of European manufacturing industry and increase its resiliency to external shocks with flexible, high-performance data and networking solutions, support modular manufacturing with agile, secure and easy-to-implement non-public 5G systems that leads to more resilient production processes;
- increasing productivity and innovation capacity of the manufacturing industry by speeding up the time-deterministic cooperation of machines (robots, servers) and the time-sensitive exchange of process data over a factory floor or industrial site at scale;
- improving the resource consumption of production processes through implementation of power-efficient communication technologies and optimized architectures that support dynamic allocation of functionalities in the network;
- Reinforcing European leadership in network deployment and operations, and in manufactured goods by integrating efficient and secure data communication into products and support digital twins of a product during its lifecycle.

Scope: The scope is to accelerate the development and uptake of advanced 5G technologies by European manufacturing sector and increase resilience and cybersecurity by design. Especially SMEs and mid-caps in the manufacturing sector need easy-to-implement, secure communication technologies from the sensor or edge to the cloud in their production processes.

Private 5G networks (5G NPN) are exclusive mobile networks that manufacturers can use for a defined local production site; they can be tailored to the individual needs of the manufacturer and meet future requirements in the area of Industry 4.0. Innovative approaches to simplify the deployment and operation of such private 5G networks throughout their life cycle are needed. The keyword here is "Zero-Touch Management", using network automation, AI / ML, Self-organizing Networks (SON), etc. and taking into account the specifics of industrial environments.

Projects should target easy support for adjusting data and communication infrastructures to business operation in a rapidly changing economic environment. Known research challenges include deployment concepts based on virtualized radio access networks (vRAN) in connection with open interfaces (Open RAN / O-RAN) and developing time-deterministic and time-sensitive optical communication systems. Networks need to be able to integrate industry standard compute and storage building blocks and perform real-time applications like robot control. Implementers in industrial environments need to take a holistic view, including both the connectivity infrastructure (with 5G as a central component) and the actual production system. Relevant questions here are e.g. what performance can be achieved, what suitable architectures and deployment concepts look like (what functionality is located where and how are the individual components integrated into existing environments)? The projects should also always consider if there are alternatives that require less cost and power or are energy adaptive.

An important element for rapid deployment is also the development and evaluation of new business models for private 5G networks, e.g. how can the required upfront investment for a factory operator be kept as low as possible, without increasing the operational costs too much? And how do the costs scale? In this context, the projects should also offer opportunities for potential new entrants into the business of such innovative 5G infrastructure solutions. In particular, new players that have their main focus not on public networks but on non-public (campus) networks (NGN) for connected industries and in particular automation applications.

An initial step is the comprehensive validation of the performance of 5G (especially Rel-16) in real industrial environments. The objective is to better understand the implementation requirements for resilient private 5G networks (5G NPN) and industrial networking infrastructures. This includes workable approaches to dealing with possible jammers and investigation of the possible impact of jammers. And it should take into account the recommendations in the EU 5G toolbox and the workgroup on Service and System Aspects 3 (SA3) of the 3GPP.

Build upon H2020-EU.2.1.1. - INDUSTRIAL LEADERSHIP - Leadership in enabling and industrial technologies - Information and Communication Technologies (ICT); ICT-19-2019 - Advanced 5G validation trials across multiple vertical industries. Link to Smart Networks and Services partnership and CEF2; 5G-ACIA, Telecom Infra Project (TIP).

Section: A new way to build, accelerating disruptive change in construction

[Expected impacts addressed: #15 (Green), #20 (Human-centred)

Objective for 2030: European competitiveness and climate neutrality of the construction sector through deeper digitalisation and automation.

Current status: Construction offers 18 million jobs to the EU, contributes to 9% of the Union's GDP and is mainly driven by Small and Medium Enterprises. Construction remains one of the least digitised sectors while 70% of construction firms dedicate less than 1% of their revenues in R&D. In addition, to achieve the green and digital transition of the sector upskilling is required for more efficient construction processes. The EU is still a global leader in innovation systems for buildings in 2020, but research and innovation in this field must remain a top priority by 2030. In addition, construction activities should lead to a significant reduction of GHG emissions and resource utilisation in line with the political objectives of the EU. This will require accelerating a disrupting change in the construction activities through digitalisation and innovation towards climate neutrality, zero waste of materials during construction and optimal recycling of construction waste by 2050 at the latest.

Achievements sought / targets: Accelerating a disruptive change in construction: accelerate the development of construction-specific digital technologies and tools; reinforce pre-fabrication, on-site automated assembly and quality control; scanning and monitoring of the condition of existing assets; develop innovative ways of training and guiding the workforce to use the new technologies.

- Industrialisation in Construction (off-site construction, large-scale 3D printing, optimisation of technologies)
- Automation in Construction and de-construction (use of robots and robotic arms, autonomous vehicles, drones, 3D laser mapping;
- Building Information Modelling: BIM 4,5,6,7 and its connection and interoperability to other digital technologies throughout the building lifecycle through continuous data logging from installed sensors. Data representation and connections of the building with the urban scale and digital twins;
- Safety in Construction (research in support of regulation and standardisation, digitally enabled monitoring of the construction site);
- Materials (new recyclable non-toxic materials with low embedded energy and self-healing, facilitation of mapping and reuse of existing materials through digital technologies).

Means/Links: Considering that projects targeted by this orientation for topics will be focusing on high TRL levels, the implementation of the activities could be relevant under different funding mechanisms that go beyond R&I grants. Reaching the objective will in addition be facilitated by blending multiple funding sources from public and private actors. This could include public funding at European level (e.g. Horizon Europe, Structural Funds, Innovation Fund, etc.) and national level (e.g. national and regional funds), along with private investments from industry.]

Proposals are invited against the following topic(s):

TWIN-TRANSITION-23-2021: The use of BIM for circular construction by valorisation of construction and demolition waste (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Reduce the quantity of construction and demolition waste (CDW)
- Demonstrate a more circular and climate neutral construction sector
- Increase the reusability potential of construction products post demolition and reduce the downcycling of construction waste by facilitating modular dismantling of complex construction products

Scope: Based on volume, construction and demolition waste (CDW) is the largest waste stream in the EU. Considering that most of the waste quantities is concrete and steel, the embodied energy and CO2 emission in the CDW is significant. By recycling and reusing CDW in new constructions, the sector would come closer to the targets of becoming fully circular and climate neutral.

Quantitative waste estimation is crucial for waste management. This could be achieved by utilising technologies such as Building Information Modelling (BIM). Such a model could provide information of the materials type (e.g. whether there are hazardous materials that require special care) and quantities, and thus an estimation of the duration for removal, the number of pick-up trucks needed, cost, etc. and make waste separation easier and faster, e.g. by combining BIM with robotic arms.

Proposals should:

- Develop, test and promote the necessary BIM applications for CDW management in different types of constructions;
- Develop automated solutions for waste separation process;
- Produce all required training material for the proper use of the developed technologies;
- Demonstrate of all developed solutions in at least four construction sites across different Member States;
- Assess the value of the solutions in terms of the additional monetary value/reduction of CO2 emissions produced

Finally, the projects should provide contributions to relevant standards.

TWIN-TRANSITION-24-2021: Automated inspection and maintenance of large infrastructure (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Reduction of time and cost necessary for the inspection
- Demonstrate and increase in safety and lifetime of large infrastructures
- Demontrate a decrease of maintenance costs

Scope:

Large civil infrastructures such as railways, underground structures, sports venues and other type of large infrastructures are aging, leading to structural deterioration from aggressive chemical attack, corrosion, and other physical mechanisms. During long-term service, a civil infrastructure should meet the requirement of safety and sustainability for the operation. While structural health monitoring has gained rapid progress with the aid of advanced technologies this is often proposed at a later stage when the construction is already suffering from damages. For new constructions natural aging could be thus improved by applying inspection and automated maintenance that can be programmed already at the design step. This can be done by incorporating sensors, cameras and other inspection tools that can easily provide reliable information to infrastructure managers for decision-making on maintenance.

Proposals should:

- Propose tools and systems for fully automated real-time inspection
- Demonstrate an effective maintenance strategy
- Demonstrate the use of such systems in different climatic conditions
- Produce all required training material for the proper use of the developed technologies
- Prove collaboration with relevant standardisation bodies for the developed tools

Finally, the projects should provide contributions to relevant standards.

TWIN-TRANSITION-25-2021: Automated construction (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

Automation of at least 50% of processes on a construction site, leading to:

- Productivity increase on construction sites
- Reduction of construction costs and duration
- Increase in resources efficiency
- Reduction of labour accidents on construction sites
- Minimisation of the construction waste produced during the construction phase

Scope: Construction sector is among the least automated and digitised sector and the most labour-accident prone sector in the European Union. At the same time, many Member States are facing a shortage of skilled labour force. Higher automation it is thus necessary in order to bring down the construction duration and costs and at the same time increase productivity. The use of technologies such as additive manufacturing (3D-printing), autonomous vehicles, robots/robotic arms, etc. at a construction site would increase the degree of digitalisation of the sector while increasing resources efficiency and labour productivity. This would minimise mistakes in building works as well as construction waste and make the construction sector attractive for younger generations. In addition, the use of such technologies would make construction sites a safer working environment.

Proposals should:

- Develop, test and promote the necessary solutions, devices and systems for a highly automated construction site, exploiting latest underlying technologies;
- Demonstrate how each system is coordinated depending on the others
- Produce all required training material for the proper use of the developed technologies;
- Demonstrate all developed solutions in at least four construction sites across different Member States;

Finally, the projects should provide contributions to new relevant standards.

TWIN-TRANSITION-26-2021: Innovative approach to flexible construction (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Demonstrate quick and easy to build solutions
- Demonstrate the developed solutions in different type of constructions such as hospitals and elderly homes or as additional space to those , who xxxx, as well as in stable and barn construction.
- Demonstrate a reduction of time for installation compared to classical means by in parallel fostering sustainability aspects on the short- medium and long-term.

Scope: Based on the recent experience of the COVID19, there is a necessity for construction elements to be easily adapted to any kinds of new usage according to the need (isolation and quarantine spaces). Since temporary solutions exist, projects should build on previous experience and findings to propose new solutions for quickly build, and easy tailor-made to their new usage. The proposed solutions should be easily reconverted to other usage later when the need has vanished. This can result in new business opportunities for the construction sector and contribute directly to the Next Generation EU, by relaunching the construction sector heavily affected by the current crisis.

The projects should:

- Develop systems exploiting AI technologies for optimized design, assembly and modification of the building structure with single elements, coupled with appropriate ICT tools for multi-criteria decision making, the design and the operation management
- Develop prefabricated elements that can be easily plugged to the grid and any systems such as water, oxygen, sewage, etc. Smart textile and lightweight construction might be an option
- Target building and installation duration not exceeding a labour week
- The eco-design dimension, including re-use options should be taken into account
- Life cycle assessment and life cycle cost analysis should take into account existing sustainability standards and existing best practices.

Finally, the projects should provide contributions to new relevant standards.

TWIN-TRANSITION-27-2022: A comprehensive management of the construction site (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

Develop an advanced platform that combine the management of activities, workforce, equipment, resources and water in a construction site. This would result in:

- Productivity increase on construction sites
- Reduction of construction costs
- Reduction of labour accidents on construction sites
- Optimise the management of resources, materials, equipment and water on site.
- Minimisation of the construction waste produced during the construction phase

Scope: A construction site is a small ecosystem that can comprise of hundreds of workers in large projects, making it challenging for the management team to have a complete overview of all the ongoing activities and react on time when issues arise. In addition, the construction sector is still the most labour-accident prone sector in the European Union, its annual labour-productivity growth is only around 1% over the past 20 years while generating the highest quantity of waste.

Successful management of construction sites needs to be based on innovative components that will ensure accurate tracking of supplies and equipment, well-being of the workforce, predictive accident-avoidance systems, a holistic overview of the site and data supply for the site manager. Efficient resources management would results in minimisation of construction wastes and thus a more environment friendly construction sector. At the same time, it is necessary to consider the creation of a user experience that is simple and creates minimal disturbance to the workforce.

The proposals should:

- Develop, test and promote the necessary technologies, devices and systems for a comprehensive management of construction sites.
- Develop solutions for monitoring the wellbeing of the workforce and prevention of accidents.
- Produce all required training material for the proper use of the developed systems and tools.
- Demonstrate all developed solutions in at least four construction sites across different Member States and for a period of at least one year.
- All solutions should be evaluated by the users (site management, workforce, etc.) through surveys or other means;

Whenever possible the proposed solutions should contribute to existing or new standards.

TWIN-TRANSITION-28-2022: Demonstrate the use of Digital Logbook for buildings (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes, using quantified indicators, baselines and benchmarks:

- Measurable improvements in resource efficiency and decarbonisation of buildings and their construction/renovation, as a result of using digital building logbooks.
- Improved linkages of existing databases and sources for digital building logbooks.
- Improved usability of digital building logbooks through user eXperience.
- New or improved tools for collection and update of relevant data.
- Demonstrate other benefits of using digital building logbooks e.g. safety and health in buildings and construction; cost effectiveness, efficiency gains in terms of time.

Scope: There is a need to demonstrate and realise the potential benefits of using digital depositories of information that accompany buildings throughout their lifecycle. These digital building logbooks (DBL) can potentially result in greater efficiency, circularity and transparency in the building stock. DBLs should also improve decision making for all actors along the lifecycle of the building.

Proposals should encompass DBL features and functionalities, User eXperience, interoperability, data governance and theconnection with other initiatives. Proposals should aim to demonstrate the benefits of DBL in terms of resource efficiency, decarbonisation, safety and health.

Proposals should propose a framework for linking the large number of existing building information related databases. Examples of these include public registries (e.g. information on administrative aspects, soil, cultural heritage), Life Cycle Analysis related data (e.g. GaBi or Ecoinvent), data on technical products and systems used to construct and operate the building, databases of Energy Performance Certificates, measured data of buildings' energy or water consumption. Proposals should consider both current and future opportunities to collect data from new technologies (e.g. sensors, real-time energy use) enabling additional data platforms. The DBL could link as well to those new data platforms, which will come with new possibilities and responsibilities in terms of data privacy and security.

Connecting all these data sources and users requires common 'languages' – interfaces and protocols – to enable interoperability, data consistency (as for example through common European data spaces for the manufacturing sector to ensure enhanced access to privately held data, via industrial data platforms) and information exchange. The problem of "data matching" as one of the main obstacles must be explored. There is also a high potential for advanced technologies, such as blockchain, to support the alleviation of these issues

Proposals should ensure a coherent approach at national level to link existing databases (and automatic updating) with the DBL, to facilitate the development and implementation of DBL's and maximise interoperability. Data quality marking schemes could be considered. Proposals should take into account the outlook on expected evolutions related to new databases with linking potential for the DBL.

The DBL "features" (e.g. digital interface, data syncing, etc.) and "functionalities" (services built around the DBL) should prioritise user-friendliness and a smart interface for end-users. Proposals are expected to demonstrate a "modular and layered" structure for the DBL, ensuring that it is flexible enough to make the right information available to the right actor at the right time. The DBL should take into account User eXperience (UX) principles in order to stimulate the update of the building logbook and its use by construction professionals and building owners.

Proposals should ensure that the functionalities offered by DBL and the corresponding benefits are easily understood by construction and building professionals as well as building owners. Proposals may address the DBL to any or all types of buildings as appropriate.

TWIN-TRANSITION-29-2021: Data Spaces for Construction (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Increase productivity and sustainability of the European construction industry by establishing digital platforms across the construction sector, from planning to building to lifecycle management to deconstruction, end of life and re-use.
- Improve competitiveness of EU actors in the construction sector by facilitating data accessibility and sharing across public and private stakeholders across countries in the European context

- Establishment of a common market of digital tools and solutions which will lead to interconnection among European, National and local data spaces and platforms, including building permits and digital logbooks.

- Facilitate a circular approach through improved operations processes of construction assets, as well as higher quality and decarbonised buildings and infrastructure along their life cycles.

- Support the design of highly energy and resource efficient buildings and infrastructure, optimal integration of renewable energy, reduced raw materials consumption, pollution and greenhouse gas emissions

- Promote the diffusion of standards, interoperability, digital processes and tools with specific reference to SMEs

Scope: The Construction and Built environment sector is using a growing number of information models and digital tools/services, along with an exponential creation of digital data. This topic requests setting up data space(s) for Construction as digital platform for enhanced collaboration in the construction sector that build on existing solutions, integrate different technologies, make data from construction works easily accessible, and allow for complementary applications.

Reaching climate neutrality by 2050 will require further acceleration of smart digital technologies in buildings (including advanced connectivity) to improve the quality and sustainability of buildings and infrastructure along their life cycle and reinforce their role in integration in urban transport and energy sector (Predictive asset performance). Therefore it is essential to foster the emergence of digital standards and interfaces across the ecosystem.

The development of these data space(s) should consider commonly agreed reference architecture frameworks, such as outlined by the DigiPlace project, from planning and design to construction, operational life, deconstruction and end of life. Proposals should integrate advanced digital technologies and should address digital twining as well as security, safety and privacy by design, notably when deploying Internet-of-Things sensors. They must also take into account results from other relevant activities in the field of Building Information Modelling and Digital Building Logbooks. Projects should be demonstrated in at least two use cases.

Proposals shall address all four essential areas of platform development as follows:

- developing the tools and technologies of an open digital construction data space in line with commonly agreed reference architecture;
- piloting the data space in several realistic use cases from the Construction and built environment;
- contributing to standards, interoperability and reference implementations;
- ecosystem building, i.e. raising the interest of stakeholders to develop complementary applications using the data space

They will, if applicable, collaborate with other projects funded under this area.

TWIN–TRANSITION-30-2022: Innovative use of data in construction (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes, using quantified indicators, baselines and benchmarks:

- Improve the efficiency and quality of design and construction processes through novel use of data
- Accelerate uptake of solutions such as digital construction platforms, digital logbooks, and data spaces by SMEs and midcaps in the construction sector, supported by Digital Innovation Hubs.
- Increase stakeholder knowledge and capacity regarding the potential of data sharing as a basis for better collaboration between participants in the Architecture, Engineering and Construction (AEC) industry.
- Demonstrate models for business processes that are optimized by data based collaboration.

Scope: The recent economic crisis made it very clear that we need to invest further in the digitalization of processes to make them more resilient. Small and Medium-sized Enterprises (SMEs) as well as public sector organisations and other construction sector stakeholders must better understand how they can use data and innovative digital technologies such as Artificial Intelligence (AI) to significantly improve their production and business processes. The Construction sector is among the least automated and digitised sectors and the most labour-accident prone sector in the European Union. The implementation of a platform thinking approach throughout the industry is still missing. And this despite the immense potential for optimization that lies in digital technologies. Digital transformation can significantly contribute to:

- Productivity increases in planning, design, construction and demolition works
- Reduction of errors
- More efficient use of resources and materials, including with the use of automated, additive, robotic and prefabricated technologies
- Reduction of design and construction costs and duration
- Reduction of labour accidents on construction sites
- Optimised building operations during the whole lifecycle (such as reducing energy and resource consumption, carbon emissions, maintenance costs; and optimising space usage)

In order to realise this potential it is important that data and information is processed and enriched by AI, people and organizations collaborate on data spaces, and AI-based applications empower all stakeholders including SMEs by using processed and enriched data, apply and use precise, knowledge rich digital twins that replicate, simulate and evaluate the physical twin.

Delivering climate neutrality by 2050 will require further acceleration and a higher quality of building construction and renovation processes and uptake of smart technologies in buildings, enhancing the digitalisation of the construction ecosystem and facilitating energy system integration. Digital technologies can improve design and construction processes, producing useful data for the whole building lifecycle.

To master this challenge, SMEs in particular need low entry barrier test opportunities to better understand how digital technologies can help to transform their business. Digital Innovation Hubs (DIH) are one-stop shops that help companies become more competitive with regard to their business/production processes, products or services using digital technologies, by providing access to technical expertise and experimentation, so that companies can "test before they invest". They also provide innovation services, such as financing advice, training and skills development that are needed for a successful digital transformation. DIHs will also support companies and public sector organisations in the use of digital technology to improve the sustainability of their processes and products, in particular with regard to energy consumption and reduction of greenhouse gas emissions. The focus of the proposals should be on demonstrating automation in construction and de-construction as well as data representation, including the connections of buildings with their urban context and connected infrastructures. Proposals must allocate at least 50% of their budget to include SMEs of the broad construction sector in experiments with Financial Support to Third Parties (Annex XX of the Work Programme).

The proposals shall develop concepts for, and implement, pilot demonstrations in the construction sector, that

- Support development and uptake of smart and decarbonised buildings and infrastructure, through the digitisation of processes in the construction sector.
- Integrate collaborative and automated design and construction
- Determine novel business models to strengthen sectorial cooperation along the value chain and cross-sectorial towards enhanced circularity and decarbonisation. This will help to drive deeper understanding of how the market and the construction ecosystem can utilize digital twins to enable new ways of doing business and create new opportunities.
- Offer learning environments to experience innovative components that will ensure accurate tracking of supplies and equipment, provide a real-time digital representation of a construction site up to a digital twin, which accompanies a building throughout its life cycle as a virtual representation of its data.
- Demonstrate tools that enable a more circular and climate neutral construction sector
- Improve the skills of construction sector workers and professionals, including upskilling on the use of existing digital tools and technologies, make available

required training material and connect with adequate training providers, for example by making links with the Blueprint on Sectoral Cooperation on Skills[1], or the BUILD UP Skills initiative[2].

TWIN-TRANSITION-53-2021: Digital building permits (CSA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Increased uptake by public authorities of BIM and GIS enabled building permit processes with interoperable and neutral data formats, rule interpretation and machine-readable regulations.
- Measurable efficiency gains in the processing of permits
- Development of a framework for the digitalisation and automation of building permits for construction and renovation works
- Development of common tools, procedures, data sharing protocols and interoperability.

Scope: As part of the ongoing work with the European Union's Construction 2020 Strategy and the collaboration with the EU Building Information Modelling (BIM) Task Group, there is a need to further develop, connect and assure alignment of different technologies and tools for digital construction. The potential is clear for the optimisation of public procurement for construction through BIM. There is a need to streamline and accelerate the processing and delivery of building permits through BIM enabled tools. The recent technological trends and the opportunities they present, in combination with the pandemic crisis, call for improved automatised methods of building and of authorising construction works. The information produced in BIM during the design phase can facilitate the application and granting of administrative permits, including by making connections with Geographic Information Systems (GIS) and different types of digital twins of greater scale (city level or country level digital twins). Proposals should show how digital permites can help to reduce errors and streamline processes, with consequent savings in costs and time. There is a need to accelerate authorisation permits to increase the rate of building renovations in Europe and to support greater activity by the construction ecosystem in the recovery phase.

Proposals should address barriers to the use of digital building permits including knowledge gaps, technology deployment, and the regulatory context. Proposals should also address support to policymaking. Proposals should take into account the wide range of actors involved in applying for and receiving building permits (e.g. building design and construction professionals, IT experts, academia, industry and public authorities).

[1] See https://ec.europa.eu/social/main.jsp?catId=1415&langId=en
[2] See https://ec.europa.eu/easme/en/section/horizon-2020-energy-efficiency/build-skills

Proposals should take into account the international contexts and developments in BIM and GIS but also the capacities and opportunities presented in different parts of Europe. Proposals may address any or all types of buildings as appropriate.

Section: Hubs for circularity, a stepping stone towards climate neutrality and circularity in industry

[Expected impacts addressed: #15 (Green), #16 (Industrial leadership)

Objective: Establish at least 10 new Hubs for circularity by 2025, providing large scale demonstration platforms (e.g. industrial cluster regional level) for (near) climate neutral, near zero waste and zero landfill concepts at TRL 7 and above.

Current status: The European process industry faces a number of challenges (strong competitive global pressure (e.g. China, USA), and pressure to transform itself to decrease GHG and pollutant emissions, resource utilisation and its overall environmental impact, in line with the political objectives of the EU). This will require reaching climate neutrality, near zero waste, zero pollution and zero landfill by 2050 at the latest. Industrial / urban symbiosis can be a key enabler towards realising these objectives, fostering broad stakeholder engagement, across industry sectors, utilities and local communities, providing sectors and value chain integration to use resources more efficiently and transforming waste and emissions into valuable secondary raw materials. In this context, Hubs for circularity can bridge the gap between research and commercial deployment of industrial symbiosis solutions.

Achievements sought / targets:

- Large-scale industrial symbiosis projects (Hubs for circularity), with strong industrial relevance and cross-sectorial nature, engaging actors at local, regional and national level (e.g. utilities, local communities, municipalities, etc.) to realise fully integrated solutions in existing industrial cluster and regions.
- Significant reduction of emissions and waste, promoting resource and energy efficiency, waste streams valorisation and secondary raw materials uptake, along with integration of renewable energy in industry, to achieve circularity and climate neutrality. For example, Hubs for circularity may implement solutions for process and heat electrification, waste heat recovery, renewable energy, use and storage for grid stabilisation, (novel energy vectors (e.g. hydrogen) waste recycling and emissions valorisation (e.g. CO2 capture and usage) as well as integrated water utilisation in closed loops.
- Digital technologies will be developed as needed in all the R&I activities to achieve this orientation for topics objectives (e.g. material and product passports for zero waste value chains, develop an industry led-reporting and certification system for industrial symbiosis exchange).
- Design for circularity and safety by design principles will also considered as relevant.

Means/links: This orientation for topics will be implemented through several partnership initiatives such as the co-programmed partnerships Processes 4 Planet, Made in Europe and Clean Steel, as well as the institutionalised partnership on Hydrogen. This orientation for topics will have strong links with the activities in Cluster 5 (Energy infrastructures, CCUS, Hydrogen), Cluster 6 (Circular Economy) and other areas in Cluster 4 (manufacturing and advanced materials). Considering the scale of the projects targeted by this orientation for topics, the implementation of the activities will require instruments that go beyond R&I grants. The projects will require blending of multiple funding sources from public and private actors. This could include public funding at European level (e.g. Horizon Europe, Structural Funds, Innovation Fund, etc.) and national level (e.g. national and regional funds), along with significant private investments from industry, possibly backed by appropriate financial instruments at national level (e.g. loans and guarantees from national investment banks) and/or European level (e.g. Just transition Mechanism, InvestEU, etc.).]

Proposals are invited against the following topic(s):

TWIN-TRANSITION-31-2021: Deploying industrial-urban symbiosis models for waste utilisation at regional scale (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Step change towards closing circular loops;
- Significant reduction of waste generation (50%) by re-use and transformation of waste as secondary products
- Concepts for overcoming relevant barriers (e.g. end of waste criteria);
- Effective dissemination of major innovation outcomes towards the implementation of Industrial-Urban Symbiosis, connection to the EU Community of Practice, development of learning resources with flexible usability.
- Clear environmental gains in absolute figures, and weighted against EU and global environmental footprints, should be demonstrated;
- Proved replication potential in other regions.

Relevant indicators and metrics, with baseline values, should be stated clearly in the proposal.

Scope: Exemplary pilot solution of Industrial-Urban Symbiosis needs to be exploited to accelerate the transition to a circular economy. Examples could be: reducing waste, virgin raw materials, and energy and water consumption, mainly by transforming underused waste materials (both industrial waste and by-products and end of life urban waste) into feedstocks for the process industries. To support a wide implementation of Industrial-Urban Symbiosis for waste utilization, the regional dimension is important as local energy and utility networks, adjacent industrial infrastructures and available by-products and wastes should be considered in a holistic approach and the logistics should be minimised wherever possible and advantageous from the perspective of sustainability and competitiveness. Technology based innovation should prove the potential for a novel symbiotic value chains in a demonstrator involving multiple industrial sectors in pilot industrial settings.Technology based innovations should prove the potential for novel symbiotic value chains in demonstrators involving multiple industrial sectors in pilot industrial settings. Projects are expected to address:

- A broader symbiosis, from local and regional perspectives;
- Processing of side/waste streams specifically for the use as resource for plants and companies across sectors and/or across value chains;
- Process (re-)design and adaptation to integrate new processes (energy and material flow coupling, infrastructure and logistics).
- Integration of ICT and digital tools, including artificial intelligence for multi-criteria decision making, for the design and the operation management of exchange streams in

a dynamic production environment, advanced modelling to design and establish novel symbiotic interactions, data sharing and preservation of data confidentiality, as a non-exhaustive list;

- Assessment methodologies and KPIs to measure the performance of symbiosis, including environmental, economic and social impacts. Life cycle assessment and life cycle cost analysis should take into account existing sustainability standards (e.g. ISO 14000) and existing best practices.
- Development of common transport reporting methodologies for the assessment of industrial symbiosis activities and exchanges.

Clustering and cooperation with other selected projects under this cross-cutting call and other relevant projects is strongly encouraged.

TWIN-TRANSITION-32-2021: Circularity loops for solid waste in urban environment (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- 80% reduction of solid waste generation by re-use and transformation of relevant parts of the waste as secondary resource for the process, manufacturing and construction industries in comparise to curret state-of-the-art.
- Tackling relevant barriers to exploitation (e.g. end of waste criteria);
- Effective dissemination of major innovation outcomes towards the implementation of Industrial-Urban Symbiosis, development of learning resources with flexible usability, connection to the Community of Practice.
- Clear environmental gains in absolute figures, and weighted against EU and global environmental footprints, should be demonstrated;
- An analysis of barriers, standards, and new business models, covering ownership, management and fair sharing of benefits.
- Proved replication potential in other regions.

Relevant indicators and metrics, with baseline values, should be stated clearly in the proposal.

Scope: Circularity hubs for solid waste in urban environment tackles a fundamental issue of end of life materials representing a huge amount and broad range of solide wastes. There is a need of innovative solution engaging waste management actors in novel value chains to valorise a significant part of those wasts, bringing full attention to upcycling back to secondary materials instead of down cycling of low re-use. Projects are expected to address:

- Broader symbiosis, from urban perspectives;
- Management of side/waste streams (through e.g. capturing, purification, concentrating, sorting, collecting, recycling (especially chemical recycling for the valorization of waste to be used as feedstock), exchanging or preparation) specifically for the use as resource for other plants and companies across sectors and/or across value chains;
- Process (re-)design and adaptation to integrate new value chain including energy and material flow, infrastructure and logistics.

- Integration of ICT and digital tools, including artificial intelligence for multi-criteria decision making, for the design and the operation management of exchange streams in a dynamic production environment, advanced modelling to design and establish novel symbiotic interactions; data sharing and preservation of data confidentiality;
- New approach to end-of life materials removing usual barriers of exploitation, enabling novel symbiotic interactions; data sharing and preservation of data confidentiality;
- Assessment methodologies and KPIs to measure the performance of symbiosis, including environmental, economic and social impacts.
- Life cycle assessment and life cycle cost analysis should take into account existing sustainability standards (e.g. ISO 14000) and existing best practices.

Clustering and cooperation with other selected projects under this cross-cutting call and other relevant projects is strongly encouraged.

TWIN-TRANSITION-33-2021: Integration of pandemic waste knot hubs for circularity (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Meeting the EU's circular economy and environmental targets while demonstrating a clear benefit, i.e. more efficient or economic than the state of the art in order to enable market uptake in the short to medium term;
- Create new technologies and business opportunities for the recycling industry across Europe, especially in the area of composites and plastics where the challenge is high;
- Demonstrate a significant reduction in landfill waste volume;
- Reduction of the carbon footprint of the corresponding products (based on a full Life Cycle Assessment).

Relevant indicators and metrics, with baseline values, should be clearly stated in the proposal.

Scope: The ambition is that Europe becomes the world-leader in developing sustainable chemistry, smart materials and intelligent recycling, through a combination of mature and disruptive technologies.

Projects are expected to address:

- Develop re-use/recycle strategies through new value chain and disruptive business models for pandemic wastes for single use disposable devices and equipment (masks, gloves, protective materials and quarantine elements/devices, etc).
- Management of side/waste streams starting from collection, sorting, distribution for the use as resource for other plants and companies across sectors and/or across value chains;
- Proposals should demonstrate the actual circular use of such materials through re-processing of recycled products and evaluate the properties of such re-processed products compared with similar new products.

- Proposals should include the full Life Cycle Assessment (LCA) of the material production and life-cycle.
- Assessment methodologies and KPIs to measure the performance of symbiosis, including environmental, economic and social impacts.
- Life cycle costing, market analysis and business model should demonstrate rentability of the processes and products.

Priority should be given to eventual second life applications.

Clustering and cooperation with other selected projects under this cross-cutting call and other relevant projects is strongly encouraged.

TWIN-TRANSITION-34-2021: Hub for Circularity Community of Practice (ECoP) platform (CSA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Effectively working sustainable European Community of Practice (ECoP) as exchange forum/platform connecting H4C and all actors willing to invest in Industrial Urban-symbiosis (I-US) projects, giving them appropriate up-to-date support to develop their project by collecting knowledge and tools, and making them accessible through training material dedicated to circular practitioners that can drive H4C roll out across Europe.
- Analysis of technologies and tools for industrial-urban symbiosis and circularity – especially those from projects so far.
- Support the H4Cs network and promote the transfer of the circular models across sectors and borders.
- Stimulate circularity public and private investments.
- Spread the H4C concept to all regions of Europe.
- Solid plan for self-financing the Community funding is finished.

H4C are self-sustaining economic industrial ecosystems for full-scale Industrial-Urban Symbiosis and Circular Economy in a specific geographic area, closing energy, resource and data loops and bringing together all relevant stakeholders, technologies, infrastructures, tools and instruments necessary for their incubation, implementation, evolution and management.

The H4C Community of Practice is a tool connecting the Hubs into a network for tools and knowledge exchange across regions. The project will embrace possibly all existing H4C and circular systemic activities and strongly link with P4Planet.

Scope: Many initiatives and publicly funded projects exist on various levels, from European-scale to national and regional projects. Many tools, models, and technologies have been developed which need to be visible and accessible for managers of symbiosis. In order to assist them the platform should:

- Gather and synthesise state-of-the-art knowledge on circularity and industrial symbiosis;
- Characterise, classify and evaluate systematically with a constant update symbiosis and circularity-related solutions;

- Connect the regional H4C and ensure a mutually profitable knowledge and experience exchange;
- Provide tutorials and learning framework about state-of-the-art solutions;
- Support the transfer of knowledge, tools and innovation across the H4Cs, and the programming groups or ad-hoc task forces.
- Engage with other stakeholders (e.g. universities or other education institutions) to facilitate the training of circular practitioners. These practitioners should have an in-depth understanding of industrial and urban symbiosis, the state-of-the-art tools and databases, and newest business models.
- Track regional needs based on feedback of H4Cs and other supporting members in order to optimise the support;
- Enable prioritization of I-US projects by providing systematised knowledge on gaps and potential impacts;

The funded projects under P4Planet will be required to provide complete information and full collaboration to the platform.

TWIN-TRANSITION-35-2021: State-of-play analysis of regions/areas for first implementation of advanced hubs for circularity" (CSA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- A state-of-the-play analysis of regions best suitable for the first implementation of advanced hubs for circularity in Europe whith 10 regions short listed and a couple of related scenarios for technology and process implementation;
- Detailed study of the strength and weaknesses of the regions selected including the Symbosis maturity level (SRL).
- Identification of 3 regions where first of a kind pilot implementation of advanced hubs for circularity can start by 2024, aiming at a significant level of circularity by 2030.

Project should strongly link with P4Planet stakeholders and existing H4Cs.

Scope: In March 2020, the European Commission adopted a legislative proposal for a European climate law setting the objective for the EU to become climate-neutral by 2050. Circularity is an essential part of the industry transformation towards climate-neutrality and long-term competitiveness. Hubs for Circularity (H4C) are systems/tools/enablers to realize this ambition in a competitive way decreasing related costs through Industrial Symbiosis and facilitating first of a kind large demonstrators. Activities should include:

- Draw up a list of specifications/criteria for best suited regions;
- Detailed analysis of suitable regions in EU for H4Cs implementation. The regions to consider should involve resource streams from consumer waste, urban wastewater, and waste streams, preferably Industrial-Urban Symbiosis senarios that are already in place,

and proved involvement of regions and local communities. SRL level defining maturity of symbiosis processes should be preferably significant.

- Selection of then regions, good candidate, for developing the first model H4Cs by 2024. These ten hubs should become lighthouse examples of win-win cooperation between industry, public authorities and civil society on circular economy beyond 2025. The H4C could be thematic at first (e.g. focus on valorisation of emissions or circular use of plastic waste, etc.) and evolve after a successful first demonstration into a broader concept, attracting other players from other industry sectors at local, regional, national or European level and enabling industrial symbiosis in new areas and processes.

- Pre-implementation analysis of the 10 first listed regions. This should at least include technical and non technical challenges, various proposal for symbiosis process implementation, commitment level of the local authorities and communities, regional specificities (business/industrial policy and strategies), additional funding and state-aid resources, etc. These ten hubs should become lighthouse examples of win-win cooperation between industry, public authorities and civil society on circular economy beyond 2025. The H4C could be thematic at first (e.g. focus on valorisation of emissions or circular use of plastic waste, etc.) and evolve after a successful first demonstration into a broader concept, attracting other players from other industry sectors at local, regional, national or European level and enabling industrial symbiosis in new areas and processes.

- Prioritisation of the first-listed region in order to select the three first H4Cs best localisation.

TWIN-TRANSITION-36-2022: Circularity hubs for near zero emissions regions (RIA)

<u>Expected outcomes</u>: Projects are expected to contribute to the following outcomes:

- Signifficant improvement in energy efficiency and in CO2 emissions of the targeted industrial processes thanks to industrial-urban symbiosis to meet climate neutrality by 2050;

- Concepts for overcoming relevant non-technological barriers;

- Effective dissemination of major innovation outcomes to the civil society, connection to the EU H4C Community of Practice;

- Demonstration of the symbiotic processes in relevant environment with evaluation of environmental gains in absolute figures, and weighted against EU and global environmental footprints;

- Exploitation plan with co-financing

- 3 EU virtual regional case to prove the replication potential

Relevant indicators and metrics, with baseline values, should be stated clearly in the proposal.

Scope: In order to reach climate neutrality by 2050, prioritising climate change mitigation in the economic recovery is a necessity. Process industries should abate GHG emissions generated in their processes, both energy-related and process-related, to contribute to a climate neutral society. Digitalisation and regional hubs for circularity will serve as accelerators for the transformation. Digitalisation will enable the fast development of new materials and processes and of industrial-urban symbiosis, improving the energy and resource efficiency of plants and value chains. Hubs for circularity (H4C) will bring together local stakeholders to jointly find synergies and accelerate the transition exploiting the full potential of Industrial-Urban Symbiosis, reducing waste, raw material, and energy and water consumption. Projects are expected to address:

- Broader symbiosis, from local and regional perspectives, with infrastructures (e.g. waste and water management infrastructure, gas networks), communities and energy grids (e.g. smart operations scheduling, district heat integration), including distributed generation and the role that symbiosis can play in fluctuating energy grids (i.e. grid services, seasonal storage, biomass or heat pumps integration);

- Management of side/waste streams (through e.g. capturing, purification, concentrating, sorting, collecting, recycling, exchanging or preparation) specifically for the use as resource for process industries across sectors and/or across value chains;

- Process (re-)design and adaptation to integrate new value chain (energy and material flow coupling, infrastructure and logistics).

- Integration of ICT and digital tools, including artificial intelligence for multi-criteria decision making, for the design and the operation management of exchange streams in a dynamic production environment, advanced modelling to design and establish novel symbiotic interactions; data sharing and preservation of data confidentiality;

- Assessment methodologies and KPIs to measure the performance of symbiosis, including environmental, economic and social impacts. Life cycle assessment and life cycle cost analysis should take into account existing sustainability standards (e.g. ISO 10410) and existing best practices.

Section: Enabling circularity of resources in the process industries, including waste, water and CO2/CO

[Expected impacts addressed: #15 (Green), #16 (Industrial leadership)

Objective: Maximise the utilisation of CO2/CO streams and waste as secondary raw materials. Cut GHG and pollutant emissions and decrease primary raw materials utilisation.

Current status: Process industries are by nature resource intensive, using huge amounts of raw materials, often imported fossil based ones. In their operations, they generate large amounts of waste and CO/CO2 emissions. To make process industries more sustainable, it is critical to reduce resource utilisation as well as waste and emissions generation. In this context, the circular utilisation of waste streams and CO2/CO streams could provide a key pathway to turn waste into a resource, giving access to alternative feedstock for industry to replace fossil based raw materials. This would benefit both industry and society, increasing resource efficiency, while reducing polluting emissions and waste. It can also enhance the resilience and competitiveness of the European industry, by reducing dependence from imports of volatile commodities (oil, gas, minerals).

Achievements sought / targets: The development of disruptive process technologies, including decontamination technologies for a high quality of inputs to enable safe and circular valorisation of widely available waste streams and emissions (e.g. CO2/CO) turning them into secondary raw materials, intermediates and added-value products of interest for process industries (e.g. chemicals, fertilisers, steel, cement, minerals, etc.) or fuels for transport.

- Technologies for the valorisation and decontamination of inputs, waste (plastic, biomass, etc.) and CO2/CO streams (CO2 capture and usage, catalysis and artificial photosynthesis) to produce added value products and intermediates, such as materials, fuels and chemicals.
- Energy and resource efficiency will be major areas of focus for all the technology developments. The utilisation of electrified technologies will also be promoted to ensure the integration of the technologies in a future renewable energy system.
- Digital technologies as well as design for circularity and safety by design (including non-toxicity of materials) principles will be considered under the R&I activities as relevant.

Means/links: This orientation for topics will be implemented through several partnership initiatives such as the co-programmed partnerships Processes 4 Planet and Clean Steel, as well as the institutionalised partnership on Hydrogen.

This orientation for topics will have strong links with other activities in Cluster 4 (Advanced materials), as well as with activities in Cluster 5 (Energy infrastructures, CCUS, Hydrogen) and Cluster 6 (Circular Economy). Shared activities with these parts of the programme may be developed (e.g. Joint calls).]

Proposals are invited against the following topic(s):

TWIN-TRANSITION-37-2022: Develop CO/CO2 refineries (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Utilise CO/CO2 streams to produce a broad range of added value products and intermediates of wide interest (e.g. polymers, resins, chemicals, food/feed ingredients, minerals, etc.). Excluding fuels and/or energy carriers.
- Enhance the market for CO/CO2 based products providing economically viable and sustainable alternatives to existing products in a wide range of applications (e.g. consumer products, feed/food ingredients, automotive, construction, etc.).
- Develop concepts enabling 100% utilisation of RES (e.g. electrified processes, concentrated solar, etc.), coping with potential fluctuations in the energy supply.
- At least 60% GHG emissions in the overall lifecycle compared to existing processes for the same products (or relevant benchmark).

Scope: The proposals submitted under this topic are expected to provide concepts for utilisation CO/CO2 streams from point sources (e.g. large industrial installation such as steel, cement and chemical plants) converting them into added value products and/or intermediates and chemicals of wide interest (plastics, resins, composites, chemicals). The topic excludes expressely fuels and renewable energy storage concepts. The technologies proposed should support cross-sectorial concepts and sector integration paradigms. They should also be able to work efficienctly in a renewable based energy system, coping with potential fluctuations in the energy supply or be fully self-sustained from an energy standpoint. The concepts proposed are expected to:

- Process significant amounts CO/CO2 containing waste streams from energy intensive industries, including efficient approaches for the pre-treatment of the gaseous stream (e.g. cleaning, compression, drying, concentration, etc.) if needed.
- Targetting a range of products and/or intermediates with a wide variety of applications in different sectors (e.g. construction, automotive, food/feed, etc.) to replace current ones (e.g. fossil based or from virgin raw materials).
- Industrial specifications and relevant market requirements should be clearly considered. The proposal are expected to demonstate that targeted products and/or intermediates can fully relevant existing counterparts. The prevention of upcycling of hazardous substances, including their separation and disposal should be considered.
- Demonstration of the improved environmental footprint of the proposed products and processes, as well as other positive impacts should be provided using relevant methodologies (e.g. LCA, LCSA, etc.).
- Elements related to the replicability and scalability of the technology should be provided.

- Demonstration of the proposed concepts in an industrially relevant environment and at an appropriate scale is expected. The integration of the proposed technology in existing value chains and the relevance to several European contexts would be an added value.

TWIN-TRANSITION-38-2021: Plastic waste as sustainable carbon feedstock for industry (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Valorise a wide variety of unsorted plastic (and other) waste, including items such as PPEs (e.g. masks, gloves, screens, etc.), in large amounts, to avoid landfill.
- Yield material streams of high industrial interest, replacing the ones currently produced from fossil feedstocks (e.g. olefins, hydrogen, syngas, etc.).
- Develop concepts enabling 100% utilisation of RES (e.g. electrified processes), coping with potential fluctuations in the energy supply.
- At least 60% GHG emissions in the overall lifecycle compared to existing for plastic recycling (or relevant benchmark).

Scope: Plastic and other waste could potentially represent a sustainable alternative to imported feedstock (e.g. oil, gas). It contains high amounts of carbon, it is widely available and ist valorsatin could also provide environmental and societal benefits avoiding the disposal in landfill.

The proposals submitted under this topic are expected to provide concepts for utilisation of unsorted plastic (and other) waste in cracking applications, including items such as PPEs (e.g. masks, gloves, screens, etc.), for the production of material streams of wide industrial interest (e.g. hydrocarbons, olefins, syngas, hydrogen, etc.). The technologies proposed should be electrified to work efficiently in a renewable based energy system. They should also be able to cope with potential fluctuations in energy supply.

- The technologies proposed should be able to valorise a wide variety of unsorted waste, plastic could be a major source, other waste sources can be considered, providing the supply is secure and the business case is feasible. Special attention is expected to the potential variability of the input, and the presence/formation of contaminents and impurities in the process.
- The processes addressed should yield material streams which are of high industrial interest and can be readily integrated in downstream industrial processes for the production of a wide range of products (e.g. plastics, chemicals, hydrogen, fuels, materials, fertilisers, etc.).

- Industrial specifications should be considered, and proof that these secondary raw material streams can be used in downstream industries should be provided.

- Demonstration of the improved environmental footprint of the proposed products and processes, as well as their positive impact should be provided using relevant methodologies (e.g. LCA, LCSA, etc.). The prevention of upcycling of hazardous substances and their separation and disposal should be considered.

- Elements related to the replicability and scalability of the technology should be provided. Along with the relevance of the proposed approaches to solving waste related issues in existing European contexts.

- Demonstration of the proposed concepts in an industrially relevant environment and at an appropriate scale are expected. The integration of the proposed technology in existing value chains and industrial realities would be an added value.

TWIN-TRANSITION-39-2022: Upcycling technologies for plastic waste (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Upcycle plastic waste, including items such as PPEs (e.g. masks, gloves, screens, etc.), to produce added value products of comparable or higher value, solving waste related issues or improving the overall recycling process.

- Provide clear advantages (economic, environmental, social, etc.) on existing recycling routes for the same or similar plastic waste (or relevant benchmark).

- Develop concepts enabling 100% utilisation of RES (e.g. electrified processes, concentrated solar, etc.), coping with potential fluctuations in the energy supply.

- At least 60% GHG emissions in the overall lifecycle compared to existing for plastic recycling (or relevant benchmark).

Scope: The proposals submitted under this topic are expected to provide concepts for utilisation plastic waste (excluding composites), which may include sorted or unsorted waste, including one or more types of plastics (e.g. PET, PP, PS, Etc.) and items such as PPEs (e.g. masks, gloves, screens, etc.),. The concept proposed are expected to upcycle the plastic waste though chemical (and/or biochemical) processes into intermediate streams or products, of a comparable or higher value than the initial products, and with no or minimal utilisation of virgin raw materials. The technologies proposed should be able to work efficiently in a renewable based energy system. They should also be able to cope with potential fluctuations in energy supply.

- Proposals should consider the overall supply chain (i.e. plastic waste streams which are widely available in Europe) to secure raw material supply, including potential sorting needs.

- The concepts proposed should yield intermediates of products of wide interest targeting a number of industrial sectors (e.g. construction, automotive, textiles, etc.).

- Industrial and market specifications should be considered, to demonstrate that the targeted secondary raw material streams (and/or products) can replace fully existing ones produced from primary raw materials.

- Demonstration of the improved environmental footprint of the proposed intermediates, products and processes, as well as other positive impacts should be provided using relevant methodologies (e.g. LCA, LCSA, etc.). The prevention of upcycling of hazardous substances and their elimination from the process streams should be considered.

- The proposals are expected to address existing supply chains (including sorting processes, if relevant), ensuring relevance of the proposed approaches to solving/impove waste related issues and enhance waste valorisation in existing European contexts.

- Elements related to the replicability and scalability of the technology should be provided. Along with the relevance of the proposed approaches to solving waste related issues in existing European contexts.

- Demonstration of the proposed concepts in an industrially relevant environment and at an appropriate scale are expected. The integration of the proposed technology in existing value chains and industrial realities would be an added value.

TWIN-TRANSITION-40-2021: Adjustment of Steel process production to prepare for the transition towards climate neutrality

<u>Expected outcomes</u>: Projects are expected to contribute to the following outcomes:

The new low-carbon technologies bring along substantial changes concerning the internal and external flows of energy and materials. This applies in particular for the most common integrated steelworks, based on the conventional BF-BOF route with its thoroughly coordinated gas and material network.

<u>Scope</u>: tbc

TWIN-TRANSITION-41-2021: Improvement of the yield of the iron and steel making route by recovering of metal contents from metal oxides

<u>Expected outcomes</u>: Projects are expected to contribute to the following outcomes:

Recovery of metal contents from metal oxides both directly in the existing production process (e.g. agglomeration of residues rich in metal-oxides to recharge in the melting process or recharge of fines residues within DRI plant) and in a dedicated unit (e.g. pyro-metallurgic unit recovering the metals and Zn oxide by EAF/BOF residue).

Scope: tbc

TWIN-TRANSITION-42-2022: Utilisation of biomass as coal and/or gas substitute in existing steel processes

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Integration in steel plants of carbonisation, pyrolysis and gasification processes designed for using biomass as coal and/or gas substitute in existing steel processes (coke plant, sinter plant, BF, BOF, EAF)

Scope: Tbc

TWIN-TRANSITION-43-2022: Raw material preparation for clean steel production

Expected outcomes: Projects are expected to contribute to the following outcomes:

Projects related to to the two main raw-materials in the iron and steelmaking route: the iron-ore and the scrap.

As regards iron ore, the availability of high-grade iron ores is expected to become a more critical factor, as demand will increase. Therefore, technologies for the upgrade and the use of low-quality iron ores are needed. This includes low carbon technologies for sintering/ pelletisation and/or cold bonded iron ore agglomeration.

- The research on scrap will focus on the best available and applicable technologies for the reduction of impurities in post-consumer scrap. The aim is to remove these impurities before melting, in order to achieve the same quality of the finished product and reducing CO2 emissions. In addition, valorisation of low-quality scrap streams is one of the key elements for fostering a green transition of the steel production as a whole.

Scope: Tbc

TWIN-TRANSITION-44-2021: Reducing environmental footprint, improving circularity in extractive and processing value chains (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials and secondary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Reduce environmental impact of extractive and processing value chains;
- Develop demonstrators and pilot plants with a lower environmental impact;
- Reduce environmental footprint and circularity of extractive and processing value chains;
- Developed methods, technologies and processes for mining and processing aiming at significantly decreased emissions (CO2 and other emissions);
- Significantly increase resource and energy efficiency, and increased circularity of raw materials together with increased valorisation of extractive waste;
- Contribute to meeting the goals of climate neutrality, circularity and zero pollution as spelled out in the European Green Deal.

Actions are expected to contribute to the implementation of the following actions of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020):

- Use Horizon Europe funding for research into mining processes with minimal impact on the environment and life-cycle assessment;
- Support waste and extractive waste valorisation and energy efficiency through cross-sectoral cooperation and industrial symbiosis, involving the mining industry.

Scope: Actions should develop sustainable solutions to reduce dependence of extractive activities on carbon-related energy sources and process emissions. They should also address reducing materials use, water and waste valorisation at all stages of the extractive and processing cycle.

Actions should facilitate the market uptake of solutions developed through industrially- and user-driven multidisciplinary consortia covering the relevant value chain and should consider standardisation aspects when relevant.

Actions should justify the relevance of selected pilot demonstrations in different locations within the EU (and also outside if there is a clear added value for the EU economy, industry and society).

TWIN-TRANSITION-45-2022: Technologies for a more efficient utilisation and management of industrial waste waters (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Provide novel process technologies for a more efficient management of industrial waters, minimising the utilisation of freshwaters and maximising water reuse.

- Provide clear advantages (economic, environmental, social, etc.) on state of the art industrial waste water treatment processes (or relevant benchmark).

- Maximise the recovery of substances and energy present in the waste water streams, providing integrated solution for their valorisation (e.g. industry, urban districts, etc.).

- Minimise energy use and foster utilisation of RES (if needed), coping with potential fluctuations in the energy supply.

- Strong decrease GHG emissions in the overall lifecycle compared to existing for plastic recycling (or relevant benchmark).

Scope: Energy intensive industry sectors utilise large amount of water in their operations, requiring significant amount of fresh water resources and creating large amounts of waste waters streams. These streams must be further processed requiring significant amount of energy and infrastructure, as well as high investment in capex, operation and maintenance costs. Furthermore, industrial waste waters often contain significant amounts of valuable substances (e.g. organic matter, salts, phosphates, etc.) and residual heat which are not optimally valorised.,

The proposals submitted under this topic are expected to provide innovative concepts for the treatment of industrial waste waters, recovering energy and substances present (metals, organic compounds, etc.) fostering reuse of this water in industry, therefore minimising the need for fresh water and moving towards a close loop in industrial water utilisation.

- Proposals are expected to provide integrated technologies to carry out industrial water purification through physical, chemical (and/or biochemical) processes and/or a combination thereof, yielding water streams of appropriate specifications for reuse in industry (same or other industry sectors).

- The technologires proposed should allow maximising the recovery of energy and substances present in the water streams, fostering their valorisation. The technologies proposed should minimise the energy consumption (compared to existing processes) and be able to work efficiently in a renewable based energy system, coping with potential fluctuations in energy supply.

- Replicability/applicability of the proposed solutions in different industry sector should be considered, along with the possibility to achieve integrated cross-sectorial waste water treatment concepts.

-Demonstration of the improved environmental footprint of the proposed processes, as well as other positive impacts should be provided using relevant methodologies (e.g. LCA, LCSA, etc.). The prevention of upcycling of hazardous substances (e.g. micro and nano particles) should be considered as well as their separation and disposal.

-The proposals are expected to prove the relevance of the proposed approaches and their applicability in existing European industrial and/or urban/industrial contexts.

-Elements related to the replicability and scalability of the technology should be provided.

-Demonstration of the proposed concepts in an industrially relevant environment and at an appropriate scale are expected. The integration of the proposed technology in existing value chains and industrial realities would be an added value.

Section: Integration of Renewables and Electrification in process industry

[**Expected impacts addressed**: #15 (Green), #16 (Industrial leadership)

Objective: Electrify Energy intensive industries and develop technologies to enable and support the energy transition (grid services, energy storage). Foster the achievement of a climate neutral, zero GHG and pollutant emissions industry, moving away from fossil-based energy.

Current status: The transition to a renewable energy system (PV, wind) is an essential element to curb GHG emissions and fight climate change, as a major share of today's GHG emissions is linked to our heavily fossil based energy system. This change in the energy mix brings about significant challenges for industry, and especially for energy intensive industries. **Electrification** will be a key driver to utilise directly renewable electricity in industry. For Energy intensive Industries this will represent a radical step change, with the need to reinvent their processes, moving from today's steady state operations to flexible ones to cope with fluctuations in the energy supply. Furthermore, Energy intensive industries, as heavy energy consumers, sectors will need to become active actors in the energy system, providing grid stabilisation services and efficient renewable energy storage technologies, to ensure energy availability and power grid stability.

Achievements sought / targets: Development of disruptive technologies for utilisation of renewable electricity in the process industry. Integration of Energy intensive industries as active actors in the energy system (e.g. providing grid services, renewable energy storage).

- Electricity powered processes and technologies (microwave, plasma, electrical furnaces, photocatalysis, electrochemistry, etc.), management systems for real time balancing of energy demand and supply at cluster level, system integration of industry produced carbon and nitrogen based energy carriers (e.g. methanol, ethanol, synthetic methane, hydrocarbons, ammonia, etc.) as renewable energy storage sinks.

- Resource and energy efficiency will be areas of strong focus, as will be the flexibility of industrial processes (i.e. no steady state operations) and the minimisation of polluting emissions to the environment

- Digital technologies will also be in the focus for all the R&I activities, for example management systems for real time balancing of energy demand and supply at cluster level, to the extent required to achieve the orientation for topics objectives.

Means/links: This orientation for topics will be implemented through several partnership initiatives such as the co-programmed partnerships Processes 4 Planet and Clean Steel, as well as the institutionalised partnership on Hydrogen.

This orientation for topics will have strong links with other activities in Cluster 4 (Advanced materials), as well as with activities in Cluster 5 (Energy infrastructures, CCUS, Hydrogen). Shared activities with these parts of the programme may be developed (e.g. Joint calls).]

Proposals are invited against the following topic(s):

TWIN-TRANSITION-46-2021: New electrochemical conversion routes for materials and chemicals manufacturing (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Efficient integration of renewable electricity to drive the conversion process
- Significant reduction of CO_2 emissions
- Energy savings compared to the classical production routes
- Overall material (waste reduction) savings compared to the classical production routes
- Competitive costs of the new reactor and its integration in the processing line, including upstream and downstream

Relevant indicators and metrics, with baseline values, should be clearly stated in the proposal.

Scope: Renewable electricity will play a major role in the transition towards a low carbon energy supply. The manufacturing of materials and chemicals through the direct use of renewable electricity can be realised by electrochemical conversion. Besides the reduction of CO_2 emissions, other advantages of electrochemical conversion with renewable electricity can be the higher selectivity, process flexibility, or the possibility of conditions unattainable in a conventional reactor.

At present, there are promising electrochemical routes towards a wide range of products in process industries. These include processes like hydrogenation of biomass into valuable chemicals, recovery of metals from waste streams, electrosynthesis of organic molecules, production of lime by electrochemical splitting, electrolytic production of metals, (in-situ) production of hydrogen peroxide or ozone, etc.

Next to the low temperature aqueous electrochemical processes, high temperature electrochemical processes, using ionic liquids or molten salts as electrolytes, offer interesting alternatives to the classical production processes as well opportunities for the development of sustainable technology. Paired synthesis, where two valuable products are generated through the cathodic and anodic reactions, is an interesting approach to reduce investment costs (per unit product).

Proposals should address the following aspects:

- Optimisation of electrochemical parameters (current density, Faradaic efficiency, overpotential);
- Increased lifetime or reduced cost of the electrochemical reactor components (electrode, electrolyte, catalyst, membrane);
- Efficient integration of renewable electricity;
- Integration of oxidation and reduction reactions in one system;
- Development of more selective and efficient electrochemical catalysts.

The use of scarce materials or toxic materials must be minimised. The use of inert or low carbon impact materials is a positive aspect.

Proposals submitted under this topic should include a safety assessment and a life cycle assessment for the implementation of the developed technologies.

The proposed technology must not be based on conversion of CO_2, as this subject is already covered in other call topics.

TWIN-TRANSITION-47-2021: Novel high temperature heat pump technologies (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- More efficient high temperature heat pump technologies or solutions to drive industrial processes at temperatures higher than 250 °C
- Circular use of industrial heat sources for recovery and reuse of low-grade heat sources
- Significant reduction of CO_2 emissions, combining the developed technology with renewable energy sources
- Cost reduction of high temperature heat pump technologies or solutions (> 250 °C) by smart integration

Relevant indicators and metrics, with baseline values, should be clearly stated in the proposal.

Scope: Today a large part of European process industries emissions originate from the use of fossil fuels for heating purposes. The decarbonation of industrial heating and cooling is thus essential in the transition towards climate neutrality. Heat pumps have the capacity to use electricity to produce more useful heat at a higher temperature from waste heat, with the consequent reduction of non-renewable final energy demand and related emissions. In combination with renewable energy sources, heat pumps will play a major role in the decarbonisation of industrial heating and the avoidance of thermal loads on the environment, by achieving a circular use of heat. The use of heat pumps also increases the energy efficiency of processes significantly.

Currently (compression) heat pumps are commercially available that can deliver heat up to 100 °C. Research is devoted to increasing the temperature of the delivered heat up to an above 250 °C, enlarging the range of industrial processes that can benefit from this technology. Although the compression heat pump can potentially be developed for temperatures up to 250 °C, for high temperature heat pumps (>250 °C), a range of other principles is considered (e.g. based on adsorption/desorption, thermoacoustic). A more efficient use of the industrial heat is achieved when heat pumps are integrated in a specific process, which also allows the reduction of costs of the technology integration in the industrial facilities.

The implementation of novel industrial heat pump technologies will contribute to the CO_2 emission reduction targets to achieve climate neutrality by 2030 in terms of large-scale demonstrators and for the energy-intensive industry as segment by 2050.

Proposals should address the following:

- Cost reduction of heat pump systems to improve competitiveness against fossil-based heating systems;
- Increased temperature of heat delivery (>250 °C), developing new working fluids for advanced heat pump cycles, i.e. sorption, thermoacoustic and hybrid cycles;
- Development of compressor technologies for heat pumps higher than 250 °C;

- Smart process integration of heat pumps, with heat pump cycles integrated in specific processes, using waste heat from the process to provide process heat;
- Easy integration with renewable energy (solar heating or electricity from renewable production sources).

Proposals submitted under this topic should include a safety assessment and a life cycle assessment for the implementation of the developed technologies.

TWIN-TRANSITION-48-2022: Integration of hydrogen for replacing fossil fuels in industrial applications (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Significant reduction of CO2 emissions
- Improved energy efficiency
- Significant reduction of hydrogen fuel needs of the developed process with regards to the current fossil fuel needs
- Proven economic viability

Relevant indicators and metrics, with baseline values, should be clearly stated in the proposal.

Scope: Hydrogen does not emit any carbon dioxide when used and, when produced with renewable energies, it offers a solution to decarbonise industrial processes, being an important enabler to meet the 2050 climate neutrality goal of the European Green Deal and Europe's clean energy transition. Hydrogen can be used as feedstock and energy carrier in energy-intensive industry sectors.

Hydrogen presents an opportunity for European industry to reduce emissions across a number of sectors. The integration of hydrogen into new production routes, the direct use of hydrogen for heating and the use and production of GHG emission-free hydrogen instead of carbon-intensive hydrogen will be fundamental to decarbonise European industry across a number of sectors.

In energy-intensive sectors, hydrogen can replace fossil fuels to generate high temperature heat when combusted in furnaces/kilns. If GHG emission-free hydrogen is used instead of fossil fuels, a zero GHG emission heating process could be achieved. As hydrogen burns differently than the currently used fossil fuels, its use involves important changes to the furnaces/kilns or the heating process, such as need of new burners, adjustments in the combustion system, conductive zone of the furnace or the (off-)gas system, need of hydrogen compatible materials.

The proposals should address one of the following aspects:

- Redesign of the heating process for the use of hydrogen as the sole heating fuel, including redimensioning and adjustments of the combustion system, conductive zone of the furnace or the (off-)gas system;
- Modification of the heating equipment and infrastructure required for the use of hydrogen, e.g., new burners and hydrogen compatible equipment materials;

- Integration of measurement and control instrumentation for detection and regulation of fuel gas characteristics and flows;
- Proven economic viability, which will be impacted by several parameters.

Proposals submitted under this topic should include a safety assessment and a life cycle assessment for the implementation of the developed technologies.

TWIN-TRANSITION-49-2022: Design and optimization of energy flexible industrial processes (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Significant increase in flexibility of the process towards various energy sources: dynamic operation instead of steady state operation
- Significantly high response rate of the process, i.e., the rate at which energy consumption can be increased or decreased depending on the energy availability
- Development of digital tools accounting for the energy availability and the additional flexibility of the process
- Overall increased energy efficiency of the process within the energy system
- Cost reduction of the overall process through valorisation of excess streams into the energy system
- Production flexibility linked to cheap and green energy supply.

Relevant indicators and metrics, with baseline values, should be clearly stated in the proposal

Scope: Flexibility solutions are key to achieve the EU renewable energy target of at least 32% for 2030. In the coming years, European industries will need to adapt to the increased fluctuations in energy supply caused by the higher penetration of variable energy sources. Besides, an integrated energy system, linking different energy carriers, infrastructures and consumption sectors in Europe, will be set to deliver climate neutrality by 2050 in a cost effective way. The increased value of flexibility will offer competitive opportunities for process industries (additional revenue streams) and enable a leaner energy system.

Process flexibility and efficient energy storage are key to account for the variable renewable energy production. When less energy is available, process industries can consume less energy or take it from storage; whereas, when there is surplus of energy, the excess energy can be consumed or stored. To leverage the existing flexibility in the process industries, digital process control systems that optimise the process while accounting for the value of flexibility need to be implemented. The better integration of the European energy system will require greater flexibility. Moreover, the direct integration of renewable energy generation and use for higher overall efficiencies will need further flexibility solutions in process industries.

To respond to the additional flexibility demand, current processes designed to run continuously at maximum capacity can be (partially) redesigned or modified. Onsite storage in the form of electricity, heat or other energy vectors can further increase an installation's flexibility.

Proposals should address the following aspects:

- Identification of potential flexibility in an existing process, which allows an efficient and competitive operation;
- Redesign and modification of the process to enable more flexibility in operation (e.g. process that can run faster or slower depending on the needs of the grid), including the removal of process steps that limit the flexibility;
- Development of hybrid solutions that allow processes to run at maximum capacity, on a combination of both renewable and traditional energy sources;
- Development or redesign of digital process control systems to account for the flexibility of the process, and in connection to energy grid integration platforms;
- Optimisation of the new process design at pilot scale.

Onsite energy storage (electricity, heat, or other energy vectors) can be also part of the proposed flexible solution.

Proposals submitted under this topic should include a safety assessment and a life cycle assessment for the implementation of the developed technologies.

TWIN-TRANSITION-50-2022: Hydrogen as chemical feedstock in process industries (IA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Significant reduction of CO_2 emissions
- Integration of GHG emission-free hydrogen in the manufacturing of the product (material, chemical, fuel)
- Competitive process developed for the new production route, which is optimised within the processing line

Relevant indicators and metrics, with baseline values, should be clearly stated in the proposal.

Scope: Hydrogen does not emit any carbon dioxide when used and, when produced from renewable energy sources, it offers a solution to decarbonise industrial processes, being an important enabler to meet the 2050 climate neutrality goal of the European Green Deal and Europe's clean energy transition. Hydrogen can be used as feedstock and energy carrier in energy-intensive industry sectors. The integration of hydrogen into new production routes, the direct use of hydrogen for heating and the use and production of GHG emission-free hydrogen instead of carbon-intensive hydrogen are fundamental to decarbonise European industry across a number of sectors.

Nowadays, hydrogen is largely used in industrial sectors such as the chemical industries and refineries. In addition to the current processes, there are different production pathways under development using hydrogen as a chemical feedstock in low-carbon industrial processes. Hydrogen could be used as reducing agent in the production and recovery of metals, biomass optimisation or in new process routes for the production of platform chemicals and synthetic fuels (from captured CO_2 and biomass). Using renewable hydrogen as chemical in these new processes will lead to major GHG emission reductions.

The proposals should address the following aspects:

- Development of a new production route using hydrogen as chemical feedstock;

- Design of the production process coupled with green hydrogen production onsite;
- Efficient integration of the new process into the processing line, including downstream and upstream;
- Proven economic viability of the process, which will be impacted by several parameters including the value of the by-products.

Proposals submitted under this topic should include a safety assessment and a life cycle assessment for the implementation of the developed technologies.

TWIN-TRANSITION-51-2022: Modular and hybrid heating technologies in steel production

Expected outcomes: Projects are expected to contribute to the following outcomes:

Flexibility actions involving materials and energy supplied, use a wide control range of heating capacity by modular heating technologies such local regenerators, and of hybrid heating, based on both fuel gases and electricity. Integration of fuel cells of alternative coal-based products for non-fossil coke, as well as increased use of non-fossil energy and reactants (e.g. green electricity for heat generation, biomass, green hydrogen) in downstream processes.

Scope: tbc

TWIN-TRANSITION-52-2022: Adjustment of Steel process production to prepare for the transition towards climate neutrality (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by improving energy efficiency in raw materials value chains.

The projects are expected to:

- Significant reduction of CO2 emissions in metallurgical process of steel and other metals by emissions by 2050 by at least 80 to 95% compared to 1990 levels;
- Improve energy and resource efficiency and increase utilisation of renewable energy sources in metallurgical processes;
- Development of demonstrators for such technologies and their uptake by the industry;
- Accelerate the transition of processing industry to a low-carbon and circular economy;
- Contribute to a successful transition to a climate-neutral and circular economy;
- Enabling steel and non ferrous metals production through carbon direct avoidance (CDA) technologies at a demonstration scale;

- Fostering smart carbon usage (SCU – Carbon capture) technologies in steelmaking routes at a demonstration scale;
- Increasing the recycling of steel scrap and recovery of other metals from waste and secondary streams (residues, slags, scraps);
- Demonstrating clean steel breakthrough technologies;
- Development of demonstrators for such technologies and their uptake by the industry;
- Accelerate the transition of processing industry to a low-carbon and circular economy;
- Contribute to a successful transition to a climate-neutral and circular economy.

Scope: The Commission’s Strategic Vision “A Clean Planet for all” indicates that deep CO2 emissions reductions in the steel sector are possible through a combination of technological pathways, including steel recycling, carbon capture utilisation and storage, process integration, and electricity/hydrogen-based metallurgy.

While energy intensity has reduced significantly over the past decades, the steel industry remains a large source of emissions (220 Mt CO2 in 2010) due to preferred use of coal and energy needed to reduce iron oxides.

With alternative pathways used with green electricity and green gases, the emissions can be further reduced so that these pathways could achieve CO2 reductions of up to 95% by 2050 compared to 1990 levels.

There is no one solution to achieve low-CO2 steelmaking, as there will be a variety of production technologies in the future (DRI with hydrogen from electrolysis, electrowinning and CCS are amongst the technology options for emission efficiency).

Material efficiency in manufacturing (e.g., through reducing yield losses in blanking and stamping sheet metal or re-using old structural steel without melting) included increasing the recycling of steel scrap and residues will also play a key role as well as Energy and resource efficiency (e.g., through furnace insulation, process coupling, or increased material recycling);

The EU non-ferrous metals sector has the potential for an 81% overall reduction in greenhouse gas emissions (vs. 1990 levels), once indirect emissions have been eradicated in a decarbonised EU power sector and the climate-neutral transition pathway could encompass breakthrough technologies as follows:

- New digitisation and automated process management and energy efficiency in furnaces;
- Innovation in electrolysis process such as inert anode technology for further efficiency gains of up to 20% and direct emissions reduction while reducing energy use;
- Further electrification of pyrometallurgical processes and/or shift to hydrometallurgical processes in smelting processes;

- Shifts to bio-based energy and bio-feed in non-ferrous metals industry, specifically for recovery of metals from smelting slag or leaching residues;
- Non-carbon reducing agents/hydrogen for pyro smelting processes (e.g. copper) and for recovery of metals from smelting slag or leaching residues;
- CCUS in silicon and alloys production;
- New hydrometallurgical and pyrometallurgical technologies to recover metals (incl. precious and rare) from waste and secondary streams (residues, slags, scraps).

Additional comments:

It is essential that most promising breakthrough technologies are tested at industrial scale demonstration as soon as possible in the coming decade.

External factors not directly controlled by the industry will play a crucial role, most importantly access to CO2-low energy/electricity and feedstock, as well as CO2 storage capacity at affordable prices.

DESTINATION 2 – A digitised, resource-efficient and resilient industry

The European Union has the ambition to turn into a climate-neutral, circular, non- toxic and competitive economy by 2050. In addition, the COVID-19 crisis has illustrated the need to strengthen the resilience of the EU, starting with tackling missing segments in key value chains and increasing its ability to bounce back from a shock. This will also be an opportunity accelerate the twin digital and green transitions.

Meeting the objectives of a digitised, resource-efficient and resilient industry requires a systemic approach to research and innovation, strengthening cross-sectorial cooperation along the value chain, maximising the valorisation of waste, by-products and the reduction of emissions at value chain level. This destination will focus on sectors, products and materials that have the highest impacts, including promoting value chain structuring to foster an increased utilisation of secondary raw materials, while reducing waste and the overall carbon footprint in energy-intensive industries and related value chains. SMEs are central to dynamic industrial innovation ecosystems, and play an important role in enabling the EU's twin digital and green transition. More needs to be done to improve their resilience to shocks and their ability succeed in a post-shock environment, as well as better manage value and supply chain disruptions, support agile business models, leverage new opportunities in key ecosystems, in close cooperation with activities foreseen under Pillar III.

As the green and digital transition progresses, access to primary and secondary raw materials, in particular critical raw materials, will remain, more than ever, a vital prerequisite for both Europe's strategic autonomy and a successful transition to a climate-neutral and circular economy. Yet today, the EU is highly dependent on third countries for the (critical) raw materials it needs for key strategic value chains[3] and significant vulnerabilities persist in the entire EU raw materials value chain, from sustainable and responsible exploration, extraction, processing to recycling.

New advanced materials, which are 'sustainable by design' and have enhanced functionalities, are essential in the fast-paced technological progress in a wide range of industrial processes and consumer products. Further advances in materials development, and in the underlying ecosystems, will be essential to meet the challenges of climate neutrality, transition to a circular economy, and zero pollution. In addition, Europe needs to strengthen its capacity to produce and use chemicals in a sustainable and competitive way. As chemical and related materials production is expected to double globally by 2030, in particular outside Europe, developments in these areas would help Europeovercome its reliance on imports of basic chemicals and support resilience.

This destination will directly support the following Key Strategic Orientations, as outlined in the Strategic Plan:

[3] such as fuel cells, batteries, solar and wind energies, robotics, drones and digital technologies.

- C, '**Making Europe the first digitally led circular, climate-neutral and sustainable economy** through the transformation of its mobility, energy, construction and production systems.'
- A, '**Promoting an open strategic autonomy by leading the development of key digital, enabling and emerging technologies, sectors and value chains** to accelerate and steer the digital and green transitions through human-centred technologies and innovations.'
- D, '**Creating a more resilient, inclusive and democratic European society,** prepared and responsive to threats and disasters, addressing inequalities and providing high-quality health care, and empowering all citizens to act in the green and digital transitions.'

Proposals for topics under this Destination should set out a credible pathway to contributing to a digitised, resource-efficient and resilient industry, and more specifically to the following expected impact of Cluster 4:

- **Industrial leadership and increased autonomy in key strategic value chains with security of supply in raw materials,** achieved through breakthrough technologies in areas of industrial alliances, dynamic industrial innovation ecosystems and advanced solutions for substitution, resource and energy efficiency, effective reuse and recycling and clean primary production of raw materials, including critical raw materials.

This Destination is structured into the following sections:

- Novel paradigms to establish resilient and circular value chains
- Raw materials for EU strategic autonomy and successful transition to a climate-neutral and circular economy
- Green and Sustainable Materials
- Materials for the benefit of society and the environment and materials for decarbonising Industry
- Materials and data cross-cutting actions
- Improving the resilience and preparedness of EU businesses, especially SMEs and Startups

The following call(s) in this Work Programme contribute to this Destination:

The Destination structure and the allocation of topics to calls and year will be decided at a later stage.

Section: Novel paradigms to establish resilient and circular value chains

[Objective: Develop sustainable counterparts to carbon intensive products (low carbon steel, cement and chemicals, etc.), contributing to the zero pollution and carbon neutrality ambitions. Promote value chain structuring to foster an increased utilisation of secondary raw materials, while reducing waste and the overall carbon footprint in energy-intensive industries and related value chains.

Current status: Process industries (e.g. chemicals, steel, cement, minerals and non-ferrous metals, etc.) are key industrial sectors as they are central to virtually all value chains. Nonetheless, they are also known to be high energy and resource intensive, being responsible for 20% of global GHG emissions, significant waste creation and resource depletion. Decreasing emissions and promoting circularity in these sectors will be critical to achieve the 2030 EU objectives and require action at value chain level.

Achievements sought / targets: Develop the necessary technological and non-technological elements (e.g. business models) to underpin the creation of novel low emission and circular industrial value chains. Develop the information exchange platforms to ensure the full traceability of products and materials along the value chain, to provide a solid and transparent base to assess the environmental footprint of products. Focus areas will include:

- Novel business models to strengthen cross-sectorial cooperation along the value chain towards enhanced circularity and greenhouse gases emissions reductions (e.g. process industry –chemicals, steel, cement, minerals and non-ferrous metals, manufacturing industry, waste management and recycling industries).
- Novel technologies to maximise the valorisation of waste, by products and reduce emissions at value chain level (sorting, disassembly, recycling, etc.), ensuring the increased utilisation of secondary raw materials, into intermediates and finished products.

Strong focus will be given to R&I to provide sustainable counterparts to carbon-intensive products (low carbon steel, cement and chemicals, etc.), following design for circularity (material design for safety, durability and recyclability) and safety by design principles. Digital technologies will be crucial to achieve the objectives of this orientation for topics, for example in terms of ICT platforms and data exchanges to ensure traceability and transparency of products and materials along the value chains, to provide a solid base to assess the real footprint of products

Means/Links: This orientation for topics will be implemented through several partnership initiatives such as the co-programmed partnerships Processes4Planet, Made in Europe and Clean Steel, as well as the institutionalised partnership on Hydrogen. Other relevant programmes include: Innoenergy, EIT KIC Raw Materials. This orientation for topics will have strong links with other activities in Cluster 4 (Manufacturing), as well as with activities in Cluster 5 (Energy infrastructures, CCUS, Hydrogen) and Cluster 6 (Circular Economy). Shared activities with these parts of the programme may be developed (e.g. Joint calls).]

Proposals are invited against the following topic(s):

RESILIENCE-01-2021: Ensuring circularity of complex multi-material products in energy intensive value chains (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Demonstrate a reduction of greenhouse gas emission through reuse of materials
- Demonstrate circularity of complex multi-materials products
- Demonstrate competitiveness of the approach

Scope: Complex multi-materials, such as composites and consumer products have a wide use in today's applications and their use continues to increase. Nevertheless, their recycling represents a key challenge for energy intensive value chains. The main problem in recycling multi-material products is related to the difficulty in separating their components. It is thus important to find new ways for their separation and sorting. At the same time, while multimaterials processing can be costly due to their complex structure, new solutions should be envisaged to allow their recycling with very few or no need to separate them without a compromise to downcycling.

Projects should:

- develop and integrate novel solutions for a higher recycling and recovery of secondary raw materials;
- develop and integrate novel solutions for a higher reuse of whole products and components (i.e. products' reusability, upgradability, reparability, etc);
- propose innovative dismantling and sorting systems enabling functional recycling of complex multi materials

Where relevant, any solution proposed for the reduction of the content of toxic elements or compounds in the resulting materials should also include the appropriate management of the hazardous substances removed. Special attention should be paid to the definitive treatment of hazardous components from materials. They should be removed from the environment in a definite way via safe sinks or appropriate treatment.

Finally, the projects should provide contributions to standardisation. Guidelines for acceptable and non-acceptable combinations of materials in function of recycling should be developed as well.

RESILIENCE-02-2022: Circular and low emission value chains through digitalisation (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Demonstrate an increase in the waste reduction by application of digital technologies
- Demonstrate optimisation of use of secondary raw materials in the value chains.

Scope: Circularity is an essential part of a wider transformation of industry towards climate neutrality and long-term competitiveness. It can deliver substantial material savings throughout value chains and production processes, generate extra value and unlock economic opportunities. While circularity is in simple terms addressed by waste from one process becoming secondary materials for others, an efficient use in the value chain in order to close the loop or reuse in other industries, can be ensured only through a transparent information system. There is thus a need for designing and piloting an information system for raw materials and components in products throughout the whole value chain of process industries.

Proposals should:

- Propose new solutions for improved use of secondary raw materials along the value chain of the own industry or in other industries
- Propose methodologies for digital tracing and certification of secondary raw materials. This should include real-time access to information on material compositions and material quality along the whole value chain,
- Propose digital tools for integration of product passport and/or certification schemes
- Propose open source software, open hardware design, and easy access to data, in order to facilitate access to information for the own and for other industries
- Develop a bar-code for recycled materials indicating the composition and origin.

Finally, the projects should whenever possible contribute to standardisation.

RESILIENCE-03-2022: Innovative business models for circular value chains (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Strengthening collaboration along the complete value chain, from supply - process industries, manufacturing, to waste and recycling industries
- Demonstrate contribution to the Next Generation EU (recovery plan).

Scope: While a lot of technical progress has already been done along value chains, to contribute to more sustainable industries and products, contributing thus to circular economy, promoting a circular business model, depends a lot on the type of collaboration which is often inefficient, since it varies a lot in the type of actors involved in the value chain. In order to ensure circularity along the value chain, the product path has to be clearly specified from the beginning, at the stage of the supply chain. Projects are expected to propose new products that can follow a clear path from the supply until the recycling, closing the loop to ensure circularity. This new model has to include all stakeholders involved in the value chain to ensure circularity and could be based on smart specialisation.

Proposals should:

- Develop integrated cost-benefit simulation tools that, can determine the best utilisation options of recovered waste and their reintroduction in the value chain
- Include clear business model development and a clear path to finance and deployment. Key partners should have the capability and interest in making the developed solution a core part of their business/service model to their clients.

Section: Raw materials for EU strategic autonomy and successful transition to a climate-neutral and circular economy

[Expected impacts addressed: #15 (Green), #16 (industrial leadership and autonomy), #18 (Digital and emerging enabling technology sovereignty); #19 (Space)

Objective: Develop 10 pilot plants for raw materials to products involving the whole raw materials value chain: exploration, extraction, processing and recycling.

Current status: Access to primary and secondary raw materials, in particular critical raw materials is a vital prerequisite for both Europe's strategic security and a successful transition to a climate-neutral and circular economy. Demand for raw materials will continue to increase in the future as the EU transforms towards a green and digitised economy. Yet today, the EU is highly dependent on third countries for the raw materials, especially critical raw materials, it needs for its strategic value chains (such as fuel cells, batteries, solar and wind energies, robotics, drones and digital technologies). Significant EU vulnerabilities remain in the entire EU raw materials value chain, from sustainable and responsible exploration, extraction, processing to recycling. A wide range of actions will address these vulnerabilities involving actors from the whole EU raw materials innovation chain, including researchers, industry, end-users, public authorities and civil society.

Achievements sought / targets: Improve knowledge base on EU primary and secondary raw materials deposits and material flows, develop exploration, extraction, processing and recycling capacity for raw materials, especially critical raw materials for European strategic value chains allowing the industry to diversify and secure their sourcing through domestic supplies (in the medium-term – 2030). Enable downstream industries' secure and sustainable and responsible access to raw materials ensuring EU autonomy in sourcing; improve competitiveness of EU raw materials and the related strategic value chains; improve environmental and social performance of the raw materials sector; and improve public awareness, acceptance and trust. This will enable a successful transition to a climate-neutral and circular economy (in the long-term – 2050). Additionally, this will also contribute to the implementation of the Sustainable Development Goals (SDGs), notably SDG 12 'Responsible Consumption and Production'. R&I solutions and cooperation platforms are envisaged for the following:

Exploration (deeper exploration, improving data from existing not-mined sources, checking possibility of further use of developed resources, intelligence, traceability of raw materials and material flows in the economy and end-of-life products).

Promotion of responsible and sustainable sourcing of critical raw materials for strategic value chains, including data transparency, traceability and verifiability, level playing field of responsible and sustainable strategic value chains and cooperation platforms with resource-rich third countries, including extraction, processing and refining of critical raw materials.

Primary sourcing of raw materials: technologies for extraction (including from deeper deposits), processing and refining (especially of lower grade ores),) and recovery of raw materials and waste handling of mining and refining operations.

Secondary raw materials: technologies for recycling including sorting, separation, purification and high quality safe recycling loops from end-of-life products.

Substitution of raw materials: developing substitutes of critical raw materials with other less critical materials.

Means/links: The orientation for topics will be partly implemented through the co-programmed partnerships Processes 4 Planet and Clean Steel. This orientation for topics will have links with the activities in Cluster 5 (Batteries) and Cluster 6 (Circular Economy).]

Proposals are invited against the following topic(s):

RESILIENCE-04-2021: Identifying future availability of secondary raw materials (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to secondary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Improve knowledge base of European and third country secondary raw materials (potential, production and refining);
- Promote the utilisation of specifications of the United Nations Framework Classification for Resources (UNFC) to Anthropogenic Resources approved in 2018[4];
- Facilitate and accelerate commercial exploitation development of EU secondary resource recovery projects EU domestic secondary raw materials projects;
- Support identification of the key factors, drivers and barriers affecting development of a recovery project, and enable comparison of different options and projects;
- Develop reports on future trends in raw materials markets. The trends should be linked with change of demand related to the transition to a low-carbon and circular economy;
- Facilitate identification of supply and demand bottlenecks of future secondary raw materials supply;
- Dissemination and exploitation of projects outputs is tailored for EU institutions, Member States and industry dealing with raw materials.

- Actions are expected to contribute to the implementation of the following actions of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020):

[4] https://www.unece.org/energywelcome/areas-of-work/unfc-and-sustainable-resource-management/applications/unfc-and-anthropogenic-resources.html

- Develop the EU raw materials intelligence, strategic planning and foresight capacity by 2022;
- Map the potential supply of secondary raw materials from waste and stock in the EU including its regions and help identify viable recovery project for funding by 2022.

Scope: A successful transition to a climate-neutral, circular and digitised EU economy relies heavily on a secure supply of raw materials. In order to strengthen EU autonomy and reduce over-dependency, we must boost domestic sourcing, both for primary and secondary raw materials.

The action should be based on a common understanding of relevant terms and codes, and develop an understanding of anthropogenic resources and derive the needed aspects for classification of recovery projects and to develop criteria for a transparent, consistent and objective classification, needed to establish a comprehensive resource classification approach.

The action should identify future availability of secondary raw materials based on collection and classification of relevant data and information in a harmonised UNFC format. The action should built on and advance further the work of UNECE – UNFC expert group on Anthropogenic resources regarding the classification of secondary raw materials and the work of H2020 project PROSUM[5] regarding collection of data and information on secondary raw materials. The action should develop a proposal for EU statistics for secondary RM.

The focus is on the following streams of secondary critical raw materials: waste batteries, WEEE, mining waste, slags & ashes, construction and demolition waste and others.

All the data and information generated through these actions should be shared in open formats on a free of charge basis with the European Commission, for its own use and for publication.

RESILIENCE-05-2021: Developing climate-neutral circular minerals and metals (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by providing advanced solutions for resource efficiency, effective reuse and recycling of secondary raw materials, for EU industrial value chains and strategic sectors.

Projects are expected to:

- Scale up promising raw materials recycling from end-of-life products technologies
- Develop demonstration pilot showing that raw materials can be produced in an innovative and sustainable way in order to make sure that research and innovation end up on the market,

[5] http://www.prosumproject.eu/

- Strengthen the competitiveness of the European raw materials industries, meet ambitious energy and climate targets for 2030, minimise environmental impacts and risks, maximise circularity or resources and gain the trust of EU citizens in the raw materials sector.

Scope: Securing the sustainable access to raw materials, including metals, industrial minerals, wood- and rubber-based, construction and forest-based raw materials, and particularly Critical Raw Materials (CRM), is of high importance for the EU economy. Complex primary and secondary resources contain many different raw materials. Their processing, reuse, recycling and recovery schemes are complex and imply different steps, ranging from collection, logistics, sorting and separation to cleaning, refining and purification of mat

The action should develop and demonstrate innovative pilots for the clean and sustainable production of non-energy, non-agricultural raw materials in the EU from end-of-life products, such as waste electrical and electronic equipment (WEEE), batteries, wood-based panels, multi-material paper packaging, end-of-life tyres, etc., finishing at Technology Readiness Levels (TRL) 6-7.

The action should contribute to building the EU knowledge base of secondary raw materials by feeding into the EC Raw Materials Information System – RMIS.

The action should also contribute to improving the awareness of relevant external stakeholders and the general public across the EU about the importance of raw materials for society, the challenges related to their supply within the EU and about proposed solutions which could help to improve society's acceptance of and trust in sustainable raw materials production in the EU.

The action should facilitate the market uptake of solutions developed through industrially- and user-driven multidisciplinary consortia covering the relevant value chain and should consider standardisation aspects when relevant.

The action should justify the relevance of selected pilot demonstrations in different locations within the EU (and also outside if there is a clear added value for the EU economy, industry and society).

The action should include an outline of the initial exploitation and business plans (with indicated CAPEX, OPEX, IRR and NPV62) with clarified management of intellectual property rights, and commitment to the first exploitation.

Actions should envisage clustering activities with other relevant selected projects for cross-projects co-operation, consultations and joint activities on cross-cutting issues and share of results as well as participating in joint meetings and communication events. To this end proposals should foresee a dedicated work package and/or task, and earmark the appropriate resources accordingly.

RESILIENCE-06-2021: Building EU-Africa partnerships on sustainable raw materials value chains (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary and secondary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

The project results are expected to:

- Steer the development of strategic partnerships for EU-Africa industrial value chains' integration, covering exploration, extraction, processing, refining and recycling (if refining capacity is in place);
- Improve sustainability (especially environmental and social aspects) in the mining and metal recycling sectors in Africa;
- Limit illegal and ethically doubtful supply chains and activities;
- Develop knowledge on raw materials potential in Africa that will facilitate investment and business decisions;
- Reduce EU vulnerabilities in raw materials sourcing;
- Diversify EU supply chains from third countries for raw materials, especially for critical raw materials;
- Contribute to connecting different stakeholders of raw materials value chains, including final users.

The project should build on and explore synergies with previous and ongoing EU funded projects for Africa and existing trustworthy EU and international initiatives, covering raw materials value chains.

Dissemination and exploitation of projects outputs is tailored for EU and African organisations and industry dealing with raw materials.

The action is expected to contribute to the implementation of the following actions of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020):

- Promote responsible mining practices through the EU's international cooperation programmes, in particular those related to the sustainable development of the informal sector (Artisanal and Small Scale Mining), which has become of strategic relevance in this field;
- Strengthen the local governance and business environment, together with other institutions and development partners (EITI, OECD, UNDP, WB, and Germany's GIZ). The focus should be on supporting the informal sector, and to promote and disseminate responsible business practices.

Scope: Actions should include:

- An in-depth analysis of critical raw materials potential in Africa and existing processing and refining capacities;

- Mapping and assessing investment opportunities in strategic raw materials value chains in Africa, considering factors as existing potential, availability of infrastructures, good governance and regulatory issues;
- Developing new business models to integrate EU and Africa raw materials value chains, considering horizontal and vertical integration;
- Developing a strategy for integration for EU and Africa value chains for the energy and digital transition;
- Building an EU and Africa business networking with upstream and downstream companies;
- Carrying an in-depth analysis on financial instruments and investment funds and loans available at member state, EU and international levels for the Africa region.

All the data and information generated through these actions should be shared in open formats on a free of charge basis with the European Commission, for its own use and for publication.

RESILIENCE-07-2021: Building primary raw materials intelligence and foresight capability in the EU (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Improve knowledge base of European and third country primary raw materials (potential, production and refining);
- Promote the utilisation of UNFC and UNRMS reporting standards in the raw materials sector;
- Accelerate development of EU domestic raw materials projects;
- Develop reports on future trends in raw materials markets. The trends should be linked with change of demand related to the transition to a low-carbon and circular economy;
- Facilitate identification of supply and demand bottlenecks of future raw materials supply;
- Dissemination and exploitation of projects outputs is tailored for EU organisations and industry dealing with raw materials.

The action is expected to contribute with intelligence and foresight capability to the implementation of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020) and to support future foresight work of the Commission related to raw materials

Scope: Actions should map European and third countries' primary and secondary raw materials potential and raw materials production and refining capacities in a harmonised form, using UNFC (United Nations Framework Classification for Resources) and UNRMS (United Nations Resource Management System). The action should also contribute to understanding EU and global raw materials supply chains and systems and deliver reports on future trends in raw materials markets on climate goals and in geopolitical context.

Actions should contribute to improving the awareness of the general public across the EU about (a) the importance of raw materials for a successful transition to a climate-neutral and digitised economy and society, and (b) the ensuing need for a secure, sustainable, and responsibly-sourced supply of raw materials, including from domestic sources to strengthen EU strategic autonomy and reduce over-dependence on third countries.

All the data and information generated through these actions should be shared in open formats on a free of charge basis with the European Commission, for its own use and for publication.

RESILIENCE-08-2021: Building innovative value chains from raw materials to sustainable products (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Develop resilient critical raw materials supply chains for the e-mobility and renewable energy ecosystems and strategic sectors, as defence, aero-space and ICT;
- Increase the EU raw materials supply capability and added value;
- Create new market opportunities for mineral raw materials sustainably produced in the EU;
- Build innovative value chains establishing a direct link between the raw materials producers and the end-users.

Scope: Actions should develop innovative and sustainable technology and business solutions finishing at the level of Technology Readiness Levels (TRL) 6-8 for new high value added and sustainable products with enhanced functional properties based on the EU produced raw materials. The industrially- and user-driven multidisciplinary consortia should cover industry players along the relevant value chains starting from raw materials to products. The focus is on raw materials necessary for the e-mobility and renewable energy ecosystems including battery raw materials[6]; strategic sectors, as defence and aero-space; or on critical raw materials[7], such as rare earths elements for highly performant permanent magnets.

RESILIENCE-09-2022: Monitoring and supervising system for exploration and future exploitation activities in the deep sea (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Develop technologies and systems to continuously monitor environmental impacts and mitigation methods of deep sea exploration and future mining;
- Provide technological and systemic solutions for forecasting potential environmental impacts of using the developed monitoring and mitigation methods;
- The action is expected to contribute to the implementation of the following actions of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020);

Use Horizon Europe funding for research into mining processes with minimal impact on the environment and life-cycle assessment.

Scope: The global economic interest on deep-sea mineral resources has been growing and so it is the concerns with the negative impacts on the deep sea ecosystems if mining activities start. The expected increase on the global demand for metals needed for the energy transition might become a driver to initiate commercial deep sea mining, paved by the technological advancements. However, before any deep-sea mining activities start, the environmental impacts, and how to mitigate it, need to be well understood; a robust legal framework needs to be in place and a reliable and transparent monitoring and supervising system for the activities taking place in the deep-sea has to be ready. For the sake of transparency and to properly assess the environmental consequences of the activities taking place in the deep sea over time, it is crucial to develop and to put in place a system capable of continuous monitoring, so the permitting and supervising authorities can access it remotely and at any moment. The project should design and develop a reliable and robust monitoring and inspection system for the exploration and future exploitation activities in the deep-sea. Before the monitoring and inspection systems are used a forecasting impact on the environment of these activities should be performed. Therefore, projects should deliver appropriate technological and systemic solutions for such forecasting assessments.

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[6] Refernce: BAP??
[7] Reference to the list of CRMs2020

A monitoring and inspection system for the activities taking place in the deep sea is very complex because the activities take place in remote areas, in the middle of the ocean, and in extreme environment, deep water column and consequent pressure and fragile ecosystems. The system needs to be fully transparent and capable to monitor all environmental parameters and at the same time respecting business confidentiality. Due to the complexity of such system, the project has to be developed by a multidisciplinary team, looking at environmental, legal and technological solutions. The project will 1) identify all the bio-chemical-physical parameters to be monitored at the bottom of the sea, along the water column and at the surface; 2) identify all technical requirements needed for a real time monitoring of all parameters at the bottom, along the water column and surface, including the use of satellite data (Global Navigation Satellite System and Copernicus' satellite constellation) and to make it continuously available for remote access; 3) identify existing technological solutions and develop new ones to fulfil the technical requirements; 4) design and develop the architecture of the system in view of incorporating the monitoring parameters, the technical requirements and the legal constrains; 5) Develop a trial version of the system and test it.

RESILIENCE-10-2022: Streamlining cross-sectoral policy framework throughout the extractive life-cycle in environmentally protected areas (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Exchange of good practices in permitting procedures related to extractive activities that may have an impact in environmentally protected areas;
- Dissemination and exploitation of projects outputs is tailored for competent EU, national and regional authorities, industry and civil society in EU Member.

Scope: Reconciling the increasing demand for Critical Raw Materials necessary for the climate neutral ambition of Europe, with nature protection, restoration and biodiversity growth, requires strengthening the raw materials policy framework. Streamlining more efficient, effective and transparent permitting procedures throughout mineral extraction life-cycle in environmentally protected areas, would contribute to securing the sustainable access to primary raw materials, whilst taking into account and reconciling requirements in environmentally protected areas.

The actions should contribute to the exchange of good practices in permitting procedures related to extractive activities that may have an impact in environmentally protected areas. They should focus on reviewing good practices at the permitting stage in areas such as evaluating natural background conditions previous to the mineral extraction, evaluating the impact on human health and biodiversity, as well as foreseen nature protection and restoration measures.

The actions should analyze cross-sectorial policy coordination and integration covering economic, environmental and social aspects in the value chain of the extractive life cycle from finding and access to deposits to closure and rehabilitation, while focusing on the contribution of streamlined permitting procedures to deliver on the climate ambition of the European Green Deal.

The actions should develop and disseminate training materials, organize capacity-building workshops and seminars for competent authorities, industry and civil society in different Member States in different regions the EU and at the EU level.

All the data and information generated through these actions should be shared in open formats on a free of charge basis with the European Commission, for its own use and for publication.

RESILIENCE-11-2022: Developing digital platforms for the small scale extractive industry (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Develop digital platforms (applications) addressing needs of small-scale operations, mining clusters and SMEs, to enable a transformative change in EU extractive industries ensuring EU raw materials autonomy, while protecting and restoring biodiversity, boost our resilience, fight climate change and recover from the COVID-19 crisis;
- Contribute to digitisation of the extractive industry.

Scope: Actions should develop digital platforms that integrate Earth Observation data, in situ data and data modelling, to improve data management and decision making during the extractive process. Proposals are encouraged to make use of, but not limited to, existing European data infrastructures.

These digital platforms should scale up to the increased data volumes of the extractive activities, incorporating assimilation techniques and interoperability best practices, automation, systemization and integrated web-based services, and be brought into pre-operational service provision, going beyond the demonstration phase.

Actions should contribute to digitalize the extractive industries operations and, being INSPIRE compliant, help data gathering at EU level for evaluating the performance and competiveness of extractive industries.

These digital platforms should contribute to increase the dialogue between the extractive industry and EU citizens, raising awareness about the impact of raw materials on the value chains and society well-being and reinforcing the commitment of the industry to protect human health and natural eco-systems.

Building on past projects, the actions should provide practical and easily applicable capacity building and training materials for a better environmental management of active operations. They should also include exchange of best practices and capacity building for the effective monitoring of extraction sites by competent authorities.

RESILIENCE-12-2022: Technological solutions for tracking raw material flows in complex supply chains (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw and secondary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Improve supply chain data transparency and traceability;
- Setting up technological solutions for tracking raw material flows (material passports);
- Identify and address gaps in due diligence;
- Develop comparable criteria, reporting and audit approaches;
- Contribute to sustainable sourcing of raw materials.

The action is expected to contribute with intelligence and foresight capability to the implementation of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020) and to support future foresight work of the Commission related to raw materials

Actions are expected to contribute to the implementation of the following actions of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020):

- Develop the EU raw materials intelligence, strategic planning and foresight capacity by 2022;
- Map the potential supply of secondary raw materials from waste and stock in the EU including its regions and help identify viable recovery project for funding by 2022.

Scope: There is a need to improve supply chain data transparency and traceability, enabling consumers and downstream producers to have information about the origins of metals in finished products. Due diligence has numerous research gaps in this area which need to be addressed in order to limit complexity and enable a level playing field for responsible sourcing of minerals.

This action should close those gaps by the setting up of technological solutions for tracking raw material flows (material passports), building upon comparable criteria, reporting and audit approaches. Examples would include transparency in payments and traceability from beginning to end of the supply chain, through a chain of custody certification, and the use of block chain technology in an effort to improve supply chain transparency and traceability.

The action should build on the experience of existing EU projects on international responsible sourcing and contribute to strengthening responsible sourcing agenda.

It is foreseen that this will facilitate responsible sourcing in complex supply chains and put companies downstream in the supply chain in a better position to influence companies upstream.

The proposal should build on the state of the art in sustainable raw materials traceability with regard to sustainability certification schemes, standards and initiatives as well as block chain technology. The proposal should also build on the experience from earlier Horizon 2020 projects in the area of responsible sourcing of raw materials in global value chains. The proposal should cover CRMs in at least 2 complex supply chains, including a batteries value chain. Actions should develop technological solutions finishing at the level of Technology Readiness Levels (TRL) 3-5.

The action should contribute to building the EU knowledge base of primary and secondary raw materials by feeding into the EC Raw Materials Information System – RMIS. The action should also contribute to improving the awareness of relevant external stakeholders and the general public across the EU about the importance of raw materials for society and of the challenges related to their sustainable supply.

RESILIENCE-13-2022: Sustainable and innovative mine of the future (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Develop sustainable and smart mining technologies for exploitation of EU mineral resources;
- Contribute to a more safe and environmentally friendly, resource- and production efficient sustainable mining;
- Develop methods, technologies and processes aiming for digitisation and automation of raw materials production;
- Projects will target minerals and metals.

- Actions are expected to contribute to the implementation of the following actions of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020):

- Use Horizon Europe funding for research into mining processes with minimal impact on the environment and life-cycle assessment;

- Support waste and extractive waste valorisation and energy efficiency through cross-sectoral cooperation and industrial symbiosis, involving the mining industry.

Scope: Actions should contribute to developing big data technologies and Artificial Intelligence methodologies addressing mining industry requirements to deliver on the climate ambition of the European Green Deal. The challenge is to accelerate the innovation in the mining sector necessary for the digital transformation. They shall aim to develop new, enabling, operational solutions to improve capabilities and performance of the raw materials value chain: from in situ mineral exploration and permitting procedures, to mineral extraction and processing including recycling, as well as closure and post closure activities.

Actions should push the EU to the forefront of a safer, more sustainable and intelligent extraction of mineral resources through the deployment of technologies such as remote controlling, automation or autonomous processes with a particular focus on historic mine sites and deep deposits. Actions should develop sustainable solutions through industrial and user-driven multidisciplinary consortia covering the relevant mining and processing value chains and technologies.

Proposals can address individual elements of the raw materials value chain or the value chain as a whole, and should provide quantitative measures of the progress beyond the state of the art. Proposals are also required to seek end user involvement to drive the research with their requirements and test the developed solutions, with a clear path to the exploitation of the results. Actions should develop technological solutions finishing at the level of Technology Readiness Levels (TRL) 6-8.

RESILIENCE-14-2022: Innovative solutions for efficient use and enhanced recovery of mineral and metal by-products from processing of raw materials (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials and secondary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Increase process selectivity, broader range and higher recovery rates of valuable raw materials, particularly critical raw materials;
- unlocking substantial reserves of new or currently unexploited/underexploited resources within the EU;

- Significantly increase economic performance in terms of higher material-, water-, energy- and cost-efficiency and flexibility in minerals processing, metallurgical or recycling processes;
- Improving significantly the health, safety and environmental performance of the operations throughout the whole life cycle which is considered, including a reduction in waste, wastewater and emissions generation and a better recovery of resources from generated waste.

The action is expected to contribute to the implementation of the following actions of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020):

- Support waste and extractive waste valorisation and energy efficiency through cross-sectoral cooperation and industrial symbiosis, involving the mining industry;

- Use Horizon Europe funding for research into mining processes with minimal impact on the environment and life-cycle assessment.

Scope: Actions should develop sustainable systemic solutions through industrially- and user driven multidisciplinary consortia covering the relevant value chain of non-fuel, non-food raw materials.

Actions should develop sustainable solutions finishing at the level of Technology Readiness Levels (TRL) 5-7.

Actions should develop energy-, material- and cost-efficient new sustainable mineral processing and/or metallurgical technologies and processes to increase the selectivity and the recovery rates of valuable by-products[8], particularly critical raw materials[9]. The importance of the targeted raw material by-products for the EU economy should be duly demonstrated in the proposal. Recycling of end-of-life products is excluded from this topic.

Actions should also contribute to improving the awareness of relevant external stakeholders and the general public across the EU about the importance of raw materials for society, the challenges related to their supply within the EU and about proposed solutions which could help to improve society's acceptance of and trust in sustainable raw materials production in the EU.

Actions should include a task to cluster with other projects financed under this topic and – if possible – with other relevant projects in the field funded by the EU.

RESILIENCE-15-2022: Earth observation technologies for the mining life cycle in support of EU autonomy and transition to a climate-neutral economy (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

[8] The term "by-products" should be interpreted here as the constituents usually accompanying the major component(s) of a raw material at low concentrations.
[9] EU list of critical raw materials 2020 – add link when published

Projects outcomes will enable achieving the expected impacts of the destination by increasing access to primary raw materials, in particular critical raw materials for EU industrial value chains and strategic sectors.

Projects are expected to:

- Unlock the potential of Earth Observation technologies, including Copernicus, through the development of downstream products and services for the whole mining life cycle,
- Strengthening EU autonomy on raw materials, while enabling a successful transition to a climate-neutral, circular and digitised EU economy.

The action is expected to contribute to the implementation of the following actions of the EU action plan on Critical raw materials (reference, to be adopted in autumn 2020):

- Deploy remote sensing and Earth-observation programmes for resource exploration, operations and post-closure environmental management.

Scope: Actions should develop and innovate new methods to analyse Earth Observation data, enabling systematic mineral exploration and continuous monitoring of extraction, closure and post closure activities. These developments and innovations should be built upon Copernicus satellite constellations, airborne and low-altitude platforms, ground based remote sensing, also including conventional in situ techniques, methods and field work measurements.

Actions targeting mineral exploration should develop EO methods that exploit multispectral, hyperspectral and in situ data permitting to systematically revise and update pre-existing maps and datasets identifying new mineral deposits at various scales, from mining regions to specific mining projects.

Actions targeting monitoring of extraction, closure and post closure activities should develop EO methods that exploit radar, optical and in situ data to innovate products and services: a) early warning systems and platforms that reduce operation risks; b) multi-sensor and multi-platform environmental monitoring systems that reduce the impacts on human health and preserve ecosystems.

Additional Comments:

Foreseen outputs of this action could be, but not limited to, new methods to exploit EO data permitting to generate the following results at various scales, from mining regions to specific mining projects.

For mineral exploration:

- improved maps of critical raw materials
- improved maps of mining waste deposits
- improved seabed mineral mapping by exploring the connection between sea shore and coastal areas

For mining monitoring:

- Ground instability maps
- Mineral stockpile volume estimation
- Acid mine drainage maps

Section: Green and Sustainable Materials

[Expected impacts addressed: #15 (Green), #16 (industrial leadership and autonomy), #20 (Human-centred)

Objective: To contribute to a safe, climate neutral and resource-efficient industrial eco-system through the adoption of a sustainable by design materials approach that would connect environmental and health safety aspects with socio-economic impact considerations and this through the material whole life-cycle. It offer a unique opportunity to strengthen Europe's capacity to produce and use chemicals and materials in a sustainable way leading the transition to safe and sustainable innovation globally, while promoting EU's standards and competitiveness.

Current status: Fast-paced technological progress necessitates the development and availability of increasing numbers of new materials with enhanced functionalities for a range of industrial and consumer products. Industry has traditionally adopted a "fitness for purpose" approach towards the development of advanced materials (including nanomaterials), which in several instances resulted in totally unforeseen consequences for the environment and/or citizens' health. In parallel chemical and related materials production is expected to double globally by 2030, in particular outside Europe. Europe needs to strengthen its capacity to produce and use chemicals in a sustainable and competitive way. This would not only help Europe to overcome its reliance on imports of basic chemicals but could also boost economic and social recovery in the aftermath of the COVID-19 crisis.

Achievements sought / targets:

Development sustainable by design materials that combine of new material systems with better recyclability and based on a more general lifecycle assessment methodology to replace current problematic materials (in the medium-term – 2030). Establishment of a "sustainable-by-design industrial ecosystem", development of sustainable new materials with enhanced functionalities (in the long-term – 2050).

The following areas of materials technologies will be addressed:

- **Sustainable by design materials** to promote Europe's affordability, sustainability and security of supply of essential chemicals and materials;
- **Safe materials with zero harmful emissions** or release of irritant or toxic substances. This area encompasses a broad field of applications and provide some perspective of the scope of the proposed effort.
- **Smart materials** to cover a very wide area of applications ranging from sensing, automation and robotics to energy harvesting and health monitoring.
- **Advanced lightweight** as well as joining technologies for dissimilar materials aiming at optimisation of the energy efficiency of structures.

<u>Means/Links</u>: A **coordination action** to manage the knowledge flow from the aforementioned research areas, to act as a pilot for future equivalent actions targeting a wider variety of "critical" materials will also be necessary. A series of ***enabling and cross cutting actions*** underpinning the work and deemed crucial for the rapid development, uptake and commercialisation of the proposed technologies will be implemented, namely:

- Integration of advanced materials modelling and characterization,
- Industry data standardisation and testing methodologies (Industry Commons) and
- Implementation of Climate Neutral and Circular Innovative Materials Technologies Open Innovation Test Beds (OITBs).

Linking with Industrial Investment is essential for success. A strong role of SMEs is expected here in the development of innovations in particular for smart materials, lightweight materials and recycling methodologies. This section will have strong links with other activities in Cluster 4 (Manufacturing Technologies).

The "Sustainability-by-design" approach adopted here is applicable to all the subsequent two sections under cluster 4 "Advanced materials" and also related to Carbon Neutral and Circular Industry partnership. In addition, as the number of applications is very wide, it is related to activities in Clusters 1, 5 and 6.]

Proposals are invited against the following topic(s):

RESILIENCE-16-2021: Establishing EU wide safe and sustainable-by-design materials community to support embedding sustainability criteria over the life cycle of products and processes (CSA)

<u>Expected Outcomes</u>: Develop a common understanding of the principles of sustainable-by-design when applied to materials, both products and processes. The challenge is to identify the key dimensions that need to be integrated in a product sustainability performance assessment and enhance a systems approach based on Life Cycle Assessment (LCA) framework. The transition to sustainable-by-design[10] is a societal urgency[11]. It is for example the prerequisite to develop alternative and safer (lower toxicity) plastics, surfactants and metal-based systems, and it is relevant for all types of materials. Projects are expected to support the uptake and utilization of the sustainable-by-design strategies by industry, especially SMEs, by contributing to the following outcomes:

[10] Sustainable-by-design concept takes a systems approach by integrating safety, circularity and functionality of advanced materials, products and processes throughout their lifecycle. This concept can be defined as a pre-market approach that focuses on providing a function (or service), while avoiding properties that may be harmful to human health or the environment. from a lifecycle perspective.

[11] Chemicals Strategy for Sustainability [Add link, when published]

- Criteria and guiding principles for sustainable-by-design (i.e. integrating safety, circularity and functionality of advanced materials, products and processes throughout their lifecycle), in line with ongoing international work by OECD and UNEP.
- A permanent structure for long-term operation of established expert's network by time of project end with the involvement of wider communities engaged, beyond consortium members.
- Broadly supported and periodically updated roadmaps based on state of the art knowledge, identified information gaps and their translation into specific R&D questions and governance needs.
- Strengthen collaboration and information exchange between relevant actors along value chains (developers, producers, downstream users) to promote the development and implementation of sustainable-by-design approach.

Scope: Establish an inclusive and self-sustained international network of experts and stakeholders in the materials community to enable multidisciplinary design processes, map skills mismatches and competence gaps, to enable transition towards an overarching framework in which sustainability is the essential entry point into markets:

- Perform landscape analyses of methodologies that focus on the de novo design, which guides sustainable products and processes and coordinate with the projects from NMBP-16-2020 to fill in the gaps in the current understanding.
- Develop working framework for creation of an expanded safety and sustainability community, with agreement to create a common mechanism to engage, mobilise and bring together diverse stakeholders.
- Map and address sustainable-by-design skills mismatches and competence gaps, and support the enhancing of adequate skills at all levels - including in university programmes, research, industry and among regulators
- Coordinate other EU-funded projects targeting Safe- and Sustainable- by-Design materials, in particular: RESILIENCE-18-2021; RESILIENCE-19-2021RESILIENCE-20-2021).

Resulting projects should establish cooperation mechanisms with relevant international initiatives to align and leverage the extensive experience. Therefore, proposals should foresee a dedicated work package for cooperation and earmark appropriate resources.

RESILIENCE-17-2021: Promote Europe's availability, affordability, sustainability and security of supply of essential chemicals and materials (IA)

Expected Outcomes: Europe needs to strengthen its capacity to produce materials and chemicals in a sustainable and competitive way. Moreover, the recent crisis has shown the importance for Europe’s chemical and material industry to increase its flexibility, and to adapt quickly its production capacities to the changing supply needs[12].

Projects are expected to contribute to the following outcomes:

- Foster global competitiveness of EU companies. Helping Europe to overcome its reliance on imports of chemicals, in particular for essential products, while boosting Europe's economic and social recovery in the aftermath of the COVID-19 crisis.
- Deliver new modular production concepts for the chemical industry that would significantly decrease process development time through the standardisation, modularisation and application of novel process intensification technologies;
- Produce highly efficient, flexible, and stand-alone production units that could be shipped to places where the need would be the highest;
- Enable decentralised production;
- Improve flexibility in products customisation with a faster response to supply chain/customer demands, creating opportunities of new business models enabled by digital technologies;

Achieve a significant impact on reducing production costs, design efforts time-to market and logistic efforts.

Scope: Building on the experience gained from flexible production units[13] it would be possible to equip base chemicals production containers with modular and standardised units capable to facilitate a swift shift in the final production outcome. The focus on the proposals under this topic should thus be the development of adaptable chemical plants with flexible outputs.

Research and innovation actions within this topic may include:

- Improving flexibility and modularity of the equipment;
- Adaptation of process analytical technologies for modular production, to support process control, automation, predictive maintenance and process coordination;
- Smart equipment in intensified up and downstream processing;
- Increasing safety of fully automatic operations and reducing occupational health related risks;
- Standardisation of modular production concepts, including international standards.

[12] Chemicals Strategy for Sustainability [Add link, when published]
[13] F3 Factory, Copiride and Synflow projects in FP7

The proposals should start at TRL 5-7 and include demonstration activities at higher industrial production scale. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-18-2021: Paving the way to a increased share of recycled plastics and added value products (RIA)

Expected Outcomes: Circularity and the increase of the content of recycled plastics in value added products are central to the European Strategy for Plastics.

Projects are expected to contribute to the following outcomes:

- Establish EU broadly accepted procedures to control the consistent quality of recyclates; characterise their suitability for specific applications and trace the recyclates back to their origin;
- Deliver a clear approach to prevent some potentially hazardous substances to enter the recycled plastics system;
- At medium term, to fulfil the growing demand for recycled plastic content in market products;
- At a longer term, to pave the way toward recyclable-by-design plastics.

Scope: To allow recycled plastics to be more promptly taken up as raw material for new products there is a need for reliable and standardised procedures to characterise, trace back origin and guarantee the safety of the recyclates. The proposals should focus on:

- Developing standard, robust and easy to use sampling and analysis procedures to ensure consistent recyclate quality and safe products. Develop methodologies to establish the degree of degradation of recycled materials and to foresee their end-of-life;
- Developing and standardising methods for traceability. Allow the identification of origin of recycled materials via digital information management, e.g. marking technologies or blockchain;
- Detect and separate legacy additive in the waste stream, and ensure safe recycling of plastics containing such additives;
- Diffusing innovation, developing overarching best practices and build up communities to stimulate demonstration.

Proposals should actively pursue the involvement of all the actors in the value chain from the chemical and material industry, to formulators, recyclers, public authorities and standardisation bodies.

RESILIENCE-19-2021: Safe and sustainable by design polymeric materials (RIA)

Expected Outcomes: The way plastics are currently made, used and discarded, fails to capture the economic, environmental and societal benefits of a more sustainable approach. Europe produces 25 million tons of plastic waste annually, less than 30% is recycled. Moreover, plastic production, use and disposal may result in the release of chemicals which may give rise to health and environmental problems. The development of a common understanding and the transition to safe- and sustainable-by-design materials, including plastics, is a societal urgency.

Projects are expected to contribute to the following outcomes:

- Recyclable-by-design polymers with inherent recyclability properties for polymers where nowadays recyclability challenge is high;
- Safer (lower toxicity) plastics, with less reliance on potentially harmful additives;
- Reduced environmental footprint associated with the end-of-life phase of the polymers due to increased recyclability and /or reduced reliance on potentially harmful additives, compared with existing products for similar applications;
- Contribute to the development of safe- and sustainable-by-design criteria and guiding principles[14] and apply them to plastics;
- Identification of priorities for substitution of plastic additives;
- New technologies and business opportunities for recycling industry across Europe.

Scope: Thanks to their versatility, polymeric materials are used in a wide range of applications from consumer goods and construction to aerospace. The proposals should focus on:

- The design and development of new recyclable-by-design polymer systems substituting/improving nowadays difficult to recycle polymers e.g. PVC, thermosets or multicomponent (multilayer or blend) polymers;
- The design and development of safer plastics with less reliance on potentially harmful additives, e.g. plasticizers. The approach should allow to decrease their health and environmental impact and improve the purity of the secondary raw material and thus the quality of recycled plastic without compromising the material optimal properties and functionality;
- Carrying out an inventory of additives detected in plastics and their function and toxicity;

[14] GREEN-INDUSTRY-15-2021: Establishing EU wide safe and sustainable-by-design materials community to support embedding sustainability criteria over the life cycle of products and processes

- Integration of safe- and sustainable-by-design aspects, including safety (toxicity), circularity and functionality of advanced polymeric materials, products and processes throughout their lifecycle.

The proposals activities and approaches should cover both specific considerations for the plastics under study, as well as developing overarching best practices that spans broader sectors of safe- and sustainable-by-design plastics. Proposals should involve all the actors in the value chain from the chemical and material industry, to formulators, recyclers and regulators. Areas for research include the intersection between chemicals and waste legislation,

In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-20-2021: Cost-effective eco-friendly coatings and engineered surfaces for multi-industrial sector applications (RIA)

<u>Expected Outcomes</u>: New metal coating systems, free of toxic substances (e.g. hexavalent Chromium), HREEs (heavy rare earth elements), LREEs (light rare earth elements), and PGMs (platinum group metals). A major challenge is the accumulation of metallic materials over the long term in the environment where they tend to have adverse reactions with the ecosystem. On the other hand, the coatings are needed for preservation of the products to prevent for instance corrosion and (bio)fouling. To ensure safety and sustainability of new metal coatings a systems approach that integrates safety, circularity and functionality of advanced materials throughout their lifecycle is required. Projects are expected to contribute to the following outcomes:

- At least 2 novel materials with improved (or at least comparable) efficiency as compared to traditional materials, associated with a reduction in metal (CRM) usage of at least 15%.
- Materials modelling, assisted by machine learning and artificial intelligence methods, integrated with safe- and sustainable-by-design models.
- Integration of eco-design and circularity concepts in the design of new metal coatings and provide recommendations for the end-of-life of the new material. This should include integration of REACH requirements in the eco-design development and pre-validation of indicators as well as tests to demonstrate the improved sustainability and reduced toxicity.
- Innovative strategies for improving recovery, recyclability, purification and re-use products at the end of life. This could include the evaluation of their reusability in other application areas other than initial intended use, requiring lower purity inputs.
- An online or/and standalone decision support tool to guide industry (especially SME) for the implementation of safe- and sustainable-by-design approaches tailored to their needs.
- Integration into the standardisation process and development of a roadmap to achieve full standardisation (of e.g. methods, protocols).

Scope: Metal coatings are applied, to enhance performance characteristics, such as corrosion resistance, colour, attractive appearance, wear resistance, optical properties, electrical resistance, or thermal protection. Applications range from building & construction and consumer goods to catalytic materials, metal organic frameworks (MOFs) and fuel cells and proposals covering all above areas will be welcome. The optimisation of functionality including sustainability and safety considerations and all aspects on resource utilisation across the materials life cycle is essential. Such materials with desired properties should be designed with the assistance of *in silico* techniques.

Proposals are expected to bring the core technology from TRL 2-3 up to TRL 5 at the end of the project.

Leveraging the extensive experience from relevant initiatives and aligning with other EU-funded projects targeting Safe- and Sustainable- by-Design materials, in particular CSA (RESILIENCE-15-2021) is essential.

The proposals activities and approaches should cover both specific considerations for the metal coatings under study, as well as developing overarching best practices that spans broader sectors of safe- and sustainable-by-design materials. Proposals should involve all the actors in the value chain.

In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-21-2021: New, sustainable and safe by design organic coatings (RIA)

Expected Outcomes: Development of organic coatings, safe- and sustainable-by-design production strategies with enhanced functionality. This includes organic coatings and additives to substitute PFAS type coatings. Due to significant technical and scientific challenges in several areas it has been difficult to find safer alternatives with the absence of hazardous additives. In the past, this has led to substance substitution with compounds that did not avoid the problem, but minimized it. Instead, a better approach is to cover the whole lifecycle of products and include avoidance of hazardous substances and the programming-in of sustainability along the product life cycle. Projects are expected to contribute to the following outcomes:

A set of computational tools (including first-principles-based, data-driven, physics based and hazard, transport and fate models) to be used for supporting Safe- and Sustainable- by Design of materials (e.g. organic coatings and additives to replace PFAS).

- At least 2 novel materials (including bio-based ones) assessed in terms of their performance (function), human and environmental hazards (end-points determined based on the application areas) as well as their carbon and water footprints, recovery and recyclability, and overall environmental impact (LCA). Reaching at least 25% reduction in environmental impacts with <20% cost increase for production.

- Contribute to the development of Safe- and Sustainable-by-Design criteria and guiding principles and apply them to organic coatings.
- Enhance the social acceptance of the new developed materials by evidence basis compiled for consumer attitudes towards, and willingness to pay for, products that are less harmful to the environment, are sustainable, low carbon etc.
- Certification programme (or equivalents) for sustainable containing products, along the whole value-chain.
- Integration into standardisation process and development of a roadmap to achieve full standardisation (of e.g. methods, protocols).

<u>Scope:</u> The largest share of the organic coatings market belongs to a family containing Polyfluorinated Alkyl substances (PFAS), used in a wide variety of consumer and industrial products. Research will therefore target development of innovative PFAS-free materials with inherently surface active functions to be used for multi-industrial sector applications. (e.g. novel bio-based materials). The proposals should focus on integration of sustainable-by-design aspects including safety (toxicity), circularity and functionality of advanced coating materials, throughout their lifecycle.Projects should include one or more of the following aspects:

- Materials design supported by in silico methods for predicting hazards (toxicity) and fate to reduce additive exposure/leaching to humans and the environment.
- Development of alternatives maintaining functionality as well as reducing hazard and/or exposure (persistence) profiles with the aid of nanoinformatics modelling in order to reduce animal and experimental testing.
- Development of assays and approaches to demonstrate the reduction of hazard and/or exposure profiles of the new (alternative) advanced materials in a streamlined and robust manner to support route to market.

Proposals are expected to bring the core technology from TRL 2-3 up to TRL 5 at the end of the project.

Leveraging the extensive experience from relevant initiatives and aligning with other EU-funded projects targeting Safe- and Sustainable- by-Design materials, in particular CSA (RESILIENCE-15-2021) is essential

The proposals activities and approaches should cover both specific considerations for the organic coatings under study, as well as developing overarching best practices that spans broader sectors of safe- and sustainable-by-design materials. Proposals should involve all the actors in the value chain.

In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-22-2022: Safe and sustainable manufacturing of newly developed nanomaterials (IA)

Expected Outcomes: Sustainable manufacturing processes for full scale industrial implementation that successfully reduce the environmental, health and safety risks, while retaining the functional performance and economic viability of newly developed nanomaterials. Adopting safe- and sustainable-by design strategies[15] when applied as early as possible along the industrial innovation process will therefore ensure coherence between industrial, environmental, climate and energy policy goals and the priorities arising from the EU Action Plan for the Circular Economy[16] and The European Green Deal[17]. Projects are expected to contribute to the following outcomes:

- Support European advanced nanomaterial sector (SMEs and large industries) in the selection and application of simple, robust and cost-effective sustainable manufacturing processes by enabling risk-benefit analysis to ensure that nanomaterials are safe without compromising their technical and/or commercial probability of success.
- Provide best practices for reducing the environmental, health and safety risks during manufacturing processes of advanced nanomaterials.
- Develop harmonized standardized test methods that can be used in a regulatory framework including test hazard assessment, biodegradability and sustainability for advanced nanomaterials.
- Enhance the social acceptance of the new developed materials by achieving a significant impact on reducing production costs, thus increasing affordability.

Scope:

- Develop tools and methods for nanomaterials industry to enhance efficiency and contributing to less waste and emissions while improving process quality in line with Life Cycle Assessment framework.
- Proposals should have a holistic approach, covering the entire life cycle of the nanomaterial, with special focus on design and manufacturing stages. Proposals should include use cases demonstrating interoperability of data across the life cycle stages, cooperation with EU funded projects under Industry Commons and other similar initiatives for interoperability and data documentation should be addressed.
- Socio-economic impacts related to the proposed manufacturing processes should be covered, as well as solutions to promote the public acceptance for such materials.
- Regulatory compliance of the new developed nanomaterials should be included, as well as link with regulatory frameworks and legislative initiatives (e.g. the Malta Initiative).
- Proposals should demonstrate connectivity with H2020 nanosafety projects.

[15] Sustainable-by-design concept takes a systems approach by integrating safety, circularity and functionality of advanced materials, products and processes throughout their lifecycle. This concept can be defined as a pre-market approach that focuses on providing a function (or service), while avoiding properties that may be harmful to human health or the environment. from a lifecycle perspective.

[16] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614&locale=en

[17] https://ec.europa.eu/info/publications/communication-european-green-deal_en

- Proposals are expected to bring the core technology from TRL 4 up to TRL 6-7 at the end of the project.

In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-23-2022: Innovative materials for advanced nanoelectronic components and systems (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- More efficient electrical/interconnected cars, smart textiles, flexible electronics, could take advantage from new multifunctional materials and components. Impacts are also envisaged to smart grids, efficient through life performance monitoring, smart manufacturing, digital industry, increased computing performance and efficient data storage.

Scope: Europe aims to become a global role model for the digital economy and society. Electronic components and systems (ECS) are the building blocks for this. Electronic components and systems are core enablers and differentiators for the development of many innovative products and services in all sectors of the economy. In 2018 electronic system production exceeded 2 000 B€ for the first time in which 15% occurs in Europe (Source: DECISION Etudes & Conseil).

Research and innovation are key to maintain the competitiveness of the European ECS industry, generating growth, creating value, jobs and prosperity. Materials innovation lies at the heart of this endeavour. Actions must address one or more of the following technologies:

1. Innovative materials design and processing for devices based on new and emerging technologies, for e.g. spintronics, neuromorphic, multisensing, photonics, advanced ferroelectrics, etc…

2. Heterogeneous integration of new materials, sensors, actuators for miniaturised chips.

Proposal should indicate the key quantitative specifications to be achieved. Proposals are also expected to prove the industrial relevance of the intended approach, establishing links to applications likely to benefit from the development.

Projects may start at the concept level TRL 2-3 and deliver the technology validated in relevant environment TRL 4-5. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-24-2022: Advanced lightweight materials for energy efficient structures (RIA)

Expected Outcomes: The positive environmental impact of lightweight composite materials most often occur due to benefits during the use-phase. The overall life-cycle benefits are often reduced as a consequence of negative environmental impacts associated with the manufacturing (energy consumption) and inherent challenges to regain the high-value components (fibre and matrix) at industrial scale. Development of new chemistries for fast curing resins, new bio-based composites (including fibres and core materials) and associated novel production techniques are expected to result in

- Reduced cost for production of renewable lightweight materials, 25 % lower cost than currently used materials.
- Light-weight products containing >50% sustainable, bio-based materials
- Up to 30% lightweight potential through tailored functionality for a range of extreme environment (aeronautics, space) applications and in surface transport.
- Reduction in CO2 emissions (LCA) of at least 20 %
- Business models and circular value chains for lightweight bio based components.
- Improved time-to-market for European providers of lightweight solutions.

Scope: A step change is needed to develop new sustainable and high performance lightweight materials and associated novel manufacturing techniques. Research areas to be addressed include:

- Development of new chemistries for fast curing resins (including bioresins) and associated novel production techniques (e.g. out-of-autoclave processes to reduce energy consumption)
- Utilisation of existing or development of cost competitive renewable resins and/or core materials in combination with new fibres to make all renewable lightweight composites and structures
- Technologies and material design paradigms that enable hybrid composites based on a variety of constituents e.g. combinations of virgin and recycled fibres, bio-fibers etc. towards maximum cost and environmental benefits with a life-cycle perspective.
- High performance high temperature polymer composites with potential to extended use at temperatures above 300C. Besides general material and manufacturing, the long-term durability of materials in service is a potential are of research and development.

- New multifunctional composites where the materials and structures, besides traditional structural capacity, also is optimized towards one or several other functions such as thermal management (heating/cooling), energy harvesting and storage, morphing etc.

- New recycling technologies for polymer composites structures and, in particular, composite constituents. The high value constituents e.g. carbon fibres or matrix are not easily separated and technologies to recycle both in the same process should be addressed.

Projects may start at the concept level TRL 2-3 and deliver the technology validated in relevant environment TRL 5-6. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-25-2022: Functional multi-material components and structures (RIA)

Expected Outcomes: Optimised lightweight designs often require the use of multi-materials, often with different physical properties, such as for example polymer composites and lightweight metals. The manufacturing of multimaterial structures is thus a challenging task and many industries are today addressing specific critical challenges that come with mixing of materials. It is of great importance that multimaterial design is analysed from a holistic and multidisciplinary perspective where all aspects from design to manufacturing and recycling are included in the process. This will help industry make the change from traditional design based on one material to multi-material design of lightweight structures. The output of the proposed research is expected to:

- Contribute to energy efficiency, increase competitiveness of new multi-materials items and multi-functional materials and products for a wide range of applications in the additive manufacturing industries and in specific industrial sectors e.g. transport including aeronautic, consumer customised goods, communications, biomaterials and energy;

- Develop optimised structures in terms of operational performance and weight with a goal of reducing weight by 50% compared to traditional designs

- Reduced lead-time of multimaterial products of 20% compared to today's design of multimaterial products that creates an increased competitiveness for the European industry

- Strengthening of the European manufacturing industry through the intensive implementation of innovative and unconventional technologies along the European manufacturing value chain

- Combine materials with high uniformity and with high mobility in industrial quantities with high reproducible quality;

- Increase of the product performance by at least 30% whilst retaining the product price;
- Dissemination of the challenges and benefits of functional multi-material components and structures in the relevant industrial sectors.

Scope: By combining several materials, proposals should advance the state of the art through the development of ready assembled multifunctional devices. The role of new development in additive manufacturing processes with dissimilar materials will be of importance. Proposals should address and demonstrate several of the below simultaneous activities:

- Quantification of improved functionalities, properties, quality and lifespan of fabricated pieces;
- Evaluation of matching materials properties to the production process to enable the joining of dissimilar materials for AM tools;
- Demonstration of a better understanding of the nanotechnology integrated materials properties and manufactures;
- Integration and validation at early stage of the qualification and certification considerations of the materials, including innovative non=destructive inspection techniques;
- Joint development with material suppliers and end-users is required for a rapid uptake by industry;
- Modelling, standardisation and regulatory aspects (especially safety and nano-safety) and the process and materials qualification.

Projects may start at the concept level TRL 3 and deliver the technology validated in relevant environment TRL 6. In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

Section: Materials for the benefit of society and the environment and materials for decarbonising Industry

[Expected impacts addressed: #15 (Green), #16 (industrial leadership and autonomy), #20 (Human-centred)

Objective: Leadership of the European industrial sector to produce materials that provide solutions for a clean, toxic/pollutant free environment, safeguard civil infrastructures, and to protect cultural heritage.

New and advanced materials to support the sustainable storage and recovery of energy, with a direct impact to reducing CO_2 emissions via storage of overproduced electricity from renewable sources and buffering of the electricity grid. More specifically, this will require advanced materials with unique functionalities to facilitate carbon capture and use (CCU) and CO_2 conversion to provide for a cost-effective production of chemicals and near-zero emissions power fuels (Power to X, Synfuels).

A sustainable by design concept for all materials developments to ensure criticality of raw materials is reduced and the environmental impact minimised.

Current Status: Manufacturing and process industries (e.g. chemicals, pharma, automotive etc.) are key industrial sectors in the EU. Industrial activities (including electricity production) account for 51% of all CO_2 emissions in Europe with transportation (including aviation) accounting for a further 25%. In order therefore to reach carbon neutrality, efforts to reduce and ultimately avoid CO_2 emissions attributed to industrial activities will have a significant impact in the overall reduction of greenhouse gas (GHG) emissions in Europe.

Achievements sought / targets:

New, sustainable-by-design materials will enable the development of novel products for the benefit of the society including environment protection.

Preservation of freshwater resources and delivery of solutions for a toxic/pollutant free environment in support the Zero Pollution strategy by the development of advanced materials for membranes and filters for water and air purification.

Antimicrobial, Antiviral, and Antifungal Nanocoatings. The need to develop additional bactericidal means has significantly increased due to the growing concern regarding multidrug-resistant bacterial strains, biofilm associated infections and the consequences of the recent COVID19 outbreak. Inorganic nanomaterials (metal nanoparticles, carbon nanotubes, metal oxide nanoparticles, and graphene-based materials) have demonstrated enhanced anti-microbial and anti-viral activity. They are also stable at high temperatures, robust, and have a long shelf life, compared to organic anti-microbial coatings. The development therefore of effective and long-term antibacterial, antiviral and biofilm-preventing inorganic coatings, applied to various surfaces such as glass, metals and various alloys, marble and stone slabs, ceramics, textiles and plastics constitute an immediate need for safeguarding the health of EU citizens.

Advanced characterisation methodologies to assess and predict the health and environmental risks of nanomaterials (e.g. nano and micro plastics).

Materials inspired by nature (biomimetic) with high functionality, but also enabling the optimised design of components and structures with minimal impact to the environment.

Development of nanoelectronic sensing devices for applications ranging from human health monitoring to industrial process monitoring and Internet of Things (IoT) applications.

Development of new advanced materials to protect and conserve cultural heritage from degradation, in support of the Commission's priorities for cultural heritage and creative industries.

Development of new materials of the rehabilitation of ageing civil infrastructures ensuring safety and functionality at a lower cost.

Energy efficient catalytic reactors and catalytic systems, establishing an innovation community for solar fuels and chemicals, and materials for hydrogen storage (in the medium-term – 2030). The development of new material systems for CCU Development of new supercapacitor materials, membranes for gas separation, based on non-critical raw materials (in the long-term – 2050).

Means/links: Due to its importance and cross-cutting societal nature, this orientation for topics will have strong links with other activities in Cluster 4 (Manufacturing Technologies), Cluster 2 (Culture, creativity & inclusive Society), as well as with activities in Cluster 6 (Food, bioeconomy, natural resources, agriculture and environment). Shared activities with these parts of the programme may be developed (e.g. Joint calls).

Proposals are invited against the following topic(s):

RESILIENCE-26-2021: Development of more energy efficient electrically heated catalytic reactors (IA)

Expected Outcomes: A shift from fired- to electrically-heated catalytic reactors, powered by renewables will lead to a large decrease in CO_2 emissions, coupled with a significant process intensification. As currently reactors are kept at high target temperatures in industrial-scale catalytic processes with energy supplied by the combustion of fossil fuels, substitution of fossil-fuel-derived heating with an emissions-free alternatives will substantially contribute to the greening of large industries. This requires the re-design of the reactor and in parallel with the development of novel catalysts as well as integration of up and downstream processes to operate with optimal energy efficiency and product yield.

Projects are expected to contribute to the following outcomes:

- A breakthrough reduction in carbon footprint for a given reaction (CO_2 emission reduction > 40%, demonstrated by LCA or similar studies);
- Demonstrate a significant process intensification (a reactor size reduction of > 50% with respect to the state-of-the-art conventional approach) and industrial scalability;
- Environmental and techno-economic feasibility of novel catalytic reactor technologies and catalyst materials demonstrated and validated at suitable scale against current industrial processes to produce the same products.
- Integrated development methodology of catalysts and reactors for an optimized design up to pilot unit of novel catalytic reactors with significant carbon footprint reduction and allowing relevant process intensification, while maintaining cost competitiveness.
- Advanced catalytic reactor concepts to operate in synergy with alternative energy resources like e.g. non-thermal plasma.

Scope: Proposals should address an integrated development of:

- The next generation of industrially scalable and robust reactor technologies and associated catalytic materials for an electrified chemical production with an optimized design, up to pilot unit;
- Environmental and techno-economic impact studies should be part of the objectives to demonstrate the industrial feasibility and integration within the value chain of production and use of renewable energy sources.
- Solutions allowing the combined use of renewable energy resources with process intensification should be investigated in order to optimise energy efficiency, product yield and purity as an integrated part of the total process.

Proposals are expected to bring the core technology from TRL 3-4 up to TRL 5-6 at the end of the project.

RESILIENCE-27-2021: New catalytic material technologies for a cost-effective distributed production and development of near-zero emissions power fuels (RIA)

Expected Outcomes: The use of renewable energy sources to drive chemical processes offers the possibility for a distributed, small-scale production of chemicals, such as fertilizers, with benefits in terms of integration with local resources, reduced costs and safety issues for to transport, better flexibility and impact in terms of greenhouse gas emissions, and environmental impact. This requires developing new catalytic technologies able to use directly renewable energy sources as energy input, such as photoelectrocatalytic (PEC) devices, and optimized for a distributed production at small-medium scale. The technology also offers new opportunities for integration with bioeconomy, for example by integration of PEC devices within biorefineries or by development of bio-based (biological and bio-hybrid) approaches, in order to realize new solutions for integration of renewable energy sources within bio-based processes and foster a circular economy in the bioeconomy.

Projects are expected to contribute to the following outcomes:

- Demonstration and validation up to mini-pilot size of the proposed technology and demonstration of the integration with local resources and territory.
- Demonstration of the socio-economic and environmental benefits of the proposed technology for local communities.
- Demonstration of the decrease of the greenhouse gas (GHG) emissions (> 50% using LCA or similar studies) deriving from the use of the proposed technology.
- Demonstration of the relevance of the proposed technology as a model for extending distributed production to other industrial relevant cases.

Scope:

- Development and validation, up to mini-pilot size, of novel catalytic technologies and/or bio-based approaches (biological and bio-hybrid), preferably integrated with the source of renewable energy in a single unit or device, for the distributed production of industrially relevant chemicals.
- The proposed solutions should demonstrate how they integrate in local districts and use local resources to favor a circular economy approach. In addition, the proposed technology should serve also as model for the more extended use of distributed production in other industrial relevant cases or fields.
- Catalytic materials shall target low-cost base chemicals limiting the use of precious metals or CRMs and to the widest possible extend be recyclable;
- Catalyst material technologies should be chosen in view of operating with electrically heated catalytic reactors.

Proposals are expected to bring the core technology from TRL 3 up to TRL 5 at the end of the project. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-28-2021: Creation of an innovation community for solar fuels and chemicals (CSA)

Expected Outcomes: Creation of an innovation eco-system gathering together the various elements necessary to accelerate the development in the area of introduction of solar fuels and chemicals. This will require a strict synergy of actions between all stakeholder components, from R&D to industry and society, in order to foster their introduction. In addition, the development of solar fuels and chemicals requires a full redesign of the current technologies and processes based on fossil fuels, and the technological gap is a main factor limiting their introduction.

Projects are expected to contribute to the following outcomes:

- Solar fuels and chemicals constitute those products that are equivalent in terms of functionality to the ones currently in use based on fossil fuels, and thus well integrating within the existing infrastructure, but produced with the aid of renewable energy sources and with a disruptive decrease in terms of reduction of greenhouse gas emissions on LCA bases, larger than that based on biomass sources. They will play a crucial role to meet targets for decarbonizing Europe.
- Structuring/developing in the short term the European ecosystem in order to speed up technologies to move from the laboratory to industry.
- Tackle long-term research challenges in the field. This would be done mainly through the RIA & IA topics of the large-scale R&I initiative, as well as with actions at national and regional levels, with overall coordination by the CSA.

Scope:

- Coordinating a large scale R&I initiative on storage of renewable (solar) energies in chemical form involving all relevant stakeholders (from academia, RTOs, industry and society) and linked with relevant international, national and local programmes and initiatives;
- Building and updating, a long-term roadmap;
- Building/structuring a community with all relevant stakeholders across EU;
- Participation of societal stakeholders to the activities of the community and initiative;
- Facilitating cooperation and communication between the stakeholders of the initiative on cross-cutting topics;
- Strengthening the engagement of the European industrial stakeholders in the long term beyond the CSA;
- Creating an innovation eco-system to foster and accelerate the technological, economic and societal impact of the initiative and pave the way to industrial exploitation of the technologies in the field of energy, transport and climate;
- Speeding-up and increasing the positive impacts of technologies on climate change and protection of environment;
- Spreading of S&T excellence across Europe and increase awareness of European activities;

- Addressing international cooperation in particular with other relevant actions (e.g. Mission Innovation);

- Preparing a large-scale research and innovation initiative beyond the CSA, as a partnership or another instrument to be discussed and agreed upon with the EC and the MS and AC.

RESILIENCE-29-2021: Sustainable storage of H2 (RIA)

Expected Outcomes: The benefits of a hydrogen based economy are well documented, since hydrogen is an abundant zero emission fuel, and possesses a higher energy density than conventional fossil fuels (e.g. petrol). However, safe hydrogen storage, either long or short term, faces several challenges. Chemical storage, fuel cells and liquefaction are all current means of hydrogen storage. Chemical storage is the prevailing method for long term storage due to the high storage density but the synthesis process needs further development to make it commercially attractive. Pressurised gaseous storage is the most attractive in practical terms but compression up to 700bar is needed to achieve practical volumetric storage capacities for transport applications which requires expensive pressure vessels and is inherently dangerous. However, new approaches using ultra porous materials have demonstrated the feasibility of high storage densities of gaseous hydrogen at pressure of 100bar. Focused research on new approaches to hydrogen storage will therefore:

- Provide commercially attractive and safe new technologies for long-term storage and transport of hydrogen;
- Enable efficient and safe hydrogen short term storage for example for fuel tanks for automobiles, rail vehicles, ships, etc., eliminating pollution caused by fossil fuels and facilitating the greening of transport;
- Elimination of economic dependence for Europe's energy needs.
- Ability for distributed production, providing opportunities for new business ventures and the development of new centres for economic growth in both rural and urban areas that currently find it difficult to attract investment in the current centralised energy system.

Scope: Research proposals should address at least one of the following:

- Development of new catalysts for ammonia synthesis at low pressures for long term hydrogen storage and distribution
- Development of new ultra porous materials for hydrogen storage with a gravimetric storage capacity in excess of 6 wt% and a volumetric storage capacity in excess of 40g/lt. The use of machine learning techniques to assess combinations and substitutions in various porous materials to help optimise the development process should also be considered.
- Development of suitable pressure vessel materials for the containment of the adsorbent ultra-porous materials

- Conduct full LCA of the new developed materials, (catalysts, ultra-porous materials) and processes (synthesis process, ultra-porous material production)
- Produce a demonstrator plant for low pressure ammonia synthesis
- Produce a demonstrator pressure vessel containing ultra-porous hydrogen adsorbents.

Proposals are expected to bring the core technology from TRL 2-3 up to TRL 5-6 at the end of the project. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-30-2021: Novel materials for supercapacitor energy storage (RIA)

Expected Outcomes: Supercapacitors are attractive alternatives to batteries because they can be charged very quickly and can sustain vastly greater number of re-charge cycles than batteries without loosing efficiency. However, their power density is lower than that of batteries but recent material research breakthroughs have indicated that this can be substantially increased. Projects are expected to contribute to the following outcomes:

- New supercapacitors with energy densities comparable to batteries able to recharge in a fraction of the time required for current batteries, have no loss of performance over time and longer life.
- Substantial impact to energy storage systems ranging from consumer goods to electrification of transport and reduction of emissions.
- Establish new industrial value chains with new energy storage products

Scope: Compared to batteries, supercapacitor energy density is low and they use more expensive and critical raw materials (CRMs). Proposals should address the challenge for new material concepts to be used in supercapacitors to at least double the energy density over current technologies reduce cost and minimise or eliminate use of CRMs.

Proposals are expected to bring the core technology from TRL 3 up to TRL 5 at the end of the project. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-31-2021: Innovative filters for a toxic free environment (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Increased population, industrial growth and other environmental factors like transport consequently lead to severe pollution of air and water. Also the issue of sustainable and healthy indoor environment is receiving increasing attention. Growing health risks and increased economic costs related to the population's health are associated with the pollution.

- Filtration is a simple, versatile, and economic method to eliminate sub-micrometric or nanometric particles, coming from pollutants in water, and air and also aerosol. Cost-effective filter materials and technologies shall be developed to efficiently provide for improved air and water cleaning.

- New materials are therefore needed for filters with increased performance having a direct contribution to clean air policy and health of citizens. Advanced filtration systems also directly contribute to energy savings for buildings.

- Nano-fibre filters for face masks.

Scope: Adapt a zero pollution action plan for air, water and soil by developing advanced filters compatible with all traditional and new pollution sources such as for example factory and ships smoke, industrial drainage, nanomaterials emissions.

Proposals should address at least one of the following challenges:

- Design fibrous filtering devices, capable of removing sub-micrometric and nanometric-sized pollutants from gas streams, improving the current efficiency of commercial filters (> 90%)

- Develop new functional, “intelligent” filters that selectively capture pollutants, specifically targeted for example at VOCs, microbes and viruses, heavy metals, etc., by using active ingredients. Functional additives could be based on nanoparticles (silver, platinum), metal-organic frameworks (MOF), molecular imprinted polymers and/or bioactive compounds.

- Scale the fabrication of nanofibres by electrospinning to a mass scale to commercially produce nanofibres at large enough volumes and low cost able to compete with existing alternative technologies or products. Produced nanofibres shall have distinct performance and/or production advantages like an improvement in the surface area, porosity and reduced thickness and/or weight.

Proposals are expected to bring the core technology from TRL 3 up to TRL 5-6 at the end of the project. In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-32-2021: Antimicrobial, Antiviral, and Antifungal Nanocoatings (RIA)

Expected Outcomes: The recent outbreak of the COVID19 virus has demonstrated that costs in both human life and economic terms can be immense if measures are not in place to contain a spread of infection. It is apparent therefore that passive measures are in place to minimise the impact of current and future infection outbreaks. Nanoparticle filled coatings such as metal nanoparticles, carbon nanotubes, metal oxide nanoparticles, and graphene-based materials have demonstrated up to 99.9998% effectiveness against bacteria, mould and viruses and therefore the development of such easily applied nanocoatings will

- Minimise the risk of spread of infections from harmful pathogens arising from everyday human activities
- Create a healthier living and working environment and offer holistic solutions to people with a diminished immune system.
- Improve citizen health and enhance the EU's reputation as a public health best practice region.
- Enhance economic benefits through reduction of lost hours of work through illness
- Boost research, development and innovation in the EU.
- Provide business opportunities especially for SMEs

Scope: Inorganic nanomaterials have demonstrated enhanced anti-microbial and anti-viral activity. They are also stable at high temperatures, robust, and have a long shelf life, compared to organic anti-microbial coatings. Research areas should address new antiviral and antibacterial nanocoatings for a range of applications addressing use on both surfaces of so-called high-traffic objects (e.g. door and window handles in public places, hospitals, public buildings, schools, elderly homes etc) and coatings for textiles (e.g. protective clothing in food processing plants, laboratory coats, face masks, etc.). The research should address the following aspects:

- Synthesis of nanocoatings and effectiveness against a range of pathogens,
- Application methods (both on surfaces and textiles)
- Surface adhesion and durability via assessing performance against wear (e.g. abrasion, washing, etc.) on a variety of surfaces (e.g. glass, metals and various alloys, copper and stainless steel, marble and stone slabs, ceramics and tiles, textiles and plastics)
- Toxicity of nanocoatings.

Proposals are expected to bring the core technology from TRL 3 up to TRL 6 at the end of the project.

RESILIENCE-33-2021: Materials inspired by nature (biomimetic) with high functionality, but also enabling the optimised design of components and structures with minimal impact to the environment (RIA)

Expected Outcomes: All living organisms consist mainly of organic matter, but have developed the ability to produce functional inorganic materials, recognized as of biogenic origin, which offer living organisms functions such as, mechanical support and protection, light-harvesting (e.g., for photosynthesis), navigation, etc. One such class of materials are biogenic metal oxides which feature structures as highly functional and unique as the organisms generating them and often have unique crystalline structures compared to equivalent naturally occurring metal oxides. Metal oxides are important materials with wide applications as catalysts, adsorbents, superconductors, semiconductors, ceramics, photocatalysts, antifungal agents and also have several applications in medicines. The ability therefore to mimic the biological creation of such materials with structures and properties, not found in naturally occurring mineral alternatives will enable the creation of nature-inspired highly innovative materials with unique properties, addressing a number of technological challenges and enabling advances in architecture, engineering, medicine, and biomedical engineering.

Projects are expected to contribute to the following outcomes:

- At least two novel materials assessed in terms of their performance, improve resource efficiency and deliver new levels of sustainability.
- Develop clean technologies that can significantly reduce environmental contamination and decrease the hazards to human health resulting from the use of toxic chemicals and solvents currently used in conventional industrial fabrication processes;
- Bring to market, novel products in applications such as, catalysis, energy storage, energy conversion, electronics, magnetic storage media, medical restorative materials (e.g. dentistry), etc.

Scope: Research in biogenic metal oxides is expected to address a wide range of applications ranging from energy and electronics to structural design and restorative medicine.

- Research should also address self-healing of structural materials, new materials for wound stitching, smart textiles, functional coatings (anti-reflective, adhesive, hydrophobic, etc).
- Proposals should provide a full LCA to demonstrate the environmental and economic benefits of biomimetic based products
- Fully functioning demonstrators should be developed and produced by project end, demonstrating at least a 20% improvement in performance of the biomimetics based material solution,

Proposals are expected to bring the core technology from TRL 3 up to TRL 6 at the end of the project. In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-34-2021: Novel and improved materials for green nanoelectronic components and devices for industrial applications (RIA)

Expected Outcomes: The ambition to achieve zero emissions towards 2050 is driving the need for change in the energy landscape through distributed variable renewable energy sources and bidirectionality in the grid landscape. Electronics components and devices support the development of this landscape with the lowest dissipation losses, integrated intelligence and smallest form factors.

By way of complementing its contribution to more efficient energy generation and distribution, electronics components and devices, and in particular power technologies, also have a huge potential impact for energy consumption in the industry.

Projects are expected to develop and validate novel and improved materials for new generation of green electronic component and device technologies and solutions that contribute to sustainability and preserve natural resources.

Scope: The scope of the research and development efforts cover electronic components and systems to support smart energy, smart lighting, smart water management, and other “green” facilities in smart cities, smart buildings, smart homes, and smart agriculture.

Proposals can address one or more of the following topics below:

- Advanced Materials for Power Electronics based on III/V and other wide bandgap semiconductor materials (e.g SiC, GaN on silicon, AlN, diamond, diamond on silicon or nanowire-based materials, etc…).
- New or improved materials for energy harvesters and storage devices (e.g. microbatteries, supercapacitors), including 2D, 3D and solid-state for feeding low or zero power devices
- Innovative materials, design and “green” processing of semiconductor products with zero waste

Proposals should identify applications likely to benefit from the intended approach with indication of key parameters (for e.g. power, energy-efficiency, size, frequency, and cost, etc…) and quantitative targets to be achieved (figures of merit). Proposals should lead to increased efficiency, reliability and manufacturability, enhancing the European industry capability and value chains.

Proposals are expected to bring the core technology from TRL 2-3 up to TRL 4-5 at the end of the project. In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-35-2021: Novel recycling technologies for composite materials (RIA)

Expected Outcomes: The European composites market size was worth €16 billion in 2018 and is estimated to register an annual growth rate of 7.5% from 2020 to 2025 owing to increasing demand for lightweight materials in various industries such as wind energy, transport, construction, sports and leisure, aeronautics, space and defence. However, polymer composites are difficult to recycle and available technologies such as high-temperature pyrolysis, and grinding (to be used as filler material) are either not environment friendly or economically unattractive. Environmental legislation on recycling of end-of-life components and structures will mean that 80,000 tons of fibre reinforced polymer composites will have to be recycled every year from 2025 in Europe. It is therefore imperative that technologies are found to recover and reuse these materials in useful and sustainable manner.

Projects are expected to contribute to the following outcomes:

- Reduction of waste sent to landfill, or inceneration, positive environmental impact and creation of new value streams through new technologies with potential for commercial exploitation.
- Enhanced lightweight designs for transport and other industrial applications currently limited due to costs and adherence by industry to environmental legislation and the End of life directive.
- Clean recycling technologies and material re-use for more efficient use of resources
- New business opportunities and revenew streams for recycling companies, benefiting particularly SMEs which dominate this sector of the market.

Scope: Recent research has demonstrated that for a number of thermosetting resins chemical decomposition, recovery and re-polymerisation is feasible for a number of polymer resins, raising the prospect of materials recovery and re-use. However, the use of aggressive chemical compounds (e.g. nitric acid) are used which has limited the prospects of upscaling and commercialisation of the processes developed.

Proposals should therefore address:

- Development of novel, safe, environment friendly and commercially attractive methods of recycling of a range of polymer composites (e.g. PVC, polyesters, vinyl esters, epoxies, etc.) via decomposition techniques.
- Demonstate at pilot plant level the commercial feasibility of the recycling process and recovery of recyclate material, including options for re-use of the recyclate (both resin and reinforcement).

Proposals are expected to bring the core technology from TRL 3 up to TRL 6 at the end of the project. In line with the Union’s strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-36-2022: Membranes for gas separations - membrane distillation (IA)

Expected Outcomes: Advanced membrane materials are essential to achieve the goals of the European Green Deal with significant reductions of industrial emissions in waste streams like wastewater and waste gas like removal of gas / volatile pollutants from liquid emissions or purification of wastewater.

Projects are expected to contribute to the following outcomes:

- The next generation membrane materials, delivering smart solutions for greening of industrial plants.
- Advanced membrane materials for recycling of waste streams from industrial plants to support the Zero Pollution strategy.
- Better materials with outstanding separation performance and/or superior properties either in chemical, mechanical or thermal stability compared to commercial materials.
- Reduction of the water footprint of 10% in industrial plants for the preservation of freshwater resources.
- Up-scaling the desalination process by solar powered membrane distillation systems and coupling membrane distillation with solar / photovoltaic collectors.
- Energy saving by 10% through the application of a new generation of membranes.

<u>Scope:</u> Membranes separation is one of the key process elements needed for the next level of resource efficiency and for greener industrial plants. Proposals will address the development of the new generation membrane materials from gas separation to membrane contactors in comparison to the current state-of-the-art.

Proposals should address at least two of the following activities:

- Advanced membrane materials for the recovery of valuable components (ammonia, alcohols, reactants, products, catalysts) from aqueous, organic and mixed aqueous/organic process and waste streams to enhance the resource efficiency in industrial plants.
- Separating gas streams (e.g. CO_2 utilisation processes) in the process emissions by using membrane technologies, where in addition to the produced product, other gases are in the stream (e.g. unreacted CO_2 and hydrogen).
- Demonstrate the next generation of porous membranes for membrane contactors (membrane distillation, gas/liquid contactors, liquid/liquid contactors) with use of renewable energy sources (solar energy or waste heat) to achieve significant reduction in CAPEX and process costs of gas separations and distillation.
- Up-scaling the desalination process by solar powered membrane distillation systems by coupling membrane distillation with solar / photovoltaic collectors.
- New membrane materials to reduce the water footprint in industrial plants for the preservation of freshwater resources (e.g solvent tolerant reverse osmosis membranes, forward osmosis).

Projects may start at the concept level TRL 4 and deliver the technology validated in relevant environment TRL 6. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-37-2022: Materials, manufacturing processes and devices for advanced flexible printed organic and large area electronics for medical applications (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- New medical applications based on the combination of printed and (Organic and Large Area Electronics) OLAE processed electronics in flexible and wearable electronics; taking into consideration the sustainability of the materials;
- Improvement in performance (e.g. sensitivity and selectivity) and environmental stability (e.g. long term calibration, degradation over time, fouling of active surface components);
- Decreasing sample volume and the size of the device;
- Lowering power demand;
- Improvement in cost competitiveness, lifetime and processability as well as manufacturing capability for OLAE materials and electronics;

Scope:

- New materials for medical applications, characterized by low production costs, low energy consumption and biocompatibility.
- Disruptive and precise devices as key enabler for digital healthcare and well-being.
- Improve the quality of life of patients by developing smaller and less-invasive point-of-care devices.
- Decrease the burden on medical facilities with devises characterized by an increased durability and reduced requirements for maintenance.

Projects may start at the concept level TRL 2-3 and deliver the technology validated in relevant environment TRL 5-6. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-38-2022: Advanced characterisation methodologies to assess and predict the health and environmental risks of nanomaterials (IA)

Expected Outcomes: The development of reliable and practical tools to ensure the safe and sustainable use of nanomaterials has not kept pace with the rapid commercialization of nanotechnology-enabled products. The dynamic nature of many nanomaterials in complex environmental matrices is recognized as a major challenge for their detection, quantification and characterization. Consequently, there is an urgent need to establish appropriate methods for cost-efficient assessment and prediction of the health and environmental effects of nanomaterials, providing better decision criteria, based on quantitative rather than qualitative information and taking into account the full life cycle of a material. Projects are expected to contribute to the following outcomes:

- Develop methods for quantification and characterization of nanomaterials (e.g. nono and microplastics) in complex matrices and determinations of their transformations in such environments.
- Increase availability of validated protocols to advance both nanosafety studies and material characterization.
- Ensure appropriate control experiments and more realistic in vitro models to address current gaps in nanotoxicology.
- Deliver reliable data and improved data reporting guidelines, supported by computational modelling, in order to allow the development of grouping and read across methods.
- Develop harmonized standardized test methods that can be used in a regulatory framework including test hazard assessment, biodegradability and sustainability for advanced nanomaterials.
- Increase the efficiency and effectiveness of materials and product development by reducing costs and time for product design, time-to-market and regulatory compliance

Scope:

- Develop advanced characterization tools and methods for nanomaterials industry to enhance the design and development stages of advanced materials and products contributing to less waste and emissions while improving process quality in line with Life Cycle Assessment framework.
- Include use cases to validate and demonstrate the approach(es) in industrial settings and involve comprehensive analysis and measurement of process and handling release scenarios and exposure measurements.
- Propose the validated methods to standardization bodies such as ISO or OECD for development of standards, test guidance or a guidance document.
- Demonstrate connectivity with H2020 nanosafety projects and leverage the extensive experience from relevant initiatives. Cooperation with EU funded

projects under Industry Commons and other similar initiatives for interoperability and data documentation should be addressed.

- Contribute to the objectives of the European Materials Characterisation Council (EMCC) and European Materials Characterisation Council (EMCC).

Proposals are expected to bring the core technology from TRL 4 up to TRL 6-7 at the end of the project.

In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-39-2022: Building and renovating by exploiting advanced materials for energy and resources efficient management (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Compared to state of the art materials and components, the newly developed materials should deliver

- Reduction by at least 30% of the embodied energy and CO2 at component level;
- Improvement by at least 20% of insulation properties;
- Reduction by at least 15% of the total costs compared to existing solutions;
- Demonstration of at least a 5% reduction of the energy spent during the whole life cycle of a building;
- Improvement of the quality of information from product manufacturers to facilitate better decision making;
- Strengthening of the competitiveness of the European construction sector in the field of "green" construction technologies;
- Sustainable building materials will be supporting the circular design. Self-sustaining buildings in respect to energy usage;
- Proof of concept in terms of one (or more) component(s) containing the new materials developed should be delivered within the project

Scope: Building envelopes and renovation materials that boost energy savings, save resources and decrease carbon emissions, both during construction and operation of the buildings. Proposals should address and demonstrate several of the below activities:

- Development of new materials and/or solutions for building envelope components with reduced embodied energy, lower CO2 emissions and improved insulation properties during operation;

- New components shall also contribute to improve indoor air quality, by limiting VOCs emissions and/or by advanced properties aiming to absorb and biodegrade indoor contaminants;
- Enhanced durability for increased use duration, reduced maintenance and consequently reduced costs, respect of sustainability principles (the sustainability of each developed solution should be evaluated via life cycle assessment studies carried out according to the International Reference Life Cycle Data System - ILCD Handbook);
- New components shall find application to both new build and renovation and deliver realistic solutions at a reasonable price;
- New components have to be lightweight construction with an ease of installation and provide for increased comfort and noise reduction.

Projects may start at the concept level TRL 4 and deliver the technology validated in relevant environment TRL 6.

RESILIENCE-40-2022: Energy conservation through retrofit building insulation materials (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Buildings are responsible for approximately 40% of energy consumption and 36% of CO2 emissions in the EU. Renovation of existing old buildings has the potential to lead to significant energy savings – potentially reducing the EU's total energy consumption by 5-6% and lowering CO2 emissions by about 5%;
- Demonstrate innovative retrofitting solutions as real cases approaching net zero energy standards;
- Reduction of at least 60% in energy consumption compared to the values before renovation while ensuring affordability;
- Demonstrate a high replicability potential;
- Return on investment should be below 7 years for deep retrofitting of buildings;
- Advent of a new generation of skilled workers and SME contractors in the construction sector aware of the need of a systemic approach towards energy efficiency should be promoted through the proposed activities.

Scope: Fossil energy is used at larger extent in residential buildings for space heating and Domestic Hot Water production. In view of the climate targets, Europe's building infrastructure needs a deep rehabilitation of residential buildings (including buildings of historic value) while lowering the costs of refurbishment.

Proposals should address and demonstrate several of the below activities:

- New insulation materials (not external cladding) that are cost effective, environmentally safe, fire resistant and can be easily applied on existing surfaces (e.g. spray coating);
- Retrofit of such insulating materials should be applicable to interior building space and not affect the decorative aspects of the space it is applied to;
- Systemic approaches need to be developed which integrate the most promising cost-effective technologies and materials;
- Energy efficiency shall be addressed by system integration and installation, exploiting synergies between technologies, which proved valid at a small scale and need a larger scale demonstration.
- Environmental impact should be demonstrated by life cycle assessment, while the process has to be fully digitized in order to comply with specific topological/geographical climate needs, facilitating materials selection. Proper design and properties need to be targeted, assisted also by BIM.
- Synergy with existing relevant Open Innovation Test Beds is welcome.

Projects may start at the concept level TRL 3 and deliver the technology validated in relevant environment TRL 6.

RESILIENCE-41-2022: Conserving our Cultural Heritage through sustainable and durable materials and advanced characterisation methods (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To protect and conserve our Cultural Heritage for future generations, new advanced materials and characterisation methods shall protect, reverse or slow down degradation processes, caused by environmental and microbial factors, and anthropic actions (e.g. pollution and inappropriate conservation practice), whilst being sustainable and safe and offering at the same time long-lasting durability,
- Practical and affordable solutions in terms of cost and/or complexity of operation by those who will use the materials and techniques developed;
- Contribution to achieving EU policies, in line with the Lisbon Treaty recommendation to take actions on a global scale to ensure that Europe's cultural heritage is conserved, safeguarded and enhanced (Article 3).

Scope: It is a challenge for European society to preserve its unique Cultural Heritage. However, repeated restoration works may in the long term irreversibly damage materials and surfaces. A more sustainable approach is needed and should be based on prevention, monitoring and regular maintenance.

Proposals should address and demonstrate several of the below activities:

- Develop one or more functional materials or highly innovative techniques in the restoration and preventive conservation of works of art;
- Apply a sustainable approach which covers the inherent durability and life cycle of new products. Develop reliable methods and protocols for the assessment and monitoring of the durability of treatments both in lab and in real life application;
- International cooperation with international organisations to set relevant standards for these methods and protocols.
- Valorisation including market uptake of the proposed solution(s), the participation of companies leading the conservation market is an essential element of the R&I projects.

Projects may start at the concept level TRL 2-3 and deliver the technology validated in relevant environment TRL 5-6. In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

RESILIENCE-42-2022: Critical raw material substitution for EU's low-carbon technologies (RIA)

Expected Outcomes: The demand for critical raw materials used in green technologies is continuously increasing. In future, the availability of critical raw materials may turn out to be the limiting factor in Europe's aim to become climate neutral by 2050. Togetehr with recycling, replacing critical raw materials with more abundantly available ones that offer similar performances is an important mitigation strategy to alleviate Europe's dependency and possible supply risks.

Projects are expected to contribute to the following outcomes:

- Creation of a multidisciplinary integrated community, involving all the actors in the value chain, driving innovation in the field of critical raw material substitution for the benefit of EU low-carbon industry and the transition towards a climate neutral society;
- Creation of lasting ecosystems of innovation, including relevant national and regional initiatives, resulting in the establishment of a limited number of CRM substitution virtual labs;
- Demonstration of the CRM substitution virtual labs functioning and their capacity in reducing the lead-time from TRL4 to TRL7;
- Updated substitutability roadmaps for novel alternatives to Critical Raw Materials for EU's low carbon technologies;

- Strategies on how to better implement an awareness on criticality in the materials scientist and industry communities.
- At the longer term boost competitiveness and decrease European industry reliance on critically available raw materials.

Scope: The projects should aim at significantly enhancing innovation in the critical raw materials substitution for low-carbon technologies. The proposals must aim at sharing knowledge, facilitating matchmaking activities as well as supporting Europe's competitiveness and business creation. In particular, the proposal should aim at:

- Diffuse innovation in the domain of substitution of critical raw material in low-carbon technologies and build up communities, namely ecosystems of innovation, to stimulate demonstration;
- Structure the stakeholder community around regional, national, European[18] international initiatives, programmes, projects, labs etc, in CRM substitution, with the goal to support exploitation, raise awareness and support a shared technological vision;
- Use the ecosystems of innovation to stablish a limited number of thematic CRM substitution virtual labs;
- Demonstrate (conceptualise, implement, monitor and revise) virtual labs systemic innovation potential for at least three real test cases;
- Actively pursue the involvement of public authorities and policy-makers, businesses and business enablers active in the as well as academic, training, research, and innovation-oriented organisations.

In line with the Union's strategy for international cooperation in research and innovation, international cooperation is encouraged.

[18] European Institute of Innovation and Technology(EIT) for raw materials; European Innovation Partnership on raw materials

Section: Materials and data cross-cutting actions

[A series of ***enabling and cross cutting actions*** underpinning all work on advanced materials and deemed crucial for the rapid development, uptake and commercialisation of the proposed technologies will be implemented, namely:

- Integration of advanced materials modelling and characterization,
- Industry data standardisation and testing methodologies (Industry Commons) and
- Implementation of Climate Neutral and Circular Innovative Materials Technologies Open Innovation Test Beds (OITBs).]

Proposals are invited against the following topic(s):

RESILIENCE-43-2021: Optimized Industrial Systems and Lines through digitalisation (IA)

<u>Expected Outcomes</u>: The digital transformation of the European manufacturing industry depends on the availability and uptake of high-quality, efficient, affordable and optimised systems, such as those offered by cloud infrastructures, simulation-based twin technologies, data driven approaches. However, there is a low uptake in Europe for such technologies, for example in the case of cloud computing only 1 company in 4 apply it and only 1 in 5 for SMEs[19].

Projects are expected to contribute to the following outcomes:

- Support the transition towards industrial digitalisation
- Increase speed of innovation by optimising the use of existing research results and facilitating uptake of new projects results;
- Design digital tools for industry (e.g. cloud systems, simulation-based twin technologies, data driven approaches) to enhance efficiency and product quality, as well as to increase the capability for better and faster reaction to market changes;
- Contribute to the development of advanced material modelling solutions in particular for manufacturing industry;
- Enhance data interoperability and new type of services related to the data analysis, simulations and/or visualisation techniques in each stage of the material value chain (design, processing, manufacturing, etc.) using FAIR data principles;

19 https://ec.europa.eu/eurostat/statistics-explained/index.php/Cloud_computing_-_statistics_on_the_use_by_enterprises.

- Scale up the TRL level above TRL 6

Scope: Digital tools can enable industry to control manufacturing processes and address issues more efficiently and effectively as they run and update the production plant, while improving key product and production performance indicators such as yield and throughput.

Proposals under this topic have to

- design robust digital tools integrating materials modelling and materials process development for industry,
- contribute also to the development of simulation and optimisation methods to facilitate more efficient design space exploration via experimentation, thereby reducing physical testing and improving quality
- enhance efficiency of the manufacturing process,
- improve process and product quality,
- improve decision making efficiency, quality and understanding, while at the same time maintaining low operational costs.

Interconnection between processes and other industries is also in the scope, as there is an increased integration of different domains and disciplines in complex workflows. To overcome the problem, proposals have to address interoperability by implementing available data standards like MODA, CHADA and ontologies like EMMO, as well as cooperation with the Industry Commons developments.

The proposed use cases for the developed tool should demonstrate the business case and how more sustainable solutions are achieved in the market, for example by reducing waste and/or emissions during production. A Life Cycle Assessment should be included to estimate the environmental improvement, together with a Life Cycle Cost assessment to demonstrate the lower operational costs.

RESILIENCE-44-2021: Embedding sustainability and health data in the industrial production of future smart materials (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Creating a platform to allow researchers and producers across the value-chain to store data on the environmental impacts in a highly structured, open source, and standardised way. It should build a key part of the infrastructure for managing future smart materials. The platform will be discussed / co-created with potential stakeholders to jointly shape its development.

- Taking into account the whole life cycle of substances, materials and products, including their reuse and recycling, building on the ongoing work on the product environmental footprint.

Scope: As part of the European Data Strategy, develop a common open data platform facilitate sharing, access and re-use of all information on safety, recyclability and environmental impact of materials.

- Develop a new tool for making all relevant data easily and readily accessible for the assessment and decision-making processes in appropriate formats to ensure interoperability.
- Facilitate extracting, analysing and re-using of the data with modern data processing technologies e.g. Artificial Intelligence;
- Provide innovative trainings and manuals for the use of the database and its documentation;
- Develop a business model for the maintenance of the database demonstrating its sustainability beyond the funding period.

Proposals submitted under this topic should include actions designed to facilitate cooperation with other projects; to enhance user involvement; and to ensure the accessibility and reusability of data produced in the course of the project by agreeing on metadata for the description of materials databases.

RESILIENCE-45-2021: Sustainable Industry Commons (RIA)

Expected Outcomes: Data has an enormous economic impact and yet, only a small share of industrial data is retained and used for value creation. European industry needs solutions to mitigate the barriers for industrial data reusability and facilitate the unlocking of value from data, which will make a significant difference to the performance and competitiveness of European industry. At the same time, the efforts to make European industry more competive and innovative need to be achieved without compromising the future of forthcoming generations, therefore it is also important to provide European industry with tools that aid them in improving their sustainability.

Projects are expected to contribute to the following outcomes:

- Develop tools to support industry in sustainable production and consumption of goods, which assist to improve the overall sustainability performance and contribute to the development of more sustainable solutions by embedding circular economy strategies;
- Develop ontology based data documentation for the application domain to facilitate interconnection by data exchange between designers, manufacturers, users and collectors of used/waste products, applying FAIR data principles;

- Reinforce European industry capacities and adapt to the new trends in the areas of sustainability and digitalization, and contribute to the development and/or creation of standards;
- Increase competences for data handling among the potential data users (e.g. by providing trainings);
- Advance the TRL by a minimum of two levels by the end of the project.

Scope: To develop tools for industry to enhance efficiency and contributing to less waste and emissions while improving material/product/process quality all along the lifecycle of a product/service system. The proposals should have a holistic approach, with a minimum of three demonstrators/use-cases, covering the entire material/product/process life cycle and proving the interoperability of data across the life cycle stages across industry domains. The developed tools have to be compliant with existing standards, and the proposals should contribute to development and/or creation of new ones.

The developed tools have to address circular economy strategies (as for example improvement of durability, reusability, recyclability, recycled content, product reparability, etc.) in order to guide companies to the development of their sustainability agendas with an effective and user-friendly interface. Improvement of the overall environmental performance should be demonstrated applying Life Cycle Assessment.

The developed tools have to be semantically interoperable and associated application domain ontologies and data format have to be built upon the emerging developments of the Industry Commons projects of H2020. Actions designed to facilitate cooperation with other projects, to enhance user involvement and to ensure the accessibility and reusability of data produced in the course of the project should be addressed.

Proposals are expected to bring the core technology from TRL 4 up to TRL 6 (or more) at the end of the project.

RESILIENCE-46-2022: Advanced materials modelling and characterization (RIA)

Expected Outcomes: The future of European industrial manufacturing requires further advances in characterisation methods and computational modelling, in order to lead the way to the reliable design of new and sustainable materials and processes, rapid upscaling, and effective quality control. These advances can only be achieved through the development of innovative techniques and a new generation of instrumentation, responding to industrial needs.

Projects are expected to contribute to the following outcomes:

- Develop an open repository for knowledge transfer, data sharing for integration between advanced materials characterisation (material properties/functionalities) and modelling (data and physics based, engineering modelling), allowing full interoperability between data and workflows (CHADA, MODA and EMMO), with direct connection to manufacturing process;

- Enable a model-based innovation processes covering all stages from materials design to product development and life cycle assessment, with the aim, in particular, of translating industry needs into scientific problems and provide solutions;
- Increase the efficiency and effectiveness of materials and product development by reducing costs and time for product design, time-to-market and regulatory compliance, which will enable the transition to a decarbonised economy.
- Improve handling of missing data by means of artificial intelligence/machine learning methods;
- Proposals should include a business case and exploitation strategy after the end of the action.

Scope:

- Proposals should develop a relevant range of characterisation methods and models to enhance the design – with clear demonstration of modelling and characterisation integration - and development stages of advanced materials and products, focusing on user cases related to low carbon and clean industry applications.
- Coordinates efforts towards data documentation, exchange procedures and ontologies that can aid the traceability, integrity and interoperability of data in line with Industry Commons and FAIR data principles;
- Seek the involvement of standardisation bodies for the development of standards, test guidance or guidance documents;
- Focus on the combination of theory with large-scale computational screening (e.g. Artificial Intelligence or Machine Learning);
- Facilitate the re-use of existing research results on modelling and characterisation, as well as the uptake of new project results.

RESILIENCE-47-2022: Climate Neutral and Circular Innovative Materials Technologies Open Innovation Test Beds (IA)

Expected Outcomes: Climate Neutral and Circular Innovative Materials Technologies are essential in enabling the transition towards a European decarbonised economy. They can contribute to a stronger circular economy, a cleaner Industry, a more sustainable growth and reduction of greenhouse gas emissions, which is fully in line with the Green Deal Strategy. To maintain its competititve advantage in clean Materials technologies the EU needs to increase significantly the large-scale deployment and demonstration of new technologies across sectors and across the single market, building new innovative value chains. Climate Neutral and Circular Innovative Materials Technologies Open Innovation Test Beds (OITBs) will support companies, especially SMEs, to become world leaders in clean products and technologies and projects are expected to contribute to the following outcomes:

- Increase significantly the large-scale deployment and demonstration of Climate Neutral and Circular Innovative Materials Technologies across sectors and the single market, as well as to build and maintain new innovative value chains;

- Reduce the technological risk of innovative materials and products, thus attracting more investors, and cut the time to market.

- Support companies, especially SMEs, to become world leaders in clean products and technologies by setting up a new generation of Open Innovation test Beds focused on the creation of Business Opportunities and Sustainability;

- Translation of industrial needs into scientific problems and concrete solutions, increased awareness and uptake by industry, and effective access of relevant stakeholders to know-how and advanced tools/infrastructure;

<u>Scope</u>: The following specific activities should be considered:

- Establish Open Innovation Test Beds (OITB) by upgrading existing or developing new materials facilities and pilot lines, and made available services for the design, development, testing, regulatory and environmental assessment and upscaling to industry and interested parties, specially SMEs;

- Specific focus will be given to the sustainability of the ecosystem by designing new funding instruments that would complement the already existing ones and provide further support for industrial uptake of climate neutral and circular innovative materials technologies in key strategic value chains;.

- Proposals should include actions designed to facilitate cooperation with other projects, to enhance user involvement and to reuse other projects results;

- Open access at fair conditions and cost as well as outreach and dissemination across Europe, based on a distinct methodology;

- Demonstrate measurable reduction of costs for product design, time-to-market and regulatory compliance by means of faster and cheaper evaluation of production process deviations. Relevant indicators and metrics, with baseline values, should be clearly stated in the proposal;

In order to avoid duplication, the work will be aligned with the third pillar on Open Innovation that will essentially focus on scaling up breakthrough and market-creating innovation by establishing a European Innovation Council, support the enhancement of European ecosystems of innovation and continued support to the European Institute of Innovation and Technology (EIT) OITB for: Clean hydrogen Technologies; Fuel cells and other alternative fuels; Carbon capture, storage and utilisation.

Section: Improving the resilience and preparedness of EU businesses, especially SMEs and Startups

[<u>Expected impacts addressed</u>: #16 (industrial leadership and autonomy), #20 (human-centred)

<u>Objective</u>: Improve the resilience to shocks of EU businesses, especially SMEs and Startups, by design rather than in the aftermath of crises, manage value and supply chain disruptions; support agile business models operation and cooperation; and leverage new opportunities in key ecosystems, including strategic digital technologies.

<u>Current status</u>: The current Covid-19 health crisis has demonstrated that safeguarding the resilience of sectors/economic activities which are relevant for strategic autonomy[1] and their capacity to continue to meet the needs of EU citizens calls for investments focused on strategic value and supply chains and large-scale development of innovative technologies, such as 5G, and production capacity in order to strengthen the resilience of the European economy.

<u>Targets/achievements sought</u>:

Better preparation through horizon scanning, and business intelligence, including through actions that support having a clear picture of the potential of EU industry to support the response to emerging global threats. Business intelligence that generates the required data on the knowledge capacity, R&D&I, IP and expertise in EU industry.

Rapid response capabilities, including through innovative and flexible systems to manage value chain disruptions or support diversification of supply. Activities targeting the rapid reconversion of existing production capacities into the production of essential goods can contribute to the EU's strategic autonomy and resilience to meet future pandemics by securing long-term knowledge and technical competences that are needed for the production for these essential goods.

Support for adjusting business models, **business operation and cooperation to a rapidly changing economic environment**, including tools to manage disruptions in value and supply chains, and systems to deal with disappearing suppliers and clients and the need to readapt.

Accelerate the deep transformation to reconcile sustainability and resilience, by supporting new business models, promoting startups and SMEs in critical ecosystems, including strategic digital technologies and new space, and sustain knowledge-intensive companies/ecosystems.

Bring back work on the twin green and digital transition to the forgotten places: The challenge is to avoid that regions of discontent (temporary) turn into regions of dismay

[1] As identified in the Industrial Strategy, COM(2020) 102, which include: strategic digital infrastructure, key enabling technologies, defence & space, critical raw materials and medical products & pharmaceuticals.

(permanent) [Rodriguez-Posé]. The scope includes industrial sites threatened to be closed down.

Leveraging Startups in Strategic Digital Technologies, to act as catalyst in fully utilising the potential of startups in developing applications, and technology solutions contributing to the competitive edge and digital sovereignty of the EU ICT industry in strategic technology areas and value chains. The startup communities will contribute to developing applications that foster climate-neutral, circular and clean industry, user-centric innovative technology development, encouraging inclusiveness, and incorporating European social and ethical values.

Means/Links: Strong links with activities under Pillar III (European Innovation Ecosystems and European Innovation Council).]

Proposals are invited against the following topic(s):

RESILIENCE-48-2021: Connecting and strengthening Startup Ecosystems, Innovation Radar and venture building in Strategic Digital Technologies (CSA)

Expected Outcomes: Projects are expected to contribute to at least one of the following outcomes:

- Connecting and strengthening communities of startup ecosystems in strategic digital technologies, notably AI, Advanced Computing, Cybersecurity, Next Generation Internet including Blockchain and Fintech by increasing the participation of startups in destinations of Cluster 4.
- A scaling up of capabilities in matching EU-funded technology solutions developed by highly innovative digital startups with access to finance and growth opportunities including, but not limited to, other European funding instruments (such as the Digital Europe Programme), innovation procurement and corporate innovation ventures.
- Contribute to the scaling up of innovative startups in areas of Horizon Europe digital priorities.

Scope: This Topic has a key focus on ensuring the active integration and networking of digital startup ecosystems into the Research and Innovation activities of Cluster 4, building on the Startup Europe initiative of Horizon 2020.

The action will also use intelligence from the Innovation Radar platform[20] to: facilitate the building of new ventures based on high-potential Cluster 4 innovations; and, upscale HE-funded startups by matching them with access to finance and further growth opportunities (including in the Digital Europe Programme, innovation procurement and corporate

[20] https://www.innoradar.eu/

innovation ventures). Specific support will be devoted to providing tech due diligence services[21] for spinoffs, startups and scale-ups in order to improve their access to finance.

The focus will be on Artificial Intelligence and Robotics, Advanced Computing, Cybersecurity, Next Generation Internet (including Blockchain) and FinTech.

The cross-cutting action will act as a catalyst to fulfil the potential of startups, in particular those who have secured H2020 or HE funding, in delivering market-ready applications and technology solutions that can contribute to the competitiveness and strategic autonomy of the EU's ICT industry in key technology areas and value chains. It is foreseen that the targeted startup communities will contribute to developing applications that foster climate-neutrality, the circular economy, clean industry and user-centric technology development, while also encouraging inclusiveness, and incorporating European social and ethical values.

RESILIENCE-49-2022: Leveraging standardisation in Strategic Digital Technologies (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Connecting European stakeholders ecosystems, including of SMEs, with European and International standardisation bodies and other relevant actors. Identification of ICT standardisation areas which need European intervention and proposal of actions to address them;

- Engagement of required stakeholders and experts to ensure lasting impact;
- Increase the influence or Europe into international ICT standardisation, ensuring promotion of European requirements, values and interests;
- Set-up of a facility to support participation of European specialists in international ICT SDOs and technical bodies.
- Increase the participation of European specialists in international ICT Standardisation activities to support European values and interests, including in leadership positions.
- Getting working items at the right time into the right technical bodies in international SDOs, fora and consortia.
- Synergies with other similar initiatives or European players including from EU (and national) funded R&I projects
- Common positions of European stakeholders in international ICT standardisation.
- Increase awareness and education on ICT standardisation

Scope: This action will involve and empower European stakeholders participating at the development of open technical specifications and standards with the aim to representing

[21] As foreseen in the 'Access to Finance' chapter of the European Commission's SME strategy (published 10.03.2020).

European values and ethics, strengthen the take-up, scalability cross-border and cross-sector interoperability of their technological solutions, as well as, decreasing the costs of technical due diligence to the public and private procurers.

The aim is to reinforce the presence of EU and associated states experts in the international ICT standardisation scene, by setting up a standardisation observatory and a facility supporting the participation of key European specialists (especially from SMEs and Academia) in key international and global Standard Developing Organisations.

Key tasks to be carried out are:

- Mapping of the relevant activities in international ICT standardisation, including identification of sectors where additional presence of EU experts may be needed. When relevant hosting standardisation meetings and workshops in Europe.
- Setting up of a management facility to support participation and leadership (e.g. chairing of technical committees) of key European specialists (incl. from SMEs and academia) in those organisations and technical bodies identified. The aim should be to achieve critical mass from industry, including SMEs and Startups, and academia for emerging standardisation activities.
- Liaise with relevant on-going developments in EU and national funded R&I projects, in particular with projects having identified standardisation output or with potential relevant results, including as well other coordination and support actions, and relevant PPPs.
- The consortium will define the process for an open call allowing the funding of the key European specialists to participate in international ICT standardisation activities to fulfil the scope of the call. The consortium will also define the process for an open call that will lead to a selection of an additional pool of specialist experts that may be needed to evaluate the applications for funding specialists to fulfil the scope of the proposal. In addition ad-hoc selection processes may be required. Financial support for these specialists will be typically in the order of EUR 1.000 – 10.000 per action by third party.
- Promotion of the relevance and benefits of ICT standardisation. The proposal will also include actions, including development of tools and materials, to promote education on ICT standardisation.
- The proposal should take into account the previous activities carried out on the observatory and facilities for funding experts within the topic ICT-40-2017 implemented by the StandICT.eu project and under ICT-45-2020 implemented under StandICT.eu2023 project under (see http://www.standict.eu).

RESILIENCE-50-2021: Boosting economic recovery and strategic autonomy in Strategic Digital Technologies through pre-commercial procurement (PCP action)

Expected Outcomes Projects are expected to contribute to the following outcomes:

- Leveraging PCP to fuel economic recovery in a sustainable way, increase Europe's preparedness and resilience to crisis situations and strengthen EU strategic autonomy in strategic digital technologies.
- Advancing public sector modernization by capitalising on the transformational power of strategic digital technologies to bring radical improvements to the quality and efficiency of public services.
- Leveraging PCP to drive innovation and increase resilience in the supply chain by opening up opportunities for innovative digitised companies, in particular SMEs and Startups, to access the public procurement market and scale up their business
- Increased opportunities for wide market uptake and economies of scale for the supply side through increased demand for innovative green solutions, wide publication of results and where relevant contribution to standardisation, regulation or certification.

Scope: This topic addresses Europe's Achilles heel on the road towards economic recovery, the lack and fragmentation of public demand for innovative solutions[22]. While it is well known that public sector modernisation and economic growth depend heavily on the use of ICTs, European investments on innovation procurement in ICTs are still lagging 50% behind other leading global economies[23]. Europe's startups and SMEs are indispensable in delivering the required innovations. As past experience shows that pre-commercial procurement opens up the procurement market for startups and boosts their cross-border growth, Europe's Startup community has requested the EC and Member States to increase investments in PCP[24].

By closing the gap between supply and demand in a way that reinforces EU strategic autonomy, PCPs can make a key contribution to economic recovery and growth[25]. Through forward looking procurement of R&D, PCP can also increase the resilience and preparedness of the public sector to tackle the climate challenge and crisis situations like pandemics[26].

[22] 'A key factor in engineering economic turnaround will be the adoption of innovations... Europe's focus should be primarily on ICT-using sectors because ICT-producing sectors alone are unlikely to provide significant productivity increases to the economy... The EU and governments can do this through their own procurement.', Report for EU Parliament, Oct 2018

[23] SMART 2016/0040 that benchmarked European investments and policy frameworks for innovation procurement (study results to be presented and published in September-October 2020)

[24] Startup Europe Summit recommendations, March 2019

[25] Impacts of EU funded PCPs show 20%-30% efficiency and quality improvements in public services, doubling of the amount of public procurements awarded to startups/SMEs, a factor 20 increase in the amount of cross-border contract award to startups/SMEs and a factor 4 additional financing secured by startups/SMEs. The use of place of performance and IPR/commercialization conditions that fuel commercialization in Europe in PCPs also contributes to EU strategic autonomy.

[26] PCP showcases: see impacts of PCPs that commercialised greener solutions and robots that reduced COVID-19 infections

This topic therefore supports public buyers to collectively implement PCPs to drive innovation from the demand side and open up wider commercialisation opportunities for companies in Europe to take international leadership in new markets for strategic digital technologies. The aim is to leverage PCP to encourage the development and to provide a first customer reference for the piloting and validation of breakthrough innovations.

Addressing public sector transformation typically requires combinations of different cross-cutting technologies and cooperation across public sector actors. The topic is thus open to proposals from all domains of public sector activity to address public sector challenges that require innovative ICT based solutions. It is open both to proposals requiring improvements mainly based on one specific ICT technology, and those requiring end-to-end solutions that need cross-cutting combinations of different ICT technologies. The work will complement PCP Actions foreseen under other topics.

Proposals shall demonstrate sustainability of the action beyond the life of the project. The proposal shall demonstrate how the project is anchored in a clear strategy to fuel economic recovery in a sustainable way through stronger early adoption of innovative green solutions. Activities covered shall include cooperation with policy makers to reinforce the national policy frameworks and mobilise substantial additional national budgets for PCP and innovation procurement in general beyond the scope of the project.

RESILIENCE-51-2022: Boosting economic recovery and strategic autonomy in Strategic Digital Technologies through pre-commercial procurement (PCP action)

<u>Expected Outcomes</u> Projects are expected to contribute to the following outcomes:

- Leveraging PCP to fuel economic recovery in a sustainable way, increase Europe’s preparedness and resilience to crisis situations and strengthen EU strategic autonomy in strategic digital technologies.
- Advancing public sector modernization by capitalising on the transformational power of strategic digital technologies to bring radical improvements to the quality and efficiency of public services.
- Leverage PCP to drive innovation and increase resilience in the supply chain by opening up opportunities for innovative digitized companies, in particular SMEs and Startups, to access the public procurement market and scale up their business
- Increased opportunities for wide market uptake and economies of scale for the supply side through increased demand for innovative solutions, wide publication of results and where relevant contribution to standardization, regulation or certification.

Scope: This topic addresses Europe's Achilles heel on the road towards economic recovery, the lack and fragmentation of public demand for innovative solutions[27]. While it is well known that public sector modernisation and economic growth depend heavily on the use of ICTs, European investments on innovation procurement in ICTs are still lagging 50% behind other leading global economies[28]. Europe's startups and SMEs are indispensable in delivering the required innovations. As past experience shows that pre-commercial procurement opens up the procurement market for startups and boosts their cross-border growth, Europe's Startup community has requested the EC and Member States to increase investments in PCP[29].

By closing the gap between supply and demand in a way that reinforces EU strategic autonomy, PCPs can make a key contribution to economic recovery and growth[30]. Through, forward looking procurement of R&D, PCP can also increase the resilience and preparedness of the public sector to tackle the climate challenge and crisis situations like pandemics[31].

This topic therefore supports public buyers to collectively implement PCPs to drive innovation from the demand side and open up wider commercialisation opportunities for companies in Europe to take international leadership in new markets for strategic digital technologies. The aim is to leverage PCP to encourage the development and to provide a first customer reference for the piloting and validation of breakthrough innovations.

Addressing public sector transformation typically requires combinations of different cross-cutting technologies and cooperation across public sector actors. The topic is thus open to proposals from all domains of public sector activity to address public sector challenges that require innovative ICT based solutions. It is open both to proposals requiring improvements mainly based on one specific ICT technology, and those requiring end-to-end solutions that need cross-cutting combinations of different ICT technologies. The work will complement PCP Actions foreseen under other topics.

Proposals shall demonstrate sustainability of the action beyond the life of the project. The proposal shall demonstrate how the project is anchored in a clear strategy to fuel economic recovery in a sustainable way through stronger early adoption of innovative solutions. Activities covered shall include cooperation with policy makers to reinforce the national policy frameworks and mobilise substantial additional national budgets for PCP and innovation procurement in general beyond the scope of the project.

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[27] 'A key factor in engineering economic turnaround will be the adoption of innovations... Europe's focus should be primarily on ICT-using sectors because ICT-producing sectors alone are unlikely to provide significant productivity increases to the economy... The EU and governments can do this through their own procurement.', Report for EU Parliament, Oct 2018

[28] SMART 2016/0040 that benchmarked European investments and policy frameworks for innovation procurement (study results to be presented and published in September-October 2020)

[29] Startup Europe Summit recommendations, March 2019

[30] Impacts of EU funded PCPs show 20%-30% efficiency and quality improvements in public services, doubling of the amount of public procurements awarded to startups/SMEs, a factor 20 increase in the amount of cross-border contract award to startups/SMEs and a factor 4 additional financing secured by startups/SMEs. The use of place of performance and IPR/commercialization conditions that fuel commercialization in Europe in PCPs also contributes to EU strategic autonomy.

[31] PCP showcases: see impacts of PCPs that commercialised greener solutions and robots that reduced COVID-19 infections

RESILIENCE-52-2021: Re-opening of closed industrial sites

Expected Outcomes: Projects are expected to mobilise funding to re-open closed industrial sites, in a way that:

- covers the Green Deal, Digital and Circular Economy priorities;
- contributes to Industrial Alliances, partnerships, IPCEIs;
- mobilises new supply chains across the EU, making the most out of local assets and capabilities;
- is anchored in the smart specialisation strategy, providing specific opportunities to start-ups and scale-up enterprises;
- includes on site and on the job vocational training;
- protects cultural heritage and creates new aesthetics for industrial sites; and
- teams up with successful and innovative industrial sites in other Member States to share best practice.

Scope: tbc

RESILIENCE-53-2021: 'Innovate to transform' support for SME's sustainability transition (CSA)

Expected Outcomes : Projects are expected to contribute to the following outcomes:

- Increased resilience of SMEs receiving advisory support for their sustainability transition, including increased innovation capacity.
- Leveraging synergies between existing EU networks and SME support initatives.

Scope: The Commission proposed to support SMEs in the triple transition as part the SME Strategy. As an example, the Enterprise Europe Network will set up dedicated sustainability services with sustainability advisors to help to assess the needs of SMEs and provide advice on environmental and social sustainability aspects - including on investment in more resource-efficient and circular processes and infrastructure, finding relevant commercial partners, and encouraging peer-to-peer collaboration. Organisations in EU projects and initiatives may team up and join forces as project partners. As such, it will also reinforce SME's innovation support ecosystems and create leverage amongst existing EU networks and SME support initiatives, such as Digital Innovation Hubs, Clusters, Start-up Europe, etc.

The action targets both traditional and innovative SMEs, with a clear objective to transform their business models by applying innovative solutions.

This action will consist in:

A. Advisory services

Dedicated innovation and capacity building support will be provided to SMEs, to assess their ability to transform their business models and increase their resilience. This could consist of an assessment of SMEs' innovation and sustainability practices, elaboration of recommendations, including signposting to local/national/EU sustainability service providers, and provision of coaching with the support of international sustainability experts.

This action should also include the set-up of a community, in which best practices should be exchanged and SMEs could benefit from dedicated peer-learning activities in order to learn from leaders (SMEs or larger corporates) of their own sector. . Incentives for leaders to share their best practices with peers should be identified in the context of EU support to industrial ecosystems.

Eligible costs of the actions include personnel costs for advisors, the development, maintenance and training for using Innovation management tools geared towards sustainability, the set-up of an international database of sustainability experts and the creation and animation of a community of best practices for SMEs.

B. Financial support in the form of 'Third party financing' or vouchers.

As a result of the advisory services and initial assessments, SMEs may need financial support to finance a feasibility study, set up a small pilot testing, procure specialised consultancy services, adapt their business processes, increase resilience, introduce new IT solutions etc. This financial support may be provided in the form of vouchers or 'Third party financing'-calls for SMEs, and channelled through the selected organisations above.

RESILIENCE-54-2021: SMEs' Greenovate Associate (CSA)

Expected Outcomes : Projects are expected to contribute to the following outcomes:

- Turning creative business ideas into concrete innovations in supporting of sustainability
- Increased resilience of SMEs by acquiring new skills and knowledge supporting their sustainability transition.
- Increased innovation capacity of SMEs, including increased participation in R&I projects and staff employed in R&I.

Scope: Many SMEs declare they lack expertise and skills to successfully innovate and change their business models and practices to become more sustainable and resilient. Individual SMEs are at a disadvantage to recruit specialised knowledge as they often lack Europe-wide networking connections and do not tend to have established brands as large enterprises.

Enterprise-led mobility programmes, supporting enterprises in recruiting expertise, show a high level of satisfaction and return on investment. This enterprise-led approach is to be further developed and tested, using the first experiences of the ‘Innovation Associate’ programme which has been piloted with success under the Horizon 2020 Work Programme “Innovation in SMEs”.

This action complements Marie Skłodowska Curie actions (MSCA) which focus on developing research careers, by providing additional work opportunities for experienced researchers in innovating SMEs and focusses on access to skills for SMEs in the context of their efforts to adopt new sustainability products, services or business plans, with clear links to the Green Deal.

The aim of this innovation capacity building action is to provide a grant at European level to visionary[32] SMEs that can demonstrate that the skills required for a particular innovation idea are not within reach for them at national level (for example because the required skills are not available or not affordable for SMEs). SMEs are supported to employ a highly skilled experienced researcher (referred to as an 'innovation associate') for a continuous period of one year. The innovation associate's task will be to explore, during the course of his/her contract, the potential of their innovative idea and turn it into an innovation project, supporting the SME’s transition to sustainability.

The evaluation of proposals will focus on the demonstrated benefits of recruiting transnationally i.e. the impact for the SME to get access to skills not available on the national labour market; the excellence and impact of the innovative idea, its contribution to the sustainability transition of the SME, as well as the coherence and effectiveness of the recruitment plan, which should offer the same opportunities for male/female candidates.

SMEs that will receive a grant will be obliged to advertise their vacancy on EURAXESS, unless a contract with an innovation associate has already been signed in line with the provisions above. They are also encouraged to publish the vacancy notice on any other relevant platform or media, with a clear indication that the grant was awarded.

The innovation associate's tasks shall be to identify the potential of the company's innovation idea with the objective and turn it into an innovation project and - hopefully - a continuation of the employment of the innovation associate. During the period covered by the grant, the Innovation Associate must work exclusively on the project described in the grant agreement.

In line with the orientation of the action and with the aim to accelerate the integration of the associate in the company's staff, the following costs shall be eligible for reimbursement under the grant:

- Personnel costs of the associate.

[32] Vision: 'A statement about what the organisation wants to achieve in terms of innovation. The vision should set a direction and a challenge that can inspire persons to commit and work towards, be sufficiently ambitious and not constrained by the organisation's current abilities, provide a target against which progress can be measured.' See Innovation management standard CEN/TS 16555-1 (July 2013)

- Relocation costs of the associate, which may include removal cost, travel cost of the associate and his/her immediate family (if applicable) to the new place of employment, visa cost (if applicable), translation cost of certificates (if applicable), a temporary transition allowance to cover extra costs upon arrival in the place of employment, cost for the relocation in the country of origin after the project, as well as other clearly justified expenditure directly related to relocation.

- Travel and subsistence costs of the associate to the core training programme and travel and subsistence for tailored training (as described in the personal development plan). Travel cost and subsistence for the supervisor may be eligible for up to two training sessions.

- Travel and subsistence cost for the innovation associate and the supervisor in the enterprise to one kick-off meeting in Brussels (one day), organised by the European Commission[33].

Personnel cost may include allowances that are in line with the beneficiary's standard practices (for example child education or housing allowances).

Other costs like recruitment costs, equipment costs or travel costs to action-specific workshops by the supervisor in the enterprise are covered by the flat rate indirect cost.

Any cost not directly related to the employment and training of the innovation associate - for example cost of research, dissemination or promotion activities and other cost relating to the actual implementation of the innovation idea/project - are not eligible under this call.

This topic will take the form of lump sums as defined in Commission Decision C(2017)7151 of 27 October 2017. Details of the lump sum funding pilot scheme are published on the Funding & Tenders Portal together with the specific Model Grant Agreement for Lump Sums applicable.

The following criteria will have to be met by the associate: i) PhD holder (or equivalent), ii) an expertise in line with the job requirements as outlined in the vacancy notice; iii) compliance with transnational mobility criteria as defined in the mobility rule of the Marie Skłodowska Curie Actions (MSCA)[34].

SMEs can only receive one grant for the whole duration of this topic.

The preferred start date of the innovation associates' employment is in September of the year following the call opening in order to align the timing of the action with the academic year. The execution of the action will start on the starting date of the associates' employment (exact date to be determined during the grant preparation phase).

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33 The organisation of such a meeting is subject to confirmation by the European Commission at a later stage.

34 Reference to the MSCA mobility rule will be provided at call opening.

The innovation associates are expected to be offered employment contracts or equivalent by the hosting SMEs. In return, the innovation associates must commit to a full-time position, for the full duration of the grant.

DESTINATION 3 – World leading data and computing technologies

Actions under these Orientations for topics will support Europe's position in the global data economy. The objective is to maximise the social and economic benefits from the wider and more effective use of data as well as to reinforce Europe's ability to manage urgent societal challenges (e.g. data for crisis management).

As data becomes the new fuel of the economy and a key asset to address our societal challenges, the EU cannot afford to have the data of its businesses, public sector and citizens stored and exploited largely outside its borders. This is affecting not only our economic performance but also our security, safety and sovereignty.

As announed in the EU data strategy, the EU has indeed the means to become the world most secure and trustful data hub. For that to happen, an important investment effort in the development of data technologies is needed to support the use, interoperability and analytical exploitation of EU-wide common data spaces targetting essential economic sectors and areas of public interest. The COVID-19 crisis showed how essential it is to master data technolgies to address our societal challenges and to incentivize public and private stakeholders to trustfully share data.

The investments should cover both the necessary data infrastructure, service platforms to enable virtualisation, adaptation of data and meta data (including standards for data sharing) as well as common analytics tools. Investment in this Destination will reinforce the cloud and data infrastructure supply industry and make data accessible to businesses and governments across the EU in a way that meets European values and requirements. It will focus on energy-efficient and trustworthy data infrastructures and related services. The EU also needs to swiftly develop generic cloud to edge to IoT technologies, methods, tools and platforms for the support of future hyper-distributed applications in any business/societal sector.

Europe's lead in the data economy also increasingly depends on its capability to autonomously develop key High Performance Computing (HPC) technologies, provide access to world-class supercomputing and data infrastructures, maintain global leadership in HPC applications, and foster the acquisition of HPC skills. This is the purpose of the activities funded by the EuroHPC Joint Undertaking.

Proposals for topics under this Destination should set out a credible pathway to contributing to the following expected impact:

- **Globally attractive, secure and dynamic data-agile economy**, by developing and enabling the uptake of the next-generation computing and data technologies and infrastructures (including space infrastructure and data), enabling the European single market for data with the corresponding data spaces and a trustworthy artificial intelligence ecosystem.

This Destination is structured into the following sections:

- Data sharing in the common European data space
- Strengthening Europe's data analytics capacity
- High-end computing for exascale performance and beyond
- From Cloud to Edge to IoT for European Data

The following call(s) in this Work Programme contribute to this Destination:

The Destination structure and the allocation of topics to calls and year will be decided at a later stage.

Section: Data sharing in the common European data space

[Expected impacts addressed: #15 (Green), #21 (Data), #18 (Digital and emerging enabling technology sovereignty), #20 (Human-centred)

Objective: In line with the FAIR principles (Findable, Accessible, Interoperable and Reusable) make the EU the most successful area in the world in terms of data sharing and data re-use while respecting the legal framework relating to security and privacy and fostering collaboration and building on existing initiatives.

Current status: Data sharing and data interoperability are still at their infancy, few data markets for sharing industrial data already exists. In a recent survey, more than 40% of the SMEs interviewed claim they had problems in acquiring data from other companies. The diffusion of platforms for data sharing and the availability of interoperable datasets is one of the key success factors which may help to drive the European data economy and industrial transformation.

Achievements sought / targets:

The focus of this section is on generic methods, technologies, tools and infrastructures for data pooling, manipulation, refining, sharing and re-use, applicable in any sector and for any data types, equally for data repositories and data streams, centrally or at the edge:

- improve the efficiency of and the use of trustworthy digital technologies to address the requirements of citizens, companies and administrations on privacy and commercial and administrative confidentiality as well as responsible, fair and environmentally friendly data operations.
- improve the availability of digital technologies, solutions and interoperable frameworks for data markets and data economy (e.g. industrial, administrative and societal/cultural data platforms), allowing for data assets to be discoverable, efficiently and fairly priced and shared/traded in a secured and compliant way. Promote the development of a European industrial ecosystem of the data economy capable of ensuring digital autonomy.
- develop new secure and scalable data management tools improving the usability of data in different contexts, covering data provenance, data quality management (such as data cleaning, validation, enrichment, co-creation, identification of bias and correlations), improving data interoperability, metadata management (automated ways of labelling and describing data, data linkage), and ensuring data security and integrity.

Means/links: *Links to other EU programmes:* The R&I actions under this section will complement the funding for deployment under the Digital Europe programme. The actions shall be coordinated and collaborate with national and regional programs and actions on data spaces, and with relevant European data sharing schemes, such as the European Open Science Cloud (EOSC).]

Proposals are invited against the following topic(s):

DATA-01-2021: Technologies and solutions for compliance, privacy preservation, green and responsible data operations (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- improve the efficiency and the use of trustworthy digital technologies to address the requirements of citizens, companies and administrations on privacy and commercial and administrative confidentiality as well as responsible, fair and environmentally friendly data operations.

Scope: Digital technologies, methods and architectures for safe, trustworthy, compliant, fair and environmentally sustainable collection, storage, processing, querying, analytics and delivery of data. The technologies shall facilitate sharing and manipulation of data in compliance with prevailing and emerging legislation (e.g. GDPR) for data processors and data subjects/rightholders and other stakeholders. The technologies shall in particular enable safe data handling, sharing and re-use in the context of common European data spaces in various situations and application areas. The scope also includes technologies and solutions that enable environmentally sustainable data operations (e.g. by optimising/minimising/de-centralising processing, transfer and storage of data and avoiding unnecessary data manipulations), and technologies and solutions for ensuring human, fair and ethically sound collection, processing and manipulation of data, in line with the principles of responsible/trustworthy AI.

The actions under this topic shall liaise with relevant actions in the Digital Europe programme via the Data Spaces Support Centre.

DATA-02-2021: Technologies and solutions for data trading, monetizing, exchange and interoperability (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- improve the digital technologies, solutions and interoperable frameworks for data markets and data economy (e.g. industrial, administrative and societal/cultural data platforms/data spaces), allowing for data assets to be discoverable, efficiently and fairly priced and shared/traded in a secured and compliant way. Promote the development of a European industrial ecosystem of the data economy capable of ensuring digital autonomy.

Scope: The focus is on technologies, solutions and frameworks that facilitate collection, sharing, storing, processing, trading and re-using data in compliance with the legal framework governing the data to be handled and satisfying the needs, expectations and rights of the data providers, brokers, users and data subjects. Practical and scalable solutions for handling large amounts of transactions are necessary (e.g. smart/automated contracting, data rights management, tracking of subsequent data use). Special attention should be paid to fostering approaches that ensure data and metadata interoperability, including the application of appropriate standards, reference architectures, common ontologies/vocabularies/data models allowing smooth data sharing (also across sectors). The emphasis is on the development and demonstration of practical and mature end-to-end systems, building on the results of work on data platforms (topic H2020-ICT-13-2018-2019), privacy-preserving technologies and computing technologies under Horizon 2020 and this programme.

Actions are expected to build and support data spaces of realistic scope and size, deployable in real-world applications in various application areas. In particular, the actions are expected to support the deployment of the Common European Data Spaces under the Digital Europe programme (notably via the Data Spaces Support Centre): the technologies and tools are developed under Horizon Europe actions and the deployment and operations are supported under Digital Europe actions. The actions are expected to build on and create links with other European data sharing schemes (e.g. EOSC, META-SHARE, ELRC-SHARE, European Data Portal), as appropriate. The actions shall contribute to European technologic autonomy in data sharing.

DATA-03-2022: Technologies for data management (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- develop new secure data management tools improving the usability of data in different contexts, covering data provenance, data quality management (such as data cleaning, validation, enrichment, co-creation, identification of bias and correlations), improving data interoperability, metadata management (automated ways of labelling and describing data, data linkage), and ensuring data security and integrity.

Scope: The actions under this topic are expected to provide practical, robust and scalable tools to improve the interoperability, quality, integrity of data and metadata, in the context of other topics of the section “Data sharing in the common European data space”. The data management tools and systems shall support a holistic approach of the data life cycle and comply with the FAIR principles (Findable, Accessible, Interoperable, Reusable) for data and metadata management. Where appropriate, data management tools and systems shall enable or support the creation and maintenance of common ontologies, vocabularies and data models and/or structured, standardised and automated authoring, co-creation, curation, annotation and labelling of data, in view of different later uses (especially AI) made of the data. The tools shall be adaptable to different user needs and support and encourage new business models and (where appropriate) citizen involvement. This shall be demonstrated by use cases.

Section: Strengthening Europe's data analytics capacity

[Expected impacts addressed: #21 (Data), #18 (Digital and emerging enabling technology sovereignty)

Objective: make the EU fully autonomous in processing, combining, modelling and analysing such large amounts of data for efficiently predicting future courses of action with high accuracy and advanced decision-making strategies. Reduce the use of natural resources and avoid waste by making it possible to replace classical experiments by data-driven digital models. The technological achievements under this section will support the development of responsible and useful AI solutions, built on high-quality and high-value data.

Current status: Recent developments in sensor networks, cyber-physical systems, and the ubiquity of the Internet of Things (IoT) and Artificial Intellignece (AI) have increased the collection of data (including health care, social media, smart communities, industry, manufacturing, education, construction, agriculture, water management finance/insurance, tourism, education, and more) to an enormous scale (by 2025, 463 exabytes of data will be produced every day in the world).

Achievements sought / targets:

- develop European technologies, tools and services for data mining (searching and processing) large amounts of data or sparse/dispersed/heterogeneous data (stored centrally or in distributed systems), in particular IoT and/or industrial/business/administrative/societal/environmental data.
- design automated ways for extracting meaning and providing insights from data extremely fast and/or accurately in order to optimize decision making (ranging from crisis/emergency management to predictive maintenance).

Means/links: *Links to other EU programmes*: The R&I actions under this orientation for topics will complement the funding for deployment under the Digital Europe programme.]

Proposals are invited against the following topic(s):

DATA-04-2021: Extreme-scale data mining, aggregation and analytics technologies (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- develop European technologies, tools and services for data mining (searching and processing) large amounts of data or sparse/dispersed/heterogeneous/multilingual data (stored centrally or in distributed systems), in particular IoT and/or industrial/business/administrative/environmental/societal data.

Scope: The actions under this topic are expected to provide ground-breaking advances in the performance (speed, accuracy) and usefulness of data discovery, collection, mining, filtering and processing in view of coping with the increasing volume, speed and complexity of data and the dispersed data sources. The technologies shall be able to discover and distil meaningful and useful data and deliver it to the requesting application/user with minimal delay and in the appropriate format. In particular, the advances shall enable the development of reliable, accurate and fair AI systems where quality of data is more important than quantity. Insofar the results are intended for human use, the design of these tools must take into account the human aspects.

The actions should address the integration of relevant technologies (e.g. big data, AI, IoT, HPC, language technologies, cybersecurity, telecommunications…) as a means towards achieving the goals, and foster links to the respective research, industrial and user communities.

DATA-05-2022: Methods for exploiting extreme data for extremely precise and useful outcomes (analysis, prediction, decision support), reducing complexity and presenting insights in understandable way (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- design automated ways for extracting meaning and providing insights from data extremely fast and/or accurately in order to optimize decision making (ranging from crisis/emergency management to predictive maintenance).

Scope: The actions under this topic are expected to push the frontiers of analytics, prediction, simulation and visualisation to provide extremely precise, timely and useful results from data, to support (human or automated) decision-making, saving lives or providing great positive impact (economic, societal, environmental) compared to traditional methods of decision making. *Analytics* should be flexible, fit for the purpose and user needs, intuitive and (when necessary) provided as "Analytics-as-a-Service". *Prediction* should be extremely precise and/or span over longer time period and/or account for uncertainty factors. *Simulation* should allow precise replication and modelling of the real phenomenon or system, with minimal differences. *Visualisation* should be interactive, intuitive and allow people to understand complex phenomena by smart selection of parameters, anticipation of user needs/interest and by novel ways of combining visual and non-visual elements and/or augmented reality.

Section: High-end computing for exascale performance and beyond

[Expected impacts addressed: #15 (Green), #21 (Data), #18 (Digital and emerging enabling technology sovereignty)

Objective: Ensure digital autonomy for Europe in key high-end supercomputing technology (hardware and software) and applications, and developing the first exascale supercomputer based predominantly on European technology by 2026.

Current status: Today, Europe critically depends on foreign High Performance Computing (HPC) technologies that are essential for scientific and industrial innovation and competitiveness. By 2022 the next generation supercomputers will reach exascale performance, none of them with European technology components.

Achievements sought / targets:

- Develop advanced and competitive world-class **European low-power processor and accelerators technologies for high-end computing** and their integration in **extreme computing HPC pilots and systems** capable of reaching exascale and post-exascale performance while reducing significantly their power consumption, and covering the needs of a wide range of computing applications and emerging areas and markets;
- A complete **software middleware and programming environment for extreme computing systems** supporting advanced extreme performance applications that fully exploit the computational power and parallelism of the exascale and post-exascale supercomputers;
- Develop exascale ready **HPC applications and codes** for scientific excellence and industrial competitiveness in key areas for Europe, including new areas underpinned by AI, Big Data, etc.
- A set of large scale **advanced testbeds** demonstrating the use of HPC with other key technologies (e.g. Big Data, Cloud, AI, Cybersecurity) for key industrial applications and a set of testbeds with hybrid and modular solutions that combine HPC with novel paradigms, in particular Quantum technologies.

The achievements under this orientation for topics are necessary to enable progress in *big data analytics* and the full development of *AI solutions*.

The achievements under this section related to the development of low-power technologies concentrate on high-end computing and are complementary to the achievements of “Ultra-low power processors”.

Means/links: A Joint Undertaking (‘EuroHPC’) is the instrument to coordinate national and EU related efforts and to enable European industrial and academic stakeholders to design and implement common roadmaps in significantly research-intensive areas.

Links to other Partnerships: ‘AI, Data, and Robotics’ and ‘Key Digital Technologies’.]

Proposals are invited via the EuroHPC Joint Undertaking's work programmes.

Section: From Cloud to Edge to IoT for European Data

[Expected impacts addressed: #21 (Data), #16 (Industrial leadership and autonomy), #18 (Digital and emerging enabling technology sovereignty)

Objective: establish the European supply and value chains in cloud to edge computing and tactile internet by integrating relevant elements of computing, connectivity, IoT, AI cybersecurity. New cloud/edge technologies with enhanced performance enabled by AI will increase European autonomy in data processing required to support future hyper-distributed applications.

Current status: 80% of the processing and analysis of data takes place in data centres and centralised computing facilities, and 20% in smart connected objects; only 1 European company in 4 use cloud technologies; 75% of the European cloud market is dominated by non-EU players. Considering the pace of development in this area outside of the EU, the implementation of the activities will require R&I instruments with great flexibility, including the support of SMEs and start-ups, to nurture a European ecosystem and deliver swift results.

Achievements sought / targets:

The focus of this orientation for topics is on generic cloud to edge to IoT technologies, methods, tools and platforms for the support of future hyper-distributed applications in any business/societal sector:

- Create future European platforms (**Operating Systems) for the Edge** that enable cloud and edge computing orchestrations by bringing computation, data storage and intelligence closer to where the data is produced (sensors and devices) and by which volume, variety, and velocity should be handled efficiently. This will improve end-to-end response time, optimize the operation of cloud-to-edge-to-IoT systems and services, reduce energy consumption and improve security and privacy.

- Foster an **AI-enabled computing continuum ("cognitive cloud")** that will automatically adapt to the growing complexity and data deluge by integrating seamlessly and securely diverse computing and data environments, spanning from core cloud to edge.

- Regain European competitiveness in core Internet infrastructures and key technologies of data processing. Provide open, trusted & interoperable **data-driven services** close to the users, with the aim to reduce data processing latency, in particular for real-time applications such as autonomous driving, manufacturing, health, utilities, and farming, and avoid vendor lock-in.

Means/Links: *Links to Partnerships:* The R&I actions under this section will complement the activities of the 'Smart Networks and Services' and 'Key Digital Technologies' partnerships.

Links to other EU programmes: The R&I actions under this section will complement the deployment actions under the 'Digital Europe Programme']

Proposals are invited against the following topic(s):

DATA-06-2021: Future European platforms (Operating Systems) for the Edge: Edge Operating System and Platforms (RIA and IA)

Expected Outcomes:

- Secure Operating Systems for the Edge that enable cloud and edge computing orchestrations by bringing computation, data and intelligence closer to where the data is produced (sensors and devices) and by which volume, variety, interoperability, and velocity should be handled efficiently. This will make AI inference at the edge viable and lead to a next generation of internet-enabled automation concepts virtualizing computing and networking functions, multi-state analytics and digital twinning of underlying objects to improve end-to-end response time, and to reduce energy consumption, for applications in industry, autonomous driving, health, farming, water and energy. (RIAs)
- Platforms driven by European actors underpinning an emerging open edge ecosystem including midcaps, SMEs and start-ups that supports edge solutions which represent a modular functional spectrum of executable apps and services critical to establishing a mature European supply chain under challenging and extremely competitive market conditions. Such Edge platforms shall create value in orchestrating multi-tiered data processing with control and automation on the edge, minimizing energy footprint, stimulating multi-sided marketplaces, and fostering open standards for virtualization, interoperability and data sharing between different stakeholders of the value chain – both horizontally and vertically, thereby preventing lock-in effects for users. (IAs)

Scope: Building on its strengths in key industrial and societal applications, which in future require more power at the edge, to develop the next generation operating systems and platforms for supporting the trend from cloud to edge. Aim is to bring Europe back to being a major player in computing technologies and systems to support data services. Fostering trust among variety of actors in diverse industrial ecosystems using such operating system should be achieved by leveraging open source.

DATA-07-2021: Future European platforms (Operating Systems) for the Edge: Smart Edge Nodes (RIA)

Expected Outcomes:

Agile and secure architectures for collaborating smart node software which allows dispatching edge control and swarm intelligence and enables complex planning and control tasks between the edge and emerging mesh topologies. Mesh topologies will increase the autonomy of the nodes of the edge node infrastructure, their decisional capabilities and the knowledge/value extracted from data. The topic focuses on smart edge-connected objects, node interoperability, actionable data streams and contextual interaction and data fusion between the users and the objects. Research will contribute to the vision of a Tactile Internet making the edge more responsive including time-sensitive networking protocols, analytical model distribution, delocalized computation and new mesh architectures with seamless federation of object IDs to distributed operation of a large number of heterogeneous IoT devices and systems to achieve higher resilience, security and trust in future services. Key applications are instrumental to contribute to SDGs in sectors like farming, utilities, cities and cmmunities, logistics, etc.

Scope: Building on European values and strengths in embedded sensors and devices deployed in application key for Europe’s competitiveness, which in future require more power on device-level at the edge, to support Europe in developing and using systems of smart devices in emerging innovative applications. Aim is to reinforce Europe’s position in the market of next generation smart sensors and devices integrated in a new Internet of Things with strong capacities at the edge.

DATA-08-2022: Cognitive Cloud: AI-enabled computing continuum from Cloud to Edge (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- A new AI-enabled Cloud framework that will automatically adapt to the growing complexity and data deluge by integrating seamlessly and securely diverse computing and data environments, spanning from core cloud to edge. This framework will respond and adapt intelligently to changes in application behaviour and data variability offering automatic deployment, mobility and adaptability of services from cloud to edge. The Cognitive Cloud will interface with all the layers in the computing continuum plane and will learn through the monitoring and management of resources deployed on Cloud/Edge. Applying AI-techniques will cater for dynamic load balancing to optimise energy efficiency and maintaining balanced data traffic and high, distributed, reliable throughput from cloud to edge according to the application needs and the underlying infrastructures. Application developers will be empowered with greater control over network, computing and data infrastructures and services, and the end-user will benefit from seamless access to a continuous service environment.

Scope: Highly innovation cloud management layer making the best application of artificial intelligence techniques to optimize where data are being processed (e.g. very close to the user at the edge, or in centralised capacities in the cloud). Seamless integration of diverse computing and data environments spanning from core cloud to edge, in an AI-enabled computing continuum. Automatic adaptation to the growing complexity of requirements and the exponential increase of data driven by IoT deployment across sectors while achieving optimal use of resources and holistic security.

DATA-09-2022: Regain European competitiveness in Internet infrastructures and the provision of open, trusted & interoperable data-driven services in the core and at the edge (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- CSA – to coordinate with the evolution of NGI and investments in core Internet infrastructures and support the delivery of interdisciplinary-based new services and applications on top of the cloud-edge-IoT enabled data layer with the potential to generate vast opportunities for entire ecosystems and avoid vendor-lock in at the edge.
- CSA – to coordinate, build constituency, and analyse the needs for advanced smart IoT and edge computing nodes and systems in terms of performance, price, energy footprint, real-time capability, security and trust, needed degree of customisation, etc. – and to map them to existing or emerging solutions, as well as to identify gaps. Outcomes are expected to address the most important sectors for Europe's economy, and competitiveneess as well as an analysis of cross cutting aspects and synergies.

Scope: Two CSAs shall support the Commission and the constituency in coordinating the project portfolio and exploring and exploiting synergies between European, national and private initiatives from Cloud to edge to IoT. There is an explicit need for two CSAs as they must address the topic from two different perspectives and target groups – the supply and the demand side –, which cannot be merged in one action as consortia would become too complex and driven by conflicting commercial interests.

DATA-10-2022: Challenging emerging smart industrial internet of things and edge computing systems under real life conditions (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Improvement of emerging EU-driven smart industrial internet of things and edge computing systems to perform under real life conditions, as to mature them for adoption in key applications and sectors crucial for Europe's competitiveness and strategic autonomy.

Scope: Today 80% of the processing and analysis of data takes place in data centres and centralised computing facilities, and 20% in smart connected objects, such as cars, home appliances, medical devices, agricultural machines, or manufacturing robots, and in computing facilities close to the user. By 2025, these proportions are expected to be inverted. Building on Europe's industrial leadership in many sectors and in particular in the industrial Internet of Things, this trend offers the opportunity for European actors on the demand and supply side to gain back territory from the hyper-scalars dominating today's cloud and data processing market.

Innovation Actions are used to customise, explore the limits, test, optimise and validate emerging European smart IoT and edge computing systems under the constraints of industrial mass-market applications such as network connectivity, performance, cost, data processing latency for analytics and AI-inference at the edge, scalability, trust and security, interoperability, etc. Use cases demonstrating applications of tomorrow, which particularly profit from power and customisation at the edge, shall be addressed by taking a system-level approach from hardware of smart devices to operating systems at device and at system level, to middleware and to application software.

Instruments: IAs, cascading grants for populating the use case

DATA-11-2022: Roadmap for next generation computing and systems technologies (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Support structure for the European Computing ecosystem: networking events and vision workshops for the academic and industrial computing community, yearly updated roadmaps on computing addressing the area from a broad perspective from edge device to edge cloud to cloud to HPC, from scientific to industrial to societal and research applications, and addressing all relevant aspects such as real-time, security, etc.

Scope: To support the European Commission and the European computing constituency by providing to them annually updated roadmaps for research and innovation related to computing. This topic is overarching and building the bridge between Destinations 3 (Section "From Cloud to Edge to IoT for European Data"), Destination 4 ("Ultra Low Power Processors"), as well as the Joint Undertakings on Key Digital Technologies, Smart Networks and Services, and HPC. This effort builds on the achievements and structures established by the HIPEAC project and Think Tank of all renowned European research centres on computing "at large" and their key experts. Both the academic visions as well as the industrial perspective should be taken into account.

DESTINATION 4 – Digital and emerging technologies for competitiveness and fit for the green deal

Actions under this Destination will support Europe's strategic autonomy, and reinforce and regain European industry's leaderships across the digital supply chain. It will direct investments to activities that will ensure a robust European industrial and technology presence in all key parts of a greener digital supply chain, from low-power components to advanced systems, future networks, new data technologies and platforms. Autonomy will require sustaining first-mover advantage in strategic areas like quantum computing and graphene, and investing early in emerging enabling technologies.

Electronic and photonic components, and the software that defines how they work, are the key digital technologies that underpin all digital systems. As the digitalisation of all sectors accelerates, most industries depend on early access to digital components. Dependence on these technologies represents a clear threat to Europe's autonomy, particularly in periods of geopolitical instability, exposing Europe to risks of vulnerability. Actions under this Destination will build on EU strengths in low power consumption and ultra-secure components and develop in Europe the essential electronic and photonic components for a wide range of applications such as healthcare equipment, electric and autonomous vehicles, manufacturing plants, telecom networks, aerospace vehicles.

R&I initiatives on 6G technologies are now starting in leading regions world-wide, with the first products and infrastructures expected for the end of this decade. 6G systems are expected to offer a new step change in performance from Gigabit towards Terabit capacities and sub-millisecond response times, to enable new critical applications such as real-time automation or extended reality ("Internet of Senses"). Europe must engage now to be among the top influencers of - and competitors in - these technologies and ensure that emerging network technology standards are defined following European values and energy-efficiency requirements.

Despite European scientific community's lead in AI and robotics, Europe lags behind in AI diffusion. Actions under this Destination will develop world-class technologies serving the needs of all types of European industries (e.g. manufacturing, healthcare, transport, agriculture, energy, construction), providing top-performing solutions that businesses will trust and adopt to maintain their competitiveness and maximise their contribution to environmental sustainability.

While Europe is strong in many sectors, it must take ownership of its unavoidable future transformations for competitiveness, prosperity and sustainability, by early leadership and industrial autonomy in new and emerging enabling technologies (e.g. use of biological elements as part of technology, sustainable smart materials, alternative computing models such as bio- and neuro-morphic approaches). In particular, the far-reaching impact of quantum and graphene technologies on our economy and society cannot be fully estimated yet, but they will be disruptive for many fields. Actions in this Destination will ensure that

Europe stays ahead in this global race and is in a position to achieve game-changing breakthroughs.

Proposals for topics under this Destination should set out a credible pathway to contributing to the following expected impact:

> **Sovereignty in digital technologies and in future emerging enabling technologies,** by strengthening European capacities in key parts of digital and future supply chains, allowing agile responses to urgent needs, and by investing in early discovery and industrial uptake of new technologies.

This Destination is structured into the following sections:

- Ultra-low power processors
- European Innovation Leadership in Electronics
- European Innovation Leadership in Photonics
- 6G and foundational connectivity technologies
- Innovation in AI, data and robotics
- Tomorrow's deployable Robots: efficient, robust, safe, adaptive and trusted
- European leadership in Emerging Enabling Technologies
- Flagship on Quantum Technologies: a Paradigm Shift
- Graphene: Europe in the lead

The following call(s) in this Work Programme contribute to this Destination:

The Destination structure and the allocation of topics to calls and year will be decided at a later stage.

Section: Ultra-low power processors

[Expected impacts addressed: #15 (Green), #18 (Digital and emerging enabling technology sovereignty)

Objective: ensure EU technological sovereignty through the development of low-power, low environmental impact, secure and trusted components and software for strategic value-chains.

Current status: Europe is today not present in the microprocessor market.

Achievements sought / targets:

Ultra-low-power, secure processors for edge computing. Develop European microprocessors that deliver high-performance computing at ultra-low power operation. New processor architectures may incorporate approaches such as neuromorphic, in-memory computing, neural network, spintronics and quantum technologies as well as Open Source hardware. The target is to provide by 2025 competitive home-sourced trustworthy technology with drastic reduction in energy consumption over current state-of-the-art solutions.

Embedded systems, operating systems and software technologies for edge computing. Systems and software components building on advances in specific computing field (e.g. HPC in the context of EPI or innovative computing architectures like neuromorphic), addressing on the one side safety- and time-criticality requirements and on the other side the energy constraints found in AI applications at the edge of the network (e.g. healthcare, manufacturing, transport, water supply, agriculture, mining, energy). This requires flexible architectures, new verification and validation methods for ensuring the proper behaviour of the system under a wide and changeable set of scenarios, and supporting tools to help in the entire development processes. This will result in a trustworthy software stack allowing applications to access all the functionalities of the underlying hardware, giving a significant contribution to EU digital sovereignty with regard to critical applications.

Strengthen EU technological sovereignty with Open Source software and hardware. Development of interfaces between cloud services and flagships projects targeting specific computing fields (e.g. EPI). The objective is to expand the usability of the outcomes of relevant initiatives by deploying solutions in strategic ICT markets. In this context, the usability of the next generation of software development tools will play an important role in making application development accessible to a broader public, thus contributing to reducing the lack of skills in the computing domain.

Means/links: A Joint Undertaking ('Key Digital Technologies') addressing the electronics value chain (including software technologies) and a possible upcoming IPCEI are among the necessary instruments currently proposed to enable European industrial and academic stakeholders to design and implement common roadmaps in significantly research-intensive areas.

Links to other clusters: Targets under this orientation for topics are complemented with the Cybersecurity topic 'Improved security in open-source and open-specification hardware for connected devices' in Cluster 3.

Links to other Partnerships: The technological developments in the area of "Low-power processors" contribute to the competitiveness of HPC ('EuroHPC'), mobility and space applications.]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-01-2021: Ultra-low-power, secure processors for edge computing (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Develop European secure specialised microprocessor designs that deliver high-performance computing at ultra-low power operation.
- Improve by at least two orders of magnitude the performance per watt for the targeted edge applications

Scope:

- Develop European specialised processors, architectures and computational engines that have the potential to substantially improve energy efficiency (i.e. performance per watt) for the targeted edge application.
- Examples of targeted applications (non-exhaustive list) are automated driving, artificial intelligence, machine learning, computer vision, machine translation, speech recognition, sensor fusion, etc.
- New specialised processor designs may incorporate approaches such as neuromorphic, in-memory computing, spintronics, neural networks as well as open-source hardware.
- Projects should have a longer-term perspective taking into account the reduced performance improvements of general-purpose computing, the slow-down of Moore's law and the changing economics of semiconductor manufacturing.
- Projects should include research on advanced hardware-based security at silicon-level.

Projects should include a preliminary analysis of bringing successfully to the market the proposed research either as IP blocks or as standalone chips.

DIGITAL-EMERGING-02-2021: Software for low-power operation at the edge (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Availability of a complete stack of trustworthy software components for applications at the edge of the network where low energy consumption is a primary concern
- addressing safety- and time-critical requirements typical of industrial and professional applications;
- supporting Artificial Intelligence techniques at low energy budget;
- running on innovative and heterogeneous hardware platforms;
- suitable for building complex systems in critical sectors like manufacturing, healthcare, transport, energy, telecommunications.

Scope: Complex electronics systems today are often based on technological components provided as “black boxes”, which pose risks in terms of security, access to hardware capabilities, overall quality and possibility of evolution over time. The explosion of Artificial Intelligence and other power-hungry applications at the edge of the network requires radical efficiency improvements in the software stack. This topic will strengthen the leadership of EU industry in intelligence at the edge solutions and cognitive cyber-physical systems, creating a trusted computing base for all the applications where reliability, long-term support and low energy consumption are primary concerns.

DIGITAL-EMERGING-03-2022: Open source for cloud-based services (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- The objective of this topic is to complete the continuous path from flagship projects at the component level, such as the EPI, and cloud services. Emphasis is on the software and hardware interfaces between the aforementioned new processing architectures and cloud applications with the aid of relevant widely available ICT industry standards and Open Source stacks.

Scope: Proposals will address at least one of the following two areas:

- Virtual environments, methods and tools that interface with the deployment of full open source stacks from the kernel to cloud applications featuring targeted relevant processing architectures of European initiatives, e.g. RISC-V. Proposals addressing this field should cover both of these points:
  - Required developments to provide a simulation of the targeted architecture that allows validation, verification and testing of the trustworthiness of software layers over specific architectures
  - Development and coordination with relevant software distribution to provide ports of the latter to the architectures targeted by the virtual environments.

- Open source interfaces that permit the deployment of tested stacks on the outcomes of European processor initiatives. Proposals should address at least one of these points:
  - Open hardware interfaces able to integrate components in processor architectures prepared for deploying cloud applications. The focus should be in optimizing and expanding the interface possibilities of the aforementioned components vis-à-vis existing hardware computing standards.
  - Software to provide the basic initialization of cloud servers based on processor components and the runtime interfaces for operating systems and programs.

Section: European Innovation Leadership in Electronics

[Expected impacts addressed: #15 (Green), #16 (Industrial leadership and autonomy), #18 (Digital and emerging enabling technology sovereignty)

Objective: To secure access in Europe to cutting-edge digital technologies, to strengthen current leadership in strategic value-chains, and to seize emerging opportunities addressing existing technological gaps.

Current status:

Europe's leading position in KDT for the strategic sectors of automotive, industrial manufacturing, aerospace, defence and security and healthcare.

In the emerging area of post-Moore components, there is a number of promising technological approaches with no established players or dominant regions.

Achievements sought / targets:

Reinforce European industrial leadership in KDT accelerating the maturity level of technologies and supporting their adoption in industrial value-chains. The target by 2030 is to increase EU technological sovereignty and reinforce leadership in the above mentioned markets and other strategic sectors, such as energy.

Establish Europe as a world player in the post-Moore era: Based on novel paradigms, such as neuromorphic and neural network technologies, new architectures are emerging for future digital components. They are the response to the increasing demand for embedded intelligence, energy and cost efficiency. The target is to establish by 2030 the capability in Europe to design and manufacture a new generation of trusted, low-power semiconductor components for use in multiple applications ranging from health monitoring (ultimate miniaturisation) to secure networking (trusted components).

To deliver components and systems for energy-efficient, clean and circular production to contribute to the European Green Deal objectives.

Means/links: A Joint Undertaking ('Key Digital Technologies') addressing the electronics value chain and a possible upcoming IPCEI are among the necessary instruments currently proposed to enable European industrial and academic stakeholders to design and implement common roadmaps in significantly research-intensive areas. This would include the broad integration and exploitation (e.g. through an IPCEI) of existing potential across Member States.

Links to other Partnerhsips: The technological developments in the area of "Key Digital Technologies" provide the building blocks for 'AI, data & robotics', new digital interaction technologies, computing systems, sensing, connectivity technologies and quantum. They contribute to the competitiveness of space systems, mobility, health, manufacturing and energy applications. Links would be established with 'Made in Europe' for energy-efficient, clean and circular production, as well as other relevant partnerships.]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-04-2021: Innovative semiconductor processes for the post-Moore era (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Innovative semiconductors design concepts supporting very low energy consumption, integrated security, RF connectivity and embedded functions.
- Alternative[35] semiconductor manufacturing process technologies able to sustain in the mid- and long-terms the fast pace evolution of device performance, miniaturisation and cost.
- Very advanced packaging solutions aiming at extreme miniaturisation and integration.

Scope: Proposed work is expected to address very advanced approaches with high potential not yet demonstrated in the design, fabrication process and/or packaging segments of the semiconductor value chain. Innovation focus can be on materials, physic concepts, device architecture or integration technologies.

Proposers should provide a projection of the expected gains and main figures of merit of the proposed approaches.
Proposal should address TRLs 2 to 4.

DIGITAL-EMERGING-05-2021: Multi-functional integration (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Increase integration of new functionalities at package level, with decreased size and increased autonomy
- New generations of affordable multi-functional integrated devices with significant improvements in performance
- Provide a European strategic autonomy in key integration and packaging technologies and related manufacturing value chains
- Reinforce European industrial leadership in multi-functional components for sectors such as automotive, aerospace defence and security, and healthcare

Scope: The topic will cover technological advances in heterogeneous integration for multi-functional digital devices. Work will target multi-disciplinary R&D in miniaturized systems

[35] Alternative to mainstream Silicon CMOS technologies.

based on heterogeneous integration and smart packaging, for next generation multi-functional digital devices integrating sensing, storing, processing, actuation, energy harvesting and wideband communication.

The projects will propose breakthroughs and provide demonstrations of next generations of multi-functional integrated digital devices. In smart packages, these devices will integrate most advanced functions provided by microelectronics, micro-nano-mechanic, micro-fluidic, magnetic, photonics, RF or bio-chemical.

Proposal should address TRLs 2 to 4.

DIGITAL-EMERGING-06-2022: Functional electronics for green and circular economy (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Development of new concepts, designs and technologies to support and enable circular economy and sustainability in the electronics value chains
- Development of next generation components and systems that will deliver climate-neutral digital solutions for a wide range of sectors.
- Contributions to the Circular Data Space by improving traceability and transparency during product lifetime for performance monitoring and/or for enhancing end of life management practices

Scope: Work should address one of the following areas:

a) Eco-design approach for electronic components and systems

Proposals are expected to develop functional electronics technologies based on eco-design principles[36] to reduce energy and resource consumption for better environmental performance, by including activities related to:

- optimised resource use, such as energy efficiency and material consumption;
- utilizing eco-friendly compounds to increase the potential for recyclability or reuse;
- developing new methodologies and design for green and circular production, in particular with significant enhancement of re-use, repair, re-furbish of products and more efficient recycling solutions.

Proposals should include forecasts and metrics with respect to the targets for decreasing energy consumption or improvement of recycling efficiency in their chosen approaches.

[36] Complying with the EU Ecodesign directive

b) Advancing the area of organic and printed electronics to complement inorganic-based mainstream semiconductors. This includes:

- Development of beyond-state-of-the-art electronic components and systems making use of novel substrates (e.g. flexible, stretchable, conformable) and their integration in alternative materials (e.g. textiles, plastics, glass).
- New device and components architectures; improve systems characteristics (e.g. performance, robustness, reliability) and energy autonomy; high throughput/low-cost manufacturing processes.

Issues related to life cycle, products end-of life, standardisation, certification, regulation compliance and recyclability should be considered where appropriate for both areas (a and b).

Section: European Innovation Leadership in Photonics

[Expected impacts addressed: #15 (Green), #16 (Industrial leadership and autonomy), #18 (Digital and emerging enabling technology sovereignty)

Objective: To strengthen current leadership in photonic technologies and applications, and to secure access in Europe to cutting-edge photonic technologies.

Current status: The European photonics industry has an excellent position in core segments, far above the average EU market share.

Achievements sought / targets:

Deliver communication at light speed integrating photonics in a range of data transfer scenarios such as long-reach internet backbone, mid-reach interconnects in data centres and large premises, and short-reach interconnections between and within electronic boards and components. The target is to develop by 2024 a multi-technology platform towards mass manufacturing (III-V, silicon, photonic, microelectronic) providing performance levels of 10 terabits per second for optoelectronic interfaces (from current level below 1 terabit/sec) and over 1 Petabit per second for optical fibre systems in the field.

Develop a new generation of multi-sensing systems aiming at technologies with very high performance. They will be integrated with other functions to provide higher levels of intelligence to multiple applications, many in real-time, including health, environment, green manufacturing, and advances in AI and IoT.

Develop photonic building blocks and integration schemes and platforms offering these to open up a wealth of opportunities in many application areas by enhancing spectral coverage, functionality and reliability. The target is to reduce the cost of development and manufacturing of photonic systems by a factor of 10, to kick-start new applications based on light technologies in biomedical, environmental, industrial and sensing fields and to bring ground-breaking photonic technologies within reach of entrepreneurial SMEs.

Means/links: The ‘Photonics’ co-programmed Partnership is the most important instrument currently proposed to enable European industrial and academic stakeholders to design and implement common roadmaps in significantly research-intensive areas.

Links to other Partnerships: The technological developments on Photonics in the area of “Key Digital Technologies” provide the building blocks for “AI, data & robotics”, new digital interaction, connectivity, sensing and quantum technologies. They contribute to the competitiveness of space systems, mobility, health and energy applications.

Links would be established with ‘Made in Europe’ for energy-efficient, clean and circular production, as well as other relevant partnerships.]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-07-2021: Advanced optical communication components (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Providing reliable and low latency communication with guaranteed service quality for the digital transformation of industrial processes;
- Reducing congestion in data communication when a multiplicity of applications compete for simultaneous delivery, thereby causing data loss or a delay in data delivery;
- Reducing power consumption by broader use of optical networking technologies, interconnects, integrated optical communication components to some pico-Joule per bit;
- Lower the barrier for uptake of performant communication technologies by reducing cost of transmission interfaces to around 50 cents per Gigabit per second.

Scope:

Projects should develop ultra-dynamic photonic components for data communication, using for example new optical wavelength bands, space division multiplexing, new integration schemes, optical switching and new switching paradigms, as solutions for time-deterministic and time-sensitive networks. They should also enable ultra-dynamic reconfiguration on the optical layer and mitigate amplifier power transients, while saving energy, improving bandwidth efficiency, and guaranteeing low deterministic latencies across the network. Advances should not be limited to optical switching in commercial applications but allow optical flow or packet switching approaches to become practical for the industrial Internet. Devices should be able to work in a harsh environment such as within a wide temperature operating range, or in high humidity.

DIGITAL-EMERGING-08-2022: Sensor-based systems for biomedical, environmental and other advanced applications (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Next generation multi-sensing systems for multiple applications, including real-time environmental monitoring, automated driving (e.g. LIDAR), advanced manufacturing and improved biophotonics device capabilities.
- Sensing devices instrumental to the new green deal objectives, allowing for reaching high levels of reuse/repair/repurpose, recovery and recycling of waste, with minimum power consumption.
- High performance sensing technologies, combining sensor development, system integration, packaging and cost-effective manufacturing processes to support advances in AI and IoT.

Scope:

Massively parallel multi-parameter/multi-analyte sensor systems, capable of acquiring, processing and interpreting vast amounts of data simultaneously, while communicating only the essential “insights” to the outside world. Methods and components must be selected so to be able to make the maximum use of the information achieved, and aim at high-efficiency and low consumption. Whenever justified, a modular approach with interchangeable components operating in a platform environment should be favoured.

DIGITAL-EMERGING-09-2021: Disruptive solutions for integrated photonics, PICs and hybrid technologies (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Core technologies and technology building blocks enabling new generations of integrated devices.
- The establishment of integration platforms based on centres of excellence for integration and miniaturisation of technologies for photonic devices and their fabrication including epitaxy, lithography, patterning, die fabrication, hybrid integration and assembly.
- Lowering the barrier to the use of advanced or innovative technologies for high-tech SMEs by providing Pilot Lines for prototyping and small to medium sized product runs.

Scope: Evolving photonic integration is opening up a wealth of opportunities in many application areas by enhancing functionality and spectral coverage, facilitating new applications in biomedical, environmental, industrial and sensing fields and bringing ground-breaking technologies within reach of entrepreneurial SMEs. The increasingly sophisticated requirements need new paradigms, capable of extending the functionalities of optical components through new materials and new design and fabrication techniques. These need to be augmented with new functions and performance enhancements, requiring in many cases the development of new semiconductor materials and innovative device structures. Challenges are in mastering epitaxial material growth and processing on large wafers with improved quality, uniformity and very low defect densities, broadband (“white”) light sources and high sensitivity avalanche photodetectors (including arrays) and high-efficiency semiconductor lasers operating at high temperatures (>85°C) across all wavelength bands. Incorporation of new building blocks such as magneto-optic elements for non-reciprocal functionality (e.g. optical isolation) could also be included.

Section: 6G and foundational connectivity technologies

[Expected impacts addressed: #15 (Green), #16 (Data), #21 (Industrial leadership and autonomy), #18 (Digital and emerging enabling technology sovereignty)

Objective: develop a strong supply chain for connectivity, increase European competitiveness and sovereignty in core Internet infrastructures, and to contribute to a reduction of the growing effect of the Internet on the global energy consumption with the aim of achieving a climate neutral Internet.

Current status: today European suppliers of connectivity systems are well placed with around 40% of global 5G market share, but with high competitive pressure from Asian and US players. In terms of technology, first 5G standards are available since end of 2017 enabling Gigabit/s speeds and ~millisecond latencies. Trusted industrial services based on 5G technology are at very early stage.

Achievements sought / targets:

- Reinforce European leadership in connectivity, devices and service infrastructure, with European capabilities in shaping future connectivity (6G) standards, keeping a strong position in the network supply market and seizing opportunities ofintegration with new value chains such as cloud and edge computing as well as components and devices beyond smartphones. The target is EU industry holding at least 40% of the global market of future connectivity (6G) systems

- Enable a massive digital and green transitions towards low carbon footprint of conventional (vertical) industries such as automated factories, connected cars, energy grids, agriculture, smart healthcare by managing the exponential increase of connected devices and objects (speed, latency, energy, intelligence). The target is to contribute to vertical sectors keeping a carbon emission levels of 2015 (Global e-Sustainability Initiative (GeSI) objectives).

- Enable networks to deliver advanced real-time sub-millisecond latency applications that are competitive, secure and privacy-preserving, in areas such as autonomous driving, manufacturing and farming. The target is > 10 million connected objects/km² for Smart City scenarios

- Enable trusted and energy-efficient network infrastructures delivering critical services as well as a dynamic multi-vendor supply market through new radio technologies, new architectures and open network and service paradigms such as Terahertz communications, versatile spectrum technologies, zero touch network automation, AI, blockchain and EMF aware networks. An average decrease of network consumption by a factor of 10 is targeted, as well as new classes of applications beyond 5G capabilities and an Internet of Sense.

Means/links: An institutionalised partnership (‘Smart Networks and Services’) is currently proposed to enable European industrial and academic stakeholders to design and implement common roadmaps in significantly research-intensive areas. Foundational technologies, long term, very high risk and disruptive concepts on radio and full optical networks as well as new IoT real-time concepts are addressed outside of the proposed Smart Networks and Services partnership.]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-10-2021: Ultra low energy and secure networks (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- The research covers the long term objective of ultra low energy networks and corresponding EU industrial capability for end to end all optical communications with no electro optical conversion coupled with full security applying quantum communications over fibre nets beyond the today's 400 km limitation. Additional exploratory R&I may be considered for solving IP limitations, making networks deterministic, drastically reducing energy needs at protocol level whilst increasing performances in terms of security, control by applications for differentiated features, resource administration with implementability as "Network on a Chip" and dynamic self configuration.

Scope:

Flexible Capacity Scaling

To develop technologies for rates of 10 Terabit/s for optoelectronic Interfaces and over 1 Petabit/s for optical fibre systems, symbol rates more than 100 GBd, are crucial to maintain the transportation per bit cost at the necessary levels to stimulate innovation. The exploitation of new wavelength bands will require advances in a wide range of technologies ranging from optical amplifiers, tailored to these new bands, to a wide range of opto-electronics devices and sub-systems;

New Switching Paradigms

Future applications, such as autonomous driving, augmented/virtual reality and augmented workspace, will severely change the architecture and dynamism in optical networks. New network architectures with edge clouds close to the end user and centralised clouds with flexible distribution of network and application functions will be required. Cloudlets at the edges can be viewed as ”data centres in a box”, that can be flexibly deployed at the network edge to meet the capacity or latency constrains required by the applications.

Deterministic Networking

While a lot of the success of the Internet relied on a best effort traffic paradigm, the digitalisation brings a multitude of applications in which reliability, latency and often also a certain throughput and signal quality need to be guaranteed (e.g. URLLC = ultra-reliable low latency communication in 5G). Examples range from mobile fronthaul traffic over critical control applications in the vehicular and industrial space to high-resolution machine vision or augmented/virtual reality applications. Some of the most challenging requirements discussed today are < 75 µs latency (including fibre transmission which adds 5 µs/km), < 8 ns timing error, and several tens of Gbps throughput for CPRI signals.

Optical Wireless Integration

The end-user capacity is increasing, the coverage of the mobile network becomes denser, and a split architecture in the radio access network will be introduced, where different functional splits between baseband and radio units will be supported by the same transport network. Several candidate technologies exist for enabling the coexistence of fronthaul and backhaul networks. In practice, all require a redesign and a redefinition of their application space. For example, packet switching with new packet friendly fronthaul interfaces is likely to be implemented in scenarios where many users generate a low amount of traffic data each.

Security for Mission Critical Services

A signal on an optical fibre can be easily tapped, once the physical access to the fibre is available. At this point, the data of millions of users and billions of applications is exposed to theft and manipulation. Therefore, encryption and integrity of the data is essential and also needs to be kept at a level playing field with increasing threat scenarios (crypto agility). Improvements need to consider quantum-safety, for instance by post-quantum replacements of current algorithms or by provable and long-term secure data transmission of highly sensitive information using quantum communication with photons. Also, novel research directions like physical layer security for optical networks should be explored.

Ultra-high Energy Efficiency

Increasing use of optical technologies within the IT and communications industries is one key opportunity to limit the increasing energy consumption against the massive growth of overall data capacity that networks and data-centres are handling. Since light can travel vast distances through fibres, fibre optics consumes only a fraction of the energy used by conventional technology that transports electrons via copper wires. Also, the inherently low power consumption of optics can be directly used to reduce power consumption overall, if optical functions replace more power-hungry electronics, e.g.: Functions may be turned off or switched into a low power mode if not in use • Electronic processing can be bypassed more frequently through new control mechanisms that optimise traffic flows across network layers, particularly if combined with optical space and wavelength switching. • Electronic interfaces of modern communications ICs are a strong driver of power consumption. Ways to replace those interfaces by lower power optical interfaces that are integrated or co-packaged with those chipsets can reduce power consumption substantially. • The further drive to higher capacities and interface speed per electronic chip will make optical communication within chipsets as well as chip-to-chip a future necessity.

Quantum Networking

Quantum communication will play a central role in the creation of the next generation of secure telecommunication networks. Quantum communication relies on the use of quantum resources to achieve tasks that cannot be reproduced with classical theory. Because quantum communication involves numerous technologies, platforms and application, recommendations on protocols, components and infrastructures will be developed.

DIGITAL-EMERGING-11-2022: Breakthrough technologies for sustainable, efficient and green radio systems (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- The research covers radical innovation of radio communication systems, targeting increased spectrum efficiency and dynamic spectrum sharing across multiple frequency bands, not limited to the Mobile Service (MS). It covers technologies and architectures enabling optimized co-existence with the most difficult spectrum environments (e.g. passive earth sensing), enable long term Opening of new frequency bands for mobile communication usages with better energy consumption performances, innovative sharing concepts and refarming capabilities. It leverages European capabilities in AI, advanced signal processing and microelectronics. It paves the way towards radio systems realizing fusion with physical environment for citizen visual acceptability (radio systems integrated to buildings or city structures) . It covers nano/local networks based on Nano objects connectivity with high rate connection capability at nano scale as required for advanced medical, industrial or other demanding environment, leveraging research on nanomaterials and nano-network architecture components (nodes, gateways), graphene antennas for nano-communication within the 0.1 − 10 THz spectral window, with unprecedented communication data rates despite the nano-scale

Scope:

Nano-Things Networking

The many ”Things” we are progressively interconnecting in the Internet are progressively extending to the micro-things, i.e. those computational and service elements that run on small/tiny and non-intrusive things. Nano-communications are emerging to extend the reach of smart control to the level of molecules and cells, with unprecedented impact in medicine and material manufacturing. Combating diseases via autonomous nano-machines, ultrafast degradation or toxic waste, self-healing and self-monitoring materials constitute a few of the most visionary applications. Materials with software-defined electromagnetic behaviour constitute applications presently under development, paving the way for programmable wireless environments. Further research on nanomaterials and nano-network architecture components (nodes, controllers, gateways) will open new prospects of usage of nano-scale things. At the PHY Layer, graphene antennas enable nano-communication within the 0.1 − 10 THz spectral window, which promises unprecedented communication data rates despite the nano-scale. At the MAC Layer, pivotal protocols could target Body Area Network (BAN) applications notably for health and self-monitoring and adapting industrial materials.

Spectrum Re-farming and Reutilisation

Allocated frequency spectrum is one of the main factors that determines the system capacity. But radio spectrum is a scarce resource. Especially the lower frequency bands are precious and tightly regulated. In order to satisfy the high bandwidth demands of upcoming generations of mobile systems, it is crucial to reutilise the existing spectrum resources. While the traditional approach allocates a dedicated spectrum to each radio access technology (RAT), spectrum reutilisation between RATs offers a more efficient utilisation of resources and greater flexibility, e.g., for load-balancing. Spectrum reutilisation, also known as spectrum sharing, can be applied to licensed but also unlicensed band

Optical Wireless Communication

Despite the tremendous improvements due to the small cell concept and the allocation of new radio frequency (RF) spectrum, the continued exponential growth in mobile traffic means that it will be inevitable that the RF part of the electromagnetic spectrum will not be sufficient to be able to drive the 4th industry revolution which is centred around data-driven economies and data-driven societies. It is, therefore, natural to consider the infrared and visible light spectrum both of which are part of the electromagnetic spectrum for future terrestrial wireless systems. In fact, wireless systems using these parts of the electromagnetic spectrum could be classified as nmWave wireless communications systems in relation to Section 3.2. Light based wireless communication systems will not be in competition with RF communications, but instead these systems follow a trend that has been witnessed in cellular communications by inspecting all the generations developed during the last 30 years. Light based wireless communications simply adds new capacity – the available spectrum is 2600 times larger than the entire RF spectrum.

Radio systems integrated to buildings or city structures

The use of higher frequencies, up to TeraHertz and optical wireless communications needs research in integrated antenna design as well as new materials for antennas and surrounding materials, like glasses materials allowing propagation of these frequencies.

Terahertz Communications

Wireless data rates have doubled every eighteen months for the last three decades. Following this trend, Terabit-per-second (Tbps) links are expected to become a reality within the next five years. While mmWave communications are a step in the right direction, the total consecutive available bandwidth in such systems is less than 10 GHz. Consequently, supporting Tbps would require a physical layer efficiency of 100 bit/s/Hz, which is several times higher than the state of the art.

Ultra-Massive MIMO

The grand challenge for mmWave, THz-band and optical communications is posed by the very high and frequency-selective path loss. As a result, high-gain directional antennas are needed to communicate over distances beyond a few meters. When moving to the THz-band, antennas become even smaller and more elements can be embedded in the same footprint. However, linearly increasing the number of antennas is not enough to overcome the much higher path loss in THz-band. In this context, the concept of Ultra-Massive (UM) MIMO communications, enabled by very dense plasmonic nano-antenna arrays, has been recently introduced. Instead of relying on conventional metals, nanomaterials and metamaterials can be utilised to build plasmonic nano-antennas which are much smaller than the wavelength corresponding to the frequency at which they are designed to operate. This property allows them to be integrated in very dense arrays with innovative architectures

Enhanced Modulation and Coding

Channel coding can be regarded as one of the most complex parts of the baseband transmission chain and aims to correct errors to establish reliable communication. For decades, researchers sought for channel codes with good error correction performance approaching Shannon's capacity limits with manageable complexity. Modern channel coding schemes such as Turbo, LDPC and Polar codes with excellent performance made their way into several communication standards after advancements in semiconductor technology. However, as the decoders for those codes are very complex, there will be implementation bottlenecks (w.r.t. computational complexity, algorithm parallelisation, chip area, energy efficiency, etc.) to be addressed for high throughput (e.g. when throughput is over multiple Gigabits per second) and/or low latency applications are targeted by future communication standards.

Random-Access for Massive Connections

The future vision of IoT envisages a very large number of connected devices, generating and transmitting very sporadic data. The challenge here is how to coordinate such a network without spending the whole network resources and node energy in protocol overhead

Wireless Edge Caching

A novel content-aware approach to wireless network design is needed. Such novel approach should support the paradigmatic shift "from Gigabits per second to a few Terabytes per month for all". More precisely, the special features of on-demand multimedia content can be leveraged in order to deliver a target of ~ 1 $TB/month of content data to each user in a scalable and cost-effective manner. This target is far more challenging than achieving Gbps peak rates, which have been already demonstrated by various "5G-ready" experimental platforms. Meeting this challenge requires a profound and non-incremental advance in the information theoretic foundations, in the coding and signal processing algorithms, and in the wireless network architecture design, in order to exploit the potential gain of content-awareness.

Section: Innovation in AI, data and robotics

[Expected impacts addressed: #18 (Digital and emerging enabling technology sovereignty), #16 (Industrial leadership and autonomy), #15 (Green)

Objective: Ensure sovereignty and autonomy for Europe in AI, data and robotics in developing world-class technologies serving the needs of all types of European industries, from manufacturing to healthcare, public sector, utilities, retail, finance, insurance, transport, agriculture, energy, telecommunications, environmental monitoring, construction, media, creative and cultural industries, fashion, tourism, etc. providing top-performing solutions that industries will trust and adopt to maintain their competitiveness and maximise their contribution to environmental and resources sustainability.

Current status: Europe's scientific community is leading in AI and robotics. However, Europe lags behind in AI diffusion, and less than half of European firms have adopted one AI technology, with a majority of those still in the pilot stage. 70% of these adopter companies, are only capturing 10% of full potential use, and only 2% percent of European firms in healthcare are using those technologies at 80% of potential[37]. This is further exacerbated by gaps in AI adoption between member states. Moreover, as demonstrated during the COVID-19 crisis, many AI, data and robotics solutions exist today but only a limited number of them reaches the level of autonomy necessary to solve the problems at hand. Therefore, there is room for large improvement for adoption by industry, which requires drastic increase of industry-driven R&I, from basic research to large-scale piloting. Europe has the potential to reinforce its industrial strength and maintain its competitiveness thanks to AI, and Europe has also the potential to lead in AI for B2B. In general, the industry acknowledges the potential of such technologies, but often lacks demonstrable benefits in their particular case.

Achievements sought / targets: Industry-empowering AI, Data and robotics: enable and boost vast deployment of European technologies, in demonstrating clear benefits in particular applications coming from major industrial sectors, in improving processes, products or services, contributing to their competitiveness, quality of services, and strategy for environmental sustainability. Providing industry with more autonomous and more intuitive and easy to operate technologies they can trust and that are tailored for their needs, with the adapted and guaranteed level of performances, reliability, safety, security and transparency. Providing trustworthy AI solutions combining various sources of data, sensors and information to address industrial challenges; combining the power of latest progress in AI, FAIR[38] data, autonomous or interactive robotics, smart devices and next generation networks and computing to increase automation and optimise processes, resources, and services, and addressing new scientific challenges removing barriers for industrial deployment. Non-technical barriers should also be addressed. Where relevant latest development from low power consuming sensors and actuators, as well as new energy sources and batteries will be

[37] See https://www.mckinsey.com/featured-insights/artificial-intelligence/tackling-europes-gap-in-digital-and-ai (based on data from 2017 and 2018)
[38] FAIR data are data which meet principles of findability, accessibility, interoperability, and reusability

exploited to ensure energy autonomy for robotics. Promoting versatile, flexible, scalable, resilient architecture that facilitate the future AI based services adoption.

Means/links: A co-programmed Partnership ('AI, Data and Robotics') is currently proposed as the necessary instrument to enable European industrial and academic stakeholders to design and implement common strategic research and innovation agendas and roadmaps, and develop synergies with Member States initiatives and funding.

Links to other clusters: AI, Data and Robotics technologies are general-purpose enabling technologies that can be developed and deployed in any context and economic sector, such as healthcare, agrifood, energy, security, climate, mobility, space, humanitarian challenges, disaster relief, crisis management, manufacturing, mining, culture, addressed in various Horizon Europe clusters, as well as most of the Horizon Europe missions (cancer, food, smart cities, healthy water/oceans) therefore the link with corresponding Partnerships will be established to maximise synergies (meet the needs of the application sectors) which could possibly be implemented by joined calls.

Links to other Partnerships: Smart Network and Services, High Performance Computing, KDT, 5G, Space/Copernicus, Made in Europe, and EIT-KIC Digital.]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-12-2021: AI, data and Robotics for the green deal (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Innovative AI on Innovative greener technologies for resource optimisation and minimisation of waste, including exploitation of all data an information sources and greener robots for a greener planet.
- Contribution to the green deal for environmental and waste management in the circular economy value chain with AI empowered innovative, modular and adaptive robotics solutions, as well as AI for such process optimisation.
- Smart physical intelligence and physical performance of robotics solutions in diverse harsh environments serving the Green Deal

Scope: The proposals are expected to exploit latest AI and robotics advances and demonstrate in use-cases scenarios in real or close-to-real environment, how they can directly contribute to the Green Deal, supported by KPIs, making the case for the added value of such technologies, and demonstrating scalability, and short-term deployment potential. Added value to the application field should be demonstrated by qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring process.

The proposals should be application driven, with a concrete problem solving approach, exploiting the most suitable technologies at hand. The focus should be on real-world scenarios which can benefit in short term scale from the technology and demonstrate substantial impact on the Green Deal, also taking into account the maturity of the technologies which can solve the problems at hand.

Deep involvement of all relevant stakeholders, from technology providers to user industry, and relevant experts in environmental impact assessment, will be essential.

Proposals can involve either purely robotics solutions (for instance demonstrating robotics solutions in harsh environments), or a mix of robotics and non-robotics components (for instance in application such as waste management, where a combination of robotics for waste segregation and data/sensor driven AI for process optimisation) or only include non-robotics AI (for instance in energy optimisation, from production sites, through the network, and then end-user-sites, with IoT components). At least half of the selected proposals will have to have a major robotics component.

At least 3 projects will be selected for each of the topics above: resource optimisation and minimisation of waste, environmental and waste management in the circular economy, robotics solutions in harsh environments serving the Green Deal.

All projects should build-on and re-use results from relevant previous projects developing Digital Industrial Platform for Robotics, or other relevant platforms such as the AI-on-demand platform. In return, results from projects should be made available through such relevant platforms.

DIGITAL-EMERGING-13-2021: AI and robotics at work (IA)

<u>Expected Outcomes</u>: Projects are expected to contribute to the following outcomes:

- Collaborative embodied AI, empowering end-users and workers: A new human-centred paradigm to keep away from unsafe and unhealthy jobs.
- AI supporting professionals in decision-making
- Intelligent and adaptive systems for training and coaching human workers/professionals (learning by example). Developing technology in parallel to workers/professionals' training.

<u>Scope</u>: The proposals are expected to demonstrate how AI and robotics solutions can support professionals in their daily work, improving the working conditions and improving the work performance/efficiency. Added value to the application field should be demonstrated by qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring process.

The involvement of the user industry and the workers would be key to drive the proposals, not only to identify the needs and the application scenarios, but to be involved in the testing of the solutions and providing feedback to adapt the solutions to optimise the working conditions and performances.

The selection of the application sectors should take into account sectors and use-cases where the technology can demonstrate maximum impact and added value.

Human-centred approach will be key in all the proposals, with involvement of the workers, and other relevant experts in human-centred design. They will closely collaborate with the technology providers and integrators.

Each proposal will focus on one of the following topics

- Collaborative embodied AI (robotics system), empowering end-users and workers keeping them away from unsafe and unhealthy jobs: the focus will be in demonstrating improved working conditions (health/safety/level of stress), and worker satisfaction. Meaningful human oversight should be addressed.
- AI supporting professionals in decision-making; the focus will be in demonstrating how AI can improve the effectiveness and efficiency of decision making, building on the human and machine complementarity, exploiting the best capability of both for a better outcome. Meaningful human oversight should be addressed.
- Intelligent and adaptive systems for training and coaching human workers/professionals

All projects should build-on and re-use results from relevant previous projects developing Digital Industrial Platform for Robotics, or other relevant platforms such as the AI-on-demand platform. In return, results from projects should be made available through such relevant platforms.

DIGITAL-EMERGING-14-2021: Industry optimisation (including production and services) (IA)

<u>Expected Outcomes</u>: Projects are expected to contribute to the following outcomes:

Optimisation of value-chains, optimisation of products, services, processes, to increase competitivity, working conditions, and environmental sustainability.

New flexible industry automated production line: modular and fast reconfiguration for new production (pandemic and crisis time).

Self-learning systems adapting the production workflow to the capabilities and restrictions of the humans workers

Foster the engagement of SMEs, start-ups and scale-ups in robotics through platforms that allow for a flexible engineering and construction of robotic products in a broad field of application areas.

Scope: The proposals should demonstrate how major European industries can substantially benefit from AI and/or robotics, either in the production of service sector. At least half of he selected proposals will address the service sector, where substantial added value of AI and/or robotics can be demonstrated. This should be demonstrated with real/or close to real demonstrators.

Added value to the selected use-cases should be demonstrated by qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring process.

In the context of production, the proposals should focus either on optimisation of value-chains, or optimisation of processes, to increase competitivity, working conditions, and environmental sustainability, or on flexible reconfiguration of automated production or adapting the production workflow to the capabilities and restrictions of the humans' workers.

In the context of the service sector, the focus will be on demonstrating the added value of AI and/or robotics to optimise value-chains, products, services or processes, to increase competitivity, environmental sustainability, and working conditions where relevant.

A separate focus will be on developing a platform supporting SMEs and start-up to develop robotics products. Such platform should provide the necessary support, expertise and equipment's to minimise the risks for SMEs and start-ups, they should also offer networking and support to help these SMEs to develop sound business plans and reach the market, and maximise their business opportunities. The proposal should address various application sectors, which high potential impact is expected from robotics. Fair access to the platform should be ensured throughout Europe. One large project supporting such platform is expected to be selected. Such project should further develop reference platforms (such as the AI on demand platform/Digital Industrial Platform for Robotics).

All projects should build-on and re-use results from relevant previous projects developing Digital Industrial Platform for Robotics, or other relevant platforms such as the AI-on-demand platform. In return, results from projects should be made available through such relevant platforms.

Section: Tomorrow's deployable Robots: efficient, robust, safe, adaptive and trusted

[Expected impacts addressed: #21 (Data), #18 (Digital and emerging enabling technology sovereignty), #15 (Green), #20 (Human-centred)

Objective: ensure sovereignty and autonomy for Europe in robotics, leading the way in research, development and deployment of world-class technologies.

Current status: Europe is leading in robotics industry, with the highest intensity of use of robots. Europe is also scientifically leading in robotics' cognition, safety, manipulation, soft robotics, underwater robotics, with demonstrated impacts in many use-cases in key industrial sectors (e.g.: healthcare, agriculture, inspection, marine, mobility, manufacturing).

Achievements sought / targets:

- Build the **new generation of AI-Powered Robotics:** Enable robots to have more profound impacts than they currently have, in powering them with a deeper kind of AI, endowing them with a better perception and understanding of the world (up to semantic and explainable representations), and also improving their physical performance (for example: improving robustness – to handle environment variations and unknown or new situations - and energy efficiency to run safely and autonomously for longer period of time, increased speed, integrating AR/VR and haptic technologies, some operating under extreme physical conditions such as under water, rough terrain, difficult climatic conditions, in the body, in the air, etc.). This would allow the next generation of autonomous robots, with increased capabilities to work without/with limited supervision, as well as the next generation of interactive robots, with greatly improved intuitive, safe and efficient cognitive, social and physical capabilities, to assist humans.

- Provide enabling technologies and integrate them in solutions on the one hand for taking over autonomously dangerous, dull and dirty jobs in a range of innovative applications and on the other hand, in reaching the level of reactivity, flexibility and adaptivity required for smooth and beneficial human-robot, as well as robot-robot collaboration and interaction. With the help from SSH expertise, innovative applications are expected in a vast range of applications involving humans, such as caretaking, co-working, etc.

- Develop lifelong autonomous robotics able to tackle unknown situations and adapt in the long term with new types of AI systems that combine learning, planning and acting in order to evolve in difficult environments over long period of time.

- Develop new intelligent robotic concepts (collaborative, modular and distributed, hyper redundant, highly reconfigurable) enabling adaptation to transformations of industry and society (including crisis).

- Increased robot acceptance by handling adequately both human and robotic actions, with human-centric, advanced behavioural and elaborated planning models, and adopting multidisciplinary approached including SSH, as well as end-user involvement in the design of solutions addressing their problems.

- Make robotics the interdisciplinary fulcrum of the Interaction Technologies i.e. of the methods and techniques that allow the machines to engage in a physical interaction with the environment, safely and intelligently, through specific enabling technologies: intuitiveness and usability of human-robot interfaces; integration of perception with natural and artificial intelligence; ability to physically, stably and safely interact with the environment and the surrounding people; development of physical mechatronic tools for dexterous manipulation and locomotion in diverse environments (ground, air, water, space, bodies) and in general for improved performance of the robots; energy autonomy and resilience to imperfect communication networks in on-field applications.

Means/links: A co-programmed Partnership (‘AI, Data and Robotics’) is currently proposed as the necessary instrument to enable European industrial and academic stakeholders to design and implement common strategic research and innovation agendas and roadmaps, and develop synergies with Member States initiatives and funding.

Links to other clusters: Robotics technologies are general-purpose technologies that can be developed and deployed in any context and economic sector, such as healthcare, agrifood, environment, mobility, mining, manufacturing, addressed in various Horizon Europe clusters, as well as most of the Horizon Europe missions (cancer, food, smart cities, healthy water/oceans) therefore the link with corresponding Partnerships will be established to maximise synergies (meet the needs of the application sectors) which could possibly be implemented by joined calls.

Links to other Partnerships: KDT, Smart Networks and Services, Space, Made in Europe.]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-15-2021: Pushing the limit of robotics cognition (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Smarter robotics for greater autonomy
- Reach the level of reactivity required for smooth human-robot collaboration

Scope: Two types of proposals are expected, either focusing on higher level of autonomy, expecting less reliance on human supervision, or the ones focusing on human-machine collaboration.

The first type of proposals will build on latest developments in areas such as advanced perception, smarter sensors, reasoning and learning, increased understanding of the environment, anticipation of the effect of actions, adaptation and re-planning, graceful degradation, etc. They will, as appropriate, further develop such components, and integrate them in an advanced robotics system.

The second type of proposals will further develop and integrate physical human-robot interaction as well as verbal/non-verbal communication, embedding safety, mutual understanding and perception, joint goals, shared and sliding autonomy, ethical human-like behaviour by understanding of emotions and artificial empathy, etc. to reach truly smooth human-robot collaboration. This should as well integrate latest mechatronic and control developments, and further develop them as necessary to guarantee the necessary speed for the required reactivity, ensuring natural and smooth interactions with humans. Such projects should adopt a multidisciplinary approach and involve the necessary expertise in SSH or human-centric design.

In each case, improvement in the level of robotics cognition should be demonstrated through at least 3 real-world scenarios (including measurements of functional performance), showing also the potential added value of such improvement in the chosen use-cases. Scientific and technological progress should be demonstrated by qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring process.

All projects should build-on and re-use results from relevant previous projects developing Digital Industrial Platform for Robotics, or other relevant platforms such as the AI-on-demand platform. In return, results from projects should be made available through such relevant platforms.

DIGITAL-EMERGING-16-2021: Joining forces in scientific excellence in Robotics (RIA)

<u>Expected Outcomes</u>: Projects are expected to contribute to the following outcomes:

- Creating a strong and tightly networked scientific community in robotics, making it a world-class powerhouse for robotics excellence.

<u>Scope</u>: To ensure European strategic autonomy in such critical technology as robotics, with huge potential socio-economic impact, it is essential to reinforce and build on Europe’s assets in robotics, including its world-class researcher community, in order to stay at the forefront of technological developments.

As stated in the communication from the European Commission on Artificial Intelligence for Europe and the coordinated action plan between the European Commission and the Member States, while Europe has undeniable strengths with its many leading research centres, efforts are scattered. Therefore joining forces will be crucial to be competitive at international level. Europe has to scale up existing research capacities and reach a critical mass through tighter networks of European robotics excellence centres. The proposals should develop mechanisms to reinforce and network excellence centres in AI-powered robotics, bringing the best scientists from academia and industry to join forces in addressing the major robotics challenges hampering its deployment, and to reinforce excellence in robotics throughout Europe via a tight network of collaboration.

Such networks are expected to mobilise researchers to collaborate on key robotics topics, to reach critical mass and increase the impact of the funding in progressing faster in joined efforts rather than working in isolation, with fragmented and duplicated efforts.

The proposals should

- include mechanisms to spread the latest and most advanced knowledge to all the robotics-labs in Europe
- develop synergies and cross-fertilization between industry and academia
- The network will become a common resource and shared facility, as a virtual laboratory offering access to knowledge and expertise and attracting the talents. It should become a reference, creating an easy entry point to robotics excellence in Europe and should also be instrumental for its visibility.

Composition of the Network:

- it should be driven by leading figures in robotics from major excellent research centres, bringing the best scientists distributed all over Europe. They will bring on board the necessary level of expertise and variety of disciplines and profiles to achieve their objectives.
- Industrial participation will be ensured through industrial research teams and also in bringing expertise to identify important technological limitations hampering deployment in industry.
- It will demonstrate access to the required resources and infrastructure to support R&D, such as robotics equipment, support staff and engineers to develop experiments, etc.

Activities of the Networks:

- In order to structure the activities, the proposals will focus on important scientific or technological challenges with industrial relevance and where Europe will make a difference, either in building on strengths, or strengthening knowledge to fill gaps critical for Europe.
- Based on these challenges, the proposals will develop and implement common research agendas. The main vision and roadmap with targets within the projects, as well as

methodology to implement and monitor progress will have to be specified in the proposal and can be further developed during the project.

- Progress will be demonstrated in the context of use-cases, also helping to foster industry-academia collaboration.
- Strong links will be developed among the members of the network, notably through collaborative projects, exchange programmes, or other mechanisms to be defined by the consortia
- The proposals should define mechanisms to foster excellence, to increase efficiency of collaboration, and to develop a vibrant Robotics network in Europe.
- Each network will disseminate the latest and most advanced knowledge to all the academic and industrial Robotics laboratories in Europe, and involving them in collaborative projects/exchange programmes. (This could involve projects defined initially or via financial support to third parties, for maximum 20% of the requested EU contribution).
- Each network will develop interactions with the industry (inside the consortium and beyond), in view of triggering new scientific questions and fostering take-up of scientific advances
- Each network will develop collaboration with the relevant Digital innovation Hubs, to disseminate knowledge and tools, understand their needs, and extend the industry-academia collaboration.
- These networks should also foster innovation and include mechanisms to exploit new ideas coming out of the network's work (for instance via incubators).
- Overall, each proposal will define mechanisms to become a virtual centre of excellence, offering access to knowledge and serve as a reference in robotics, including activities to ensure visibility.

The proposals should include a number of major scientific and application challenges which will mobilise the community to join forces in addressing them. Continuous evaluation and demonstration of progress towards solving the targeted challenges will motivate the entire network and support publications and scientific career developments (providing references to publish comparative results, using the reference data, scenarios, etc.), and also showcase the technology in application contexts, to attract more user industries and eventually foster take up and adoption of the technology. Scientific and Technological progress will be monitored through qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring processes.

To address limitation of the use of robots due to human factors, an interdisciplinary approach involving both technical and SSH researchers is encouraged. Indeed, human-centred approaches in combination with multi-stakeholder co-design activities can contribute to sustainable development of new enabling technologies. Putting people at the forefront is expected to generate novel transformation pathways, which can remedy existing technology in novel ways, and propose feedback loop systems that engage human users in developing new sociotechnical learning situations and tools. Further, agile sociotechnical learning designs, can remedy e.g. less efficient technologies, by emphasizing human aspects of technologies in any sector (industry, healthcare, smart homes, etc.).

The proposals are expected to include mechanisms to share resources, knowledge, tools, modules, software, results, expertise, and make equipment/infrastructure available to scientists to optimise the scientific and technological progress. To that end, tools such as the AI-on-demand platform and Digital Industrial Platform for Robotics should also be exploited and further developed by the networks, to support the network and sharing of resource, running benchmarks, maximising re-use of results.

The proposals are also expected to include collaboration mechanisms among the best robotics teams, but also mechanisms to bring all European robotics teams to the highest level of excellence.

In addition to the network projects, one project should be dedicated to maintain and further develop the AI-on demand platform and the Digital Industrial Platform for Robotics, providing the necessary support to the scientific AI and robotics community. Including benchmarking for scientific and technological monitoring.

Projects are expected to develop synergies with relevant activities in AI, Data and robotics, in destination 3, 4 and 5 and share or exploit results where appropriate.

DIGITAL-EMERGING-17-2022: Pushing the limit of physical intelligence and performance (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Advancing the functionalities, capabilities and efficiency of robots (e.g. making them faster, safer, more agile and precise), to achieve wider variety of tasks efficiently, possibly achieving tasks impossible to humans (e.g. reaching tiny areas, or precision levels beyond human capabilities, or using sensors allowing perceptions beyond humans), or to greatly improve safe and efficient human-robot physical interaction. Improving abilities and robustness of robots, allowing them to adapt to changes in the environment, and making them more energy efficient, so that they could run autonomously for longer period of time.

Scope: Proposals could investigate novel scientific approaches to improve physical capabilities of robots, such as innovative actuation principles (such as soft robotics, reconfigurable, hyper-redundant, modular robotics), or advance the field of miniaturised robotics, advanced control and improved hardware (e.g. building on latest results in mechatronics, advanced sensing and actuation, advanced materials, chips for AI, neuromorphic computing).

Projects are expected to rethink robot bodies, with improved physical and interaction capabilities (with the environment and with humans) to reach novel or advanced abilities, such as powerful, fast, precise, and intrinsically safe navigation, manipulation, etc. capabilities. Such proposals could also propose innovative approaches in building on and integrating latest development in underlying technologies, exploiting multimodalities (audio, vision, AR/VR, haptics, etc.).

The topic also covers advances in cognitive mechatronics, where sensing and actuation are closely coupled with cognitive systems to deliver improved control, motion, interaction (including all modalities), adaptation and learning, and safer systems.

Finally, research into energy efficient robots is also supported, to address the current limitation of energy autonomy in robotics.Progress should be demonstrated by qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring process.

All projects should build-on and re-use results from relevant previous projects developing Digital Industrial Platform for Robotics, or other relevant platforms such as the AI-on-demand platform. In return, results from projects should be made available through such relevant platforms.

DIGITAL-EMERGING-18-2022: Increased capabilities demonstrated in key sectors such as healthcare, dangerous, dull and dirty jobs (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Pilots demonstrating the added value of robotics and their performances to address challenges in key application sectors, and in dangerous, dull, dirty tasks or strenuous for humans.

Scope: This topic will support demonstration projects, expected to exploit latest robotics advances and demonstrate in use-cases scenarios, in real or close-to-real environment, how they can directly contribute to the chosen application, supported by quantitative and qualitative KPIs, making the case for the added value of such technologies, and demonstrating scalability, and short-term deployment potential. Progress should be demonstrated by qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring process.

The proposals should be application driven, with a concrete problem solving approach, exploiting the most suitable technologies at hand. The focus should be on real-world scenarios which can benefit in short term scale from the technology and demonstrate substantial impact on the chosen application, also taking into account the maturity of the technologies which can solve the problems at hand. The proposals are expected to demonstrate how robotics solutions can support professionals in their daily work, improving the working conditions or improving the performance.

Human-centred approach will be key in all the proposals, with deep involvement of the workers, and other relevant stakeholders including experts in human-centred design and work safety and ergonomics specialist or work organisation, as appropriate. They will closely collaborate with the technology providers and integrators.

In case of shared work-spaces, safety and efficient and intuitive interaction will be key.

Considering that human factors often are reasons of limited or less efficient use of robots, human-centred approaches in combination with multi-stakeholder co-design activities can contribute to sustainable development of new enabling technologies. Putting people at the forefront will ensure novel transformation pathways, which can remedy existing technology in novel ways, and propose feedback loop systems that engage human users in developing new sociotechnical learning situations and tools. Further, agile sociotechnical learning designs, can remedy e.g. less efficient technologies, by emphasizing human aspects of technologies in any sector (industry, healthcare, smart homes, etc.). For this, an interdisciplinary approach involving both technical and SSH researchers is needed.

The involvement of the user industry and the workers would be key to drive the proposals, not only to identify the needs and the application scenarios, but to be involved in the testing of the solutions and providing feedback to adapt the solutions to optimise the working conditions and performances. This is also essential for the acceptance of the technology.

The selection of the application sectors should take into account sectors and use-cases where the technology can demonstrate maximum impact and added value.

Each proposal will focus on one of the following topics

- Demonstrating substantial added value of robotics in major application sectors with high socio-economic potential impact, improving the effectiveness and efficiency of processes or services
- Demonstrating how robotics can improve human working conditions and satisfaction in taking over dangerous, dull, dirty or strenuous tasks, keeping workers away from unsafe and unhealthy jobs

All projects should build-on and re-use results from relevant previous projects developing Digital Industrial Platform for Robotics, or other relevant platforms such as the AI-on-demand platform. In return, results from projects should be made available through such relevant platforms.

Projects are expected to develop synergies with relevant activities in AI, Data and robotics, in destination 3, 4 and 5 and share or exploit results where appropriate.

Section: European leadership in Emerging Enabling Technologies

[Expected impacts addressed: #15 (Green), #18 (Digital and emerging enabling technology sovereignty)

Objective: identify early technologies that have the potential to become Europe's future industrial leading technologies in all areas of this cluster and to establish industry leadership in these technologies from the outset. This section has a unique focus on off-roadmap transformations with a longer time-horizon but profound potential impact

Current status: Europe's leading industry sectors have a solid track-record in constant improvement, but less so for embracing transformative ideas. The pathway from research to industry uptake is often long and staged, with no intertwining of research and industry agendas. In the age of deep-tech, though, this intertwining is essential.

Achievements sought / targets

- **General approach:** Identify and validate the potential of promising emerging enabling technologies that are crucial for the future competitiveness and Green Deal objectives of Europe, and that are showing considerable transformational potential across sectors covered in this cluster, This will bring together from the outset a critical mass of EU research and industry actors in an iterative and multidisciplinary approach for co-creating the enabling technologies of the future, such as (but not limited to) bio-enabled technologies, sustainable smart materials and alternative computing models.
- **Biological transformation of industry, including bio-intelligent manufacturing and 3D food bioprinting**: The use of biological elements as part of technology is an emerging trend that perfectly fits with pressing requirements of sustainability. Innovative and more efficient modes of production will be required to satisfy the needs of future generations. The integration of biological principles, functions and structures with other technologies – including digital – will lead to novel, more efficient, bio-intelligent manufacturing processes and methods.
- **Sustainable smart materials:** Developing future smart materials that enable new ways of recycling, repair, self-healing, shape-change, actuation or sensing can be used in industrial processes, smart devices, for new types of interfaces, or for programmable materials. Sustainability-by-design will also prevent any negative consequences for environment and human health. Embedding sustainability and health data in the industrial production of future smart materials.
- Alternative computing models: New forms of non-conventional hardware including analogue, bio- and neuro-morphic, approximate, biological and chemical approaches will lead to new computing, communication or information storage devices that are cheaper and more energy efficient than current approaches and open up radically new directions for European ICT.

Means/links:

- Topical calls for creating a critical mass of cooperation between EU research, industry and societal actors on selected technologies in a multidisciplinary approach.
- Alignment with national or regional initiatives will create an expanding innovation eco-system, anchored in local contexts across Europe, for selected emerging technologies.]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-19-2021: Exploring Emerging Enabling Technologies for Competitiveness and Prosperity – Bottom-up scheme (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Increased industry awareness and in-house competence of newly emerging enabling technologies and of their long-term transformational potential for their sectors.
- Increased academic awareness of such potential from advanced science- and technology research.
- Seeding early industrial leadership, through new or existing companies, in newly emerging enabling technologies and their application within and across industry sectors.
- Increased engagement for structural collaborations between academic and industry players for framing new technologies in industry-relevant ways early and for their co-creation.

Scope: The action will aim to explore the potential of new emerging digital, industrial and space technologies at an early stage through an open call for small-scale actions, combining low TRL work with industry exploration.

Proposals should be focusing on interdisciplinary R&D between industry (including SMEs) and academia intended to co-create a shared basis of a newly emerging enabling technology and a shared vision and roadmap for mid- to long-term transformational impact. They should be led by industry and demonstrate that the proposed works fit with industry's roadmaps. They should build on early results (TRL 3) to deliver the following:

- Advanced prototypes or early demonstrators of a new technology or novel use, targeting existing or anticipated needs and opportunities of industry partners or sectors of the cluster (TRL 4-5).
- Assessment of potential short-, mid- and long-term impacts in concrete terms for the European industrial actors as well as for their industry sectors and value chains at large. This will also consider broader impacts, in line with Commission priorities.
- Shared research-industry roadmap for maturing the technology as well as for achieving its transformational impact within the concrete setting of the partnership.

Projects exploring transformational impacts across sectors are particularly encouraged.

DIGITAL-EMERGING-20-2021: Academia-Industry Forum on Emerging Enabling Technologies (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- European thought leadership in academia and industry on future enabling technologies and their transformational potential in industrial, societal and environmental terms.
- Increased engagement for structural collaboration and co-creation between academic, industry players and other stakeholders where roles of research, industry and society intertwine in a logic of iterative co-design, all the way from low to higher TRLs.

Scope: A Coordination and Support Action to create and animate a forum for emerging interdisciplinary areas and new technological visions. These actions enable and support a broad range of participants (across research disciplines, industry sectors, stakeholders) to meet, mutually inspire, cooperate and develop together innovative ideas for future enabling technologies. They will help industry to navigate rapidly changing environments, for instance by actively transferring ideas and early technologies between players that would not normally interact, or by combinations of different foresight activities (short-term, long-term, cross-sectorial) to prioritise strategic directions while avoiding narrow visions for the future.

Concrete activities will include horizon scanning, portfolio analysis, a variety of participatory workshops, visibility in various meetings, high-profile reporting on emerging enabling technologies. This will build on (and link to) existing low-TRL programmes and research portfolios from European and member state's programmes as well as broad sourcing from foresighting and technology scouting activities, including specific ones for the cluster 4. The forum should link to existing initiatives and partnerships, but add value by active cross-fertilisation across disciplines and sectors, and by breaking the model of linear progression of technology development. Broader stakeholder engagement is expected.

The forum will become a reference for new enabling technologies at different levels of maturity, their purpose, their transformational pathways and their impacts with a distinctive anchoring in European industry and research, as well as providing guidance and reasoned alternatives for Europe's transformations, in line with the Commission priorities (in particular, Green Deal, Digitisation, and Industrial Strategy).

Proposals should involve and be driven by representatives of the relevant actors of the field (e.g., academia, RTOs, and industry, including SMEs).

DIGITAL-EMERGING-21-2021: Development of technologies/devices for biointelligent manufacturing

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- This topic will use either biological components (and data) as sensors with an interface to a technical system which does make the decision, or a biological system with intrinsic intelligence for technical applications – in best case with a bi-directional communication between the biological and technical system. (RIA)

Scope: tbc

DIGITAL-EMERGING-22-2021: 3D food bio-printing.

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- This topic will contribute to the problem of food supply developing new routes to produce protein without arable land requirement or water pollution. Healthy and environmentally friendly food that converts alternative ingredients such as proteins from algae, unused leaves, insects or microbes into attractive products. It is a complex line beyond the technology, as it touches on aspects of global change, industrial competitiveness, agriculture and public acceptance, thus with social and legal implications. (RIA)

Scope: tbc

DIGITAL-EMERGING-23-2022: Embedding sustainability and health data in the industrial production of future smart materials

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Creating a platform to allow researchers and producers across the value-chain to store data on their environmental impacts in a highly structured, open source, and standardised way. It should build a key part of the infrastructure for managing future smart materials. It will be a progressively growing knowledge base with increasing scope and increasing diagnostic and predictive value. The platform will be discussed / co-created with potential stakeholders to jointly shape its development. (RIA)

Scope: tbc

DIGITAL-EMERGING-24-2022: Neuro-morphic devices and architectures

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Prototype or functional neuromorphic devices and/or systems exhibiting a wider range of low power bio-inspired features/functionalities for specific applications (e.g. learning, neural systems, edge-computing, parallelized and scalable neuromorphic processing, neuromorphic photonics).
- Develop software tools/packages and algorithms tailored to the new generation of neuromorphic devices.
- A new generation of biomimetic AI devices and systems exhibiting much lower energy consumption and substantially higher performance levels than existing AI chips and systems.

- Concrete implementations of systems with end-to-end solutions which are economically mass-producible, i.e. can use mainstream production and testing methods.

Scope: Proposals should be focusing on interdisciplinary R&D between universities, RTOs and industry (including SMEs), building on each other strengths, and intended on solving medium term challenges such as:

- Improve computational efficiency while lowering power consumption and computing complexity with the aim to achieving significant progress in processing power approaching the one of the human brain at the neural level with equivalent requirements for functional power.

- Develop mathematical models and computing architectures of neuronal systems using spiking, event-based, rate-based and population-level neuronal dynamics, into a number of computing paradigms applicable for flexible neuromorphic hardware.

- Develop solutions that synergistically integrate neuromorphic technologies and biomimetic AI devices with more conventional approaches for increasing practical utility.

- Reduce training times and enhance performance for real-time machine learning and autonomous systems.

Ethics by design need to be taken into account from the beginning, for which participants from any organization may need specialised support.

DIGITAL-EMERGING-25-2021: Advanced spintronics: Towards next generation ICs using skyrmions and spintronics

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Disruptive hardware components for memory technologies and spin logic devices, with significant progress towards the wafer-scale integration of computational building blocks with magnetic compounds and provide industry compatible solutions for memory, imaging, communication and computation technologies.

- Build the first spin-based digital Boolean devices (Spin-chips) that exhibit significant decrease in energy consumption.
- Design large-scale complete systems that include next generation spintronics and skyrmions devices with emphasis on compatibility, integration of different materials & technologies including CMOS (e.g. spintronic computer).

Scope: The proposals should focus on interdisciplinary R&D between academic research, RTOs and industry (including SMEs) for the development of advanced materials, fabrication methods and tests, modelling and designs intended on solving medium term challenges in spintronic components and devices, e.g.:

- Develop new classes of materials (such as two-dimensional magnetic materials and heterostructures), achieving experimentally the largest effects allowed by physics to create devices beyond the state of the art especially in the fields of memory, spin-logic, magnetic field sensors, spin field-effect transistor (spin-FET).
- Boost utilization of Spin-Charge interconversion for detecting spin currents or manipulating the magnetization of ferromagnets: this is key for ultra-low power operations as well as for a change of paradigm in logic with the goal of cutting down the energy consumption by a factor of 1000, enabling ultra-low energy, autonomous and safe devices towards attojoule electronics.
- Improve the sensitivity: it is fundamental to push detection sensitivity in terms of space and time at room temperature down to the fT/√Hz level needed, among others, for brain monitoring and space applications.

Proposals should demonstrate a fully functional prototype of a spintronic device operating in relevant environment conditions (TRL 4-5) that will unlock the full potential of the field in a number of specific and high potential application areas.

DIGITAL-EMERGING-26-2022: Unconventional computing devices and architectures

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Novel information processing devices and/or architectures based on unconventional computing paradigms (e.g. out of equilibrium, optical, bacterial or chemical computing).

Scope: Proposals should focus on demonstrating novel, unconventional computing architectures, which demonstrate a clear and quantifiable advantage with respect to existing alternatives for a class of relevant problems or applications.

Examples of unconventional computing architectures proposals could focus include (but are not limited to) optical computing, chemical, biological or bacterial computing and out of equilibrium computing.

Proposals should focus their work on harnessing a physical, chemical or biological process not previously explored as the basis for computing, or they should revisit existing devices while operating them in novel modes or regimes leading to a new approach to computing.

They should also identify what are the limits of the current computing paradigms they are trying to improve and propose relevant metrics or KPIs to track progress, and demonstrate success or a superior paradigm compared with using conventional computing approaches.

Proposals should describe how the proposed computing architecture and/or novel information-processing device is controlled and programmed and address relevant i/o interface aspects.

They should come up with a functional prototype device operating in relevant environment conditions (TRL 4-5) and demonstrate the proposed computing advantage in specialised, niche applications or in general-purpose computing.

Section: Flagship on Quantum Technologies: a Paradigm Shift

[Expected impacts addressed: #19 (Green), #21 (Industrial leadership and autonomy), #22 (Digital and emerging enabling technology sovereignty), #23# (Space)

Objective: further develop quantum technologies and their applications in the areas of quantum computing, simulation, sensing and communication, in order to strengthen European technological sovereignty in this strategic field and achieve first-mover industry leadership, capitalising on Europe's established excellence in quantum science and technology.

Current status: Since 2018, the Quantum Technologies Flagship has been consolidating and expanding Europe's scientific leadership and excellence in quantum, in order to foster the development of a competitive quantum industrial and research ecosystem in Europe. The EU's aims for quantum R&I in the next decade are set out in detail in the Quantum Flagship's Strategic Research Agenda (SRA[39]) and its associated main Key Performance Indicators,[40] which have been drafted and published in 2020, focusing on quantum computing, quantum simulation, quantum communication, and quantum sensing and metrology. Projects in each of these areas are currently supported by the Flagship in its ramp-up phase (2018-2020), by other EU research initiatives and by national programmes.

Achievements sought / targets: In the next few years, a whole generation of new quantum technologies will mature. They will have a disruptive effect in many areas of our economy and society – examples include in communications, health, finance, transport, weather forecasting, space, national security, materials and chemical industry, and much more. Europe must stay globally competitive in this strategically important field, reduce its technology dependence on other world regions, and build a leading European quantum ecosystem, boosting socio-economic development. This will be based on key technological achievements in quantum computing, simulation, communication and sensing (among others), anchored in Europe-based value chains for quantum technologies (including key enabling technologies) – targets for up to 2025 include:

- **quantum computing platforms** demonstrating a universally programmable processor operating in the NISQ[41] regime with at least 100 qubits, including firmware and having sufficient coherence to perform computations involving all of its qubits; characterise with a hardware-agnostic test suite as well as with real-word applications; control needs to involve a low-level control system, a compiler and a scheduler;

- **quantum simulation** platforms of at least several hundred individual quantum constituents and able to address real problems in material science, quantum chemistry and others, including means for verifying speedup;

[39] https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=65402
[40] Link to provide later
[41] Noisy Intermediate Scale Quantum

- **software** for operating both quantum computers and quantum simulators in order to provide a complete hardware and software ecosystem, oriented towards practical use-case applications;

- **quantum communication technologies and systems**, combining the latest quantum key distribution and quantum repeater technologies, in order to enable more secure transmission of confidential data, quantum key distribution and other applications, and to pave the way to a global quantum internet;

- miniaturised, integrated, **quantum sensing devices** to realise cost efficient and user-operable products for rapid market uptake, including space-based sensors for in-orbit demonstration/validation.

Means/links: This section is of relevance to the partnerships of this cluster: 'High Performance Computing', 'Key Digital Technologies', 'Photonics', 'European Metrology', 'Global Competitive Space Systems'.]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-27-2021/2022: Large-scale quantum computers

Topic 1 (2021): Framework Partnership Agreement for developing the first large-scale quantum computers (FPA)

Expected Outcomes: Framework Partnership Agreements (FPAs) in quantum computing are expected to establish a stable and structured partnership between the EC and the institutions and organisations in quantum computing who commit themselves to establish, maintain and implement a strategic research roadmap aligned with and contributing to the Quantum Flagship Strategic Research Agenda in a scalable open quantum computing platform based on a specific quantum platform technology.

These partnerships will be set up through an FPA, which will enable the completion of the research roadmap within the context of the agreement.

The consortia responding to the call may include research institutes, universities, RTOs, foundations, industry, SMEs as well as other organisations that can play a role in the realisation of these quantum computing platforms. The FPA shall specify the objectives, the nature of the actions planned, and the procedure for awarding specific grants. Each FPA is expected to contribute to the following outcomes:

- Demonstrate a universally programmable processor of at least 100 physical qubits (by 2025) operating in the NISQ domain including firmware and having sufficient coherence to perform computations involving all of its qubits; characterise with a hardware-agnostic test suite, including real-word applications and the capability of out-performing classical computers on a number of relevant real-world use-cases; control needs to involve a low-level control system, a compiler and a scheduler.

- By 2029, build a full stack, highly connected, high fidelity quantum computer of at least one thousand physical qubits, exhibiting scalable performance and capable of out-performing classical computers on relevant real-world use-cases.

- Formulate standards and interface specifications for a complete software and hardware stack.

Scope: Fostering a vibrant European quantum computing industry will require hardware, software, and the development of user interfaces. Proposals for FPAs are expected to build on the quantum computing platforms supported under the Quantum Flagship ramp up phase. Proposals should target the development of open quantum computing platforms, integrating the key building blocks such as quantum processors in the NISQ regime (>100 qubits) with limited qubit overhead, control electronics, low-level software, verification and validation of the quantum computation, etc.

Proposals should include practical strategies towards the break-even point of fault tolerance to increase algorithmic depth (number of operations) for quantum computing on existing platforms.

Proposals for FPAs must describe how the activities carried out during the ramp-up phase will be continued involving the relevant disciplines and stakeholders, how results of the ramp-up phase will be used, and how they will provide efficient coordination under strong scientific leadership.

Proposals for FPAs should also address how to integrate in these platforms a full software stack, including a compiler and scheduler, programming tools, a suite of algorithms, etc., that would allow them to showcase their capability of solving real and concrete computational problem(s) that demonstrate a quantum advantage.

Proposals should aim at the development of open quantum computer experimental systems, and work on the reduction of their form factor.

Proposals for FPAs should also cover: (i) the cooperation with complementary projects launched specifically in the area of the enabling quantum software stack (see topic 4 below), including also the need to establish from the beginning of this cooperation appropriate IP exploitation agreements; (ii) the collaboration with other initiatives or programmes at regional, national, transnational or global level; (iii) the eventual additional support they may receive in their activities from relevant national, or regional programmes and initiatives; and (iv) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

Other issues to develop later in the call text

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe)

Topic 2 (2021): Investing on new emerging quantum computing technologies (RIA)

Expected Outcomes:

Projects are expected to contribute by investing in a few other emerging and potentially promising quantum technology platforms besides the ones supported in the ramp-up phase of the Quantum Technologies Flagship, such as for example photonic qubits and neutral atom qubits such as Rydberg atoms that would permit to complement those already funded in the Quantum Technologies flagship and that have the prospects of high scalability and fault tolerance.

Scope: In order to reach large-scale quantum computing in Europe, breakthroughs in scalability of quantum computing processors, devices and integrated platforms are needed, together with the ability to perform qubit operations such as read, write, and data transfer, and qubit manipulation with a universal set of quantum gates. Besides the traditional quantum architectures now under development in the Quantum Technologies Flagship, further qubit and platform types, such as for example neutral Rydberg atoms and photonic qubits, need to be considered as candidates for quantum computing that would require further research and development efforts.

The development of new emerging open quantum computer systems and platforms, should be integrating the key building blocks such as quantum processors (> 10qubits) with limited qubit overhead, control electronics, software stack, algorithms, applications, etc. Work should address the scalability towards large systems (>100 qubits), the verification and validation of the quantum computation, fault-tolerance and solving a concrete computational problem to demonstrate the quantum advantage.

Proposals should also cover: (i) the cooperation with complementary projects launched specifically in the area of the enabling quantum software stack (see topic 4 below), including also the need to establish from the beginning of this cooperation appropriate IP exploitation agreements; (ii) the eventual additional support they may receive from relevant national, or regional programmes and initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

Other issues to develop later in the call text

➔ Include benchmarking activities

➔ Include security measures on the participants + IP exploitation restrictions (in Europe)

Topic 3 (2022 Invitation to the selected FPA Consortia): Specific Grant Agreement for developing the first large-scale quantum computers (SGA)

Within the Framework Partnership Agreement (FPA) awarded under topic 1 above, each of the selected consortia will be invited to submit a proposal that will implement the first 3 - 4 years (TBD) of the action plan defined in their respective FPA.

The proposal must progress the quantum computing platform in accordance with the research roadmap as defined in the FPA. This covers in particular progress in key areas such as the number of qubits to reach and the scalability potential, the fidelity / physical error rate, the further development of the underlying quantum computing processors and the low-level control of the programmability capability, the standardisation aspects, etc.

The proposal should describe how the activities carried out during the ramp-up phase will be continued involving the relevant disciplines and stakeholders, how results of the ramp-up phase will be used, and how they will provide efficient coordination under strong scientific leadership. The proposal should detail activities in areas such as education, dissemination, ethics and societal aspects. It should also describe how it will grasp the technological potential in a way that accelerates innovation in all relevant application areas. Partners will be required to give other partners access to results needed for the purpose of any other specific actions under the FPA.

The proposal should also cover: (i) the cooperation with complementary projects launched specifically in the area of the enabling quantum software stack (see topic 4 below), including also the need to establish from the beginning of this cooperation appropriate IP exploitation agreements; (ii) the collaboration with other initiatives or programmes at regional, national, transnational or global level; (iii) the eventual additional support they may receive from relevant national, or regional programmes and initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

Topic 4 (2022): Strengthening the quantum software ecosystem for quantum computing platforms (RIA)

Expected Outcomes:

Projects are expected to contribute to the following outcomes:

- develop quantum-specific algorithms and methods to apply them to problem-solving in a wide variety of industrial fields, giving European industry a competitive edge.

Scope: Fostering a European quantum computing industry will require hardware, software, and the development of user interfaces. Proposals should address the development of quantum-specific algorithms and methods to solve problems, for example in chemical and materials simulation, data analysis and optimisation, and space data processing and mission planning, as well as the more general development of novel quantum algorithms for yet unexplored application areas.

Proposals should target the development of quantum applications and the development of industrial use cases for the quantum computers of the Quantum Technologies Flagship (developed under topics (1) to (3) above). Furthermore, proposals should target the development of quantum software stacks, libraries, etc., that facilitate the link from a high-level description of algorithms to a low-level implementation with quantum gates, for solving concrete problems and applications expected to demonstrate quantum advantage. The developed applications and software should be independent of the underlying qubit platform and their correct functioning should be tested on as many quantum computing platforms as possible within the Quantum Technologies Flagship.

Proposals should also cover: (i) the cooperation with projects of the Quantum Flagship supporting quantum computing platforms, including also the need to establish from the beginning of such cooperation appropriate IP exploitation agreements; (ii) the eventual additional support they may receive from relevant national, or regional programmes and initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

Other issues to develop later in the call text

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe)

DIGITAL-EMERGING-28-2021/2022: Large scale quantum simulators

Topic 1 (2021): Framework Partnership Agreement for developing large scale quantum simulation platform technologies (FPA)

Expected Outcomes: Framework Partnership Agreements (FPAs) in quantum simulation are expected to establish a stable and structured partnership between the EC and the institutions and organisations in quantum simulation who commit themselves to establish, maintain and implement a strategic research roadmap in a scalable open quantum simulation platform based on a specific quantum simulation platform technology.

These partnerships will be set up through an FPA, which will enable the completion of the research roadmap within the context of the agreement.

The consortia responding to the call may include research institutes, universities, RTOs, foundations, industry, SMEs as well as other organisations that can play a role in the realisation of these quantum computing platforms. The FPA shall specify the objectives, the nature of the actions planned, and the procedure for awarding specific grants. Each FPA is expected to contribute to the following outcomes:

- Fully programmable open quantum simulators reaching several hundred individual quantum constituents (by 2025/2026) and above 1000 quantum constituents (by 2029).
- Improved levels of control and scalability and achievement of a further entropy reduction (by a factor of 2 in 2-3 years) of quantum simulators.
- Demonstrated full quantum simulation stack and operational stability for various classes of problems by ensuring maximum online availability.
- Wide accessibility to the quantum simulation platform facilities capable of outperforming the best supercomputers in physical simulations and in a large number of hard optimisation problems relevant for real-world use-cases.

Scope: Proposals for FPAs should aim to build quantum simulators that are capable of simulating far beyond classical possibilities for hard-to-compute quantum or classical systems. The resulting simulator should be based on and reinforce existing physical platforms (such as ultra-cold atoms, trapped ions, Rydberg atoms, or other qubits), therefore consolidating the European scientific leadership in this field. The simulator platform should include user-interfaces and software to allow applications of real world problems in e.g. material science, quantum chemistry and others.

Proposals for FPAs should expand and strengthen the supply chain, aiming for the development of key enabling technologies while improving notions of control of quantum simulators. Entropy reduction and interaction engineering should be supported throughout.

Proposals for FPAs are expected to take in perspective the learning properties of physical systems or to make use of programmable quantum simulators to solve near-term problems of end-users. Applications should be identified in solving practical routing and scheduling problems, and in offering cloud services in the quantum simulation of strongly correlated quantum systems and materials. Proposals should also develop a comprehensive and strategic patent portfolio to protect innovations in the field of quantum simulation and to provide information about the IPRs that are open to licensing.

Proposals for FPAs should also cover: (i) the collaboration with other initiatives or programmes at regional, national, transnational or global level; (ii) the eventual additional support they may receive in their activities from relevant national, or regional programmes and initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

Other issues to develop later in the call text

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe)

Topic 2 (2021): Investing on new proof of performance quantum simulation platform technologies (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Proof-of-concept quantum simulators with several units
- Increased diversity of application-ready quantum simulation platforms

Scope: Proposals should aim to build quantum simulators capable of simulating beyond classical possibilities for hard-to-compute quantum or classical systems. They should aim to develop new proof-of-performance quantum simulation platform technologies complementing the quantum simulation platforms under development in the ramp-up phase of the Quantum Technologies Flagship. They should aim to build highly scalable quantum simulators based on less explored platform technologies, such as photonic simulators making use of single photons in complex networks to generate many body entangled states, or other technologies.

Proposals should aim to demonstrate various methods of validating, verifying and certifying quantum simulations, either efficiently, or by classically simulating the systems in certain accessible regimes.

Proposals should also cover: (i) eventual additional support they may receive from relevant national, or regional programmes and initiatives; and (ii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

Other issues to develop later in the call text

➔ Include benchmarking activities

➔ Include security measures on the participants + IP exploitation restrictions (in Europe)

Topic 3 (2022 Invitation to the selected FPA Consortia): Specific Grant Agreement for developing large scale quantum simulation platform technologies (SGA)

Within the Framework Partnership Agreement (FPA) awarded under topic 1 above, each of the selected consortia will be invited to submit a proposal that will implement the first 3-4 years (indicative) of the action plan defined in their respective FPA.

The proposal must progress the quantum simulation platform in accordance with the research roadmap as defined in the FPA. This covers in particular progress in key areas such as the number of addressable individual quantum constituents, the level of control and scalability and achievement of a further entropy reduction of quantum simulators, the standardisation aspects such as the software interfaces with external systems, etc.

The proposal should describe how the activities carried out during the ramp-up phase will be continued involving the relevant disciplines and stakeholders, how results of the ramp-up phase will be used, and how they will provide efficient coordination under strong scientific leadership. The proposal should detail activities in areas such as education, dissemination, ethics and societal aspects. It should also describe how it will grasp the technological potential in a way that accelerates innovation in all relevant application areas. Partners will be required to give other partners access to results needed for the purpose of any other specific actions under the FPA.

The proposal should also cover: (i) the collaboration with other initiatives or programmes at regional, national, transnational or global level; (ii) the eventual additional support they may receive from relevant national, or regional programmes and initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

DIGITAL-EMERGING-29-2021/2022: Building the Quantum Internet

Topic 1 (2021): Framework Partnership Agreements in Quantum Communications (FPA)

Expected outcomes: Framework Partnership Agreements (FPAs) in Quantum Communication Technologies are expected to establish stable and structured partnerships between the EC and the institutions and organisations who commit themselves to establish, maintain and implement a strategic research roadmap in Quantum Communication Technologies.

These partnerships will be set up through two FPAs, which will enable the completion of the research roadmap within the context of the agreements.

The consortia responding to the call may include research institutes, universities, RTOs, foundations, industry, SMEs as well as other organisations that can play a role in the realisation of Quantum Communication Technologies. The FPAs shall specify the objectives, the nature of the actions planned, and the procedure for awarding specific grants.

The first FPA (on "building the Quantum Internet") is expected to contribute to the following outcomes:

- Demonstrate long-distance (i.e., above 500 km) entanglement distribution involving quantum memories, and demonstrate a fully functional prototype of a quantum repeater operating across multiple nodes of a real world communication networks that will unlock the full potential of a global quantum internet interconnecting quantum computers, simulators and sensors via quantum networks;
- Demonstrate a platform-independent software and network stack on a quantum communication/information network consisting of at least two quantum nodes with quantum memories.

The second FPA (on "quantum encryption and future quantum network technologies") is expected to contribute to the following outcomes:

- Demonstrate open, large-scale, quantum communication networks and system architectures, based on cost-effective network devices and equipment necessary to distribute secret keys, entanglement, and perform teleportation across multi-node quantum networks, demonstrating secure communication over long distances; and, support the development of applications over such networks relevant for the EuroQCI initiative, such as digital signatures, authentication, or clock synchronisation.
- Demonstrate future quantum network technologies in support of the EuroQCI initiative, and showcase disruptive progress in the performance, reliability and efficiency of relevant digital components and devices.

Scope:

Proposals for FPAs are expected to develop quantum communication technologies with improved performance and security to ensure European leadership. They are expected to build on the ongoing projects supported under the Quantum Flagship ramp up phase and on those currently defining the EuroQCI initiative.

Their focus should lie mainly in realising a quantum communication/information network, over very large distances, well beyond what is currently possible, and enabling advanced application functionality for distributing resources such as entanglement. This includes the development of quantum memories and quantum repeaters that are the building blocks of long-distance quantum communication networks on the ground, and could be deployed in a European quantum communication infrastructure (EuroQCI).

Proposals for the first FPA (on "building the Quantum Internet") should focus on the development of a quantum internet interconnecting quantum computers, simulators and sensors via quantum networks. These quantum networks should allow long-distance (>500 kilometres) entanglement-based quantum communication involving quantum memories, and will be inter-liked via a fully functional prototype of quantum repeaters. The FPA proposal should also address the proper functioning of a platform-independent software and network stack for managing the quantum communication network consisting of at least two quantum nodes with quantum memories.

Proposals for the second FPA (on "quantum encryption and future quantum network technologies") should focus on the development of (i) a robust, non-dependent and sustainable supply chain of future-proof Quantum Key Distribution (QKD) technologies; (ii) integration and interoperability in cybersecurity systems and classical communication networks based on optical fibre networks; and (iii) the development of the next generation of quantum communication systems (e.g., device-independent, twin field QKD) with improved performance and security protocols compared to the first generation of QKD systems, to ensure European leadership in quantum network technologies. Proposals should advance quantum network technologies in the above mentioned areas with the aim to achieve improved performances (e.g., higher key rates, fidelities, link distances, robustness, …), post-processing of key generation, key management, including interface to security applications (point-to-point link), achieving higher level system integration and robustness, combining quantum network technologies with conventional network infrastructures and applications for point-to-multipoint links, including new protocols, applications and software and interface management between space and ground infrastructures.

Proposals for FPAs should also cover: (i) the cooperation with complementary projects launched specifically in the area of Quantum encryption and future quantum network technologies (see topic 2), including also the need to establish from the beginning of this cooperation appropriate IP exploitation agreements, (ii) the collaboration with other initiatives or programmes at regional, national, transnational or global level; (iii) the eventual additional support they may receive in their activities from relevant national, or regional programmes and initiatives; and (iv) contribution to the governance and overall coordination of the Quantum Technologies Flagship and (wherever relevant) EuroQCI.

Other issues to develop later in the call text

➔ Mention benchmarking activities

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe)

Topic 2 (2022): Invitation to the selected FPA Consortia): Specific Grant Agreement for building the Quantum Internet (SGA)

Within the Framework Partnership Agreement (FPA) awarded under topic 1 above, selected consortium will be invited to submit a proposal that will implement the first 3-4 years (indicative) of the action plan defined in the respective FPA.

The proposal must progress the Quantum Internet Technologies in accordance with the research roadmap as defined in the FPA. This covers in particular progress in key areas such as enabling long-distance entanglement-based quantum communication.

The proposal should describe how any results of the ramp-up phase will be accessed and exploited, and how it will provide efficient coordination under strong scientific leadership. It should detail activities in areas such as education, dissemination, ethics and societal aspects. It should also describe how it will grasp the technological potential in a way that accelerates innovation in all relevant application areas. Partners will be required to give other partners access to results needed for the purpose of any other specific actions under the FPA.

The proposal should also cover: (i) the collaboration with other initiatives or programmes at regional, national, transnational or global level; (ii) the eventual additional support it may receive in its activities from relevant national, or regional programmes and initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship.

Other issues to develop later in the call text

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe).

Topic 3 (2022 Invitation to the selected FPA Consortia): Specific Grant Agreement for Quantum encryption and future quantum network technologies (SGA)

Within the Framework Partnership Agreement (FPA) awarded under topic 1 above, the selected consortium will be invited to submit a proposal that will implement the first 3-4 years (indicative) of the action plan defined in the respective FPA.

The proposal must progress the Quantum encryption and future quantum network technologies field in accordance with the research roadmap as defined in the FPA.

The proposal should describe how any results of the ramp-up phase will be accessed and exploited, and how it will provide efficient coordination under strong scientific leadership. It should describe how it will grasp the technological potential in a way that accelerates innovation in all relevant application areas. Partners will be required to give other partners access to results needed for the purpose of any other specific actions under the FPA.

The proposal should also cover: (i) the collaboration with other initiatives or programmes at regional, national, transnational or global level; (ii) the eventual additional support it may receive in its activities from relevant national, or regional programmes and initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship and the EuroQCI initiative.

Other issues to develop later in the call text

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe).

DIGITAL-EMERGING-30-2021: Quantum sensing technologies for various applications

Topic 1 (2021): Quantum sensing technologies for market uptake (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- A host of mature quantum sensing technologies and devices (TRL 6-7) in many different application sectors supported by spin-off companies with the establishment of a reliable, efficient supply chain including first standardisation and calibration efforts for rapid market uptake.

Scope:

Proposals should address the development of relatively mature quantum sensing technologies and single or network-operating devices that have the potential to find a broad range of new applications in transportation, precise localisation, health, security, telecommunications, energy, electronics industry, construction, mining, prospection, and much more.

Proposals should demonstrate advanced prototypes of such sensing technologies that provide an unprecedented level of precision and stability, making new types of sensing, imaging and analysis possible. For rapid market uptake, they should target miniaturised, integrated, transportable quantum sensors and provide first plans for their further industrialisation through enhanced cost efficiency and user operability at higher TRL.

In order to achieve the above, proposals should include relevant actors from the whole value chain (from materials to devices and to system integration aspects). They may also include, wherever relevant, activities and actors from metrology institutes that would provide measurement methods and/or standards, including for the development of quality assurance methods and for standardisation of the targeted quantum sensing technologies.

Finally, proposals should also cover: (i) eventual additional support they may receive from relevant national, or regional programmes and initiatives; and (ii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

Other issues to develop later in the call text

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe)

Topic 2 (2021): Next generation quantum sensing technologies (RIA)

Expected outcomes: Projects are expected to contribute to the following outcome:

- Demonstrate the feasibility of next generation quantum sensing technologies and devices by showing disruptive progress in the performance, reliability and efficiency of such technologies and devices and by enhancing the TRL of all (essential) components necessary to build them.

Scope:

Proposals should focus on next generation quantum sensors that provide extreme precision and accuracy measurements in many fields, boosting the performance of consumer devices and services, from medical diagnostics and imaging, high-precision navigation, and monitoring, to future applications in the Internet of Things and for enhanced measurement and metrology.

Proposals should address: (i) the development of new methods and techniques to achieve full control over all relevant quantum degrees of freedom and to protect them from environmental noise; and/or (ii) identify correlated quantum states that outperform uncorrelated systems in a noisy environment and methods to prepare them reliably. Proposed work should exploit quantum properties (such as coherence, superposition and entanglement) emerging in individual quantum systems to improve the performance of the targeted sensors technologies (e.g. in terms of resolution, sensitivity or noise), well beyond the classical limits.

Proposals should target the development of laboratory prototypes (from TRL 2-3 to 4-5) demonstrating the practical usefulness of engineered quantum states of light/matter to improve sensing or imaging and develop and demonstrate optimized quantum software for detection applications in real-world applications. They should leverage interdisciplinary expertise and join forces with metrology institutes or other relevant technical fields to further advance the limits of sensors sensitivity and resolution and to implement the best control protocols, statistical techniques (e.g. Bayesian, among others) and machine learning algorithms.

Finally, proposals should also coordinate their respective activities within each sensing subfield (solid-state, atomic systems, photonics) and contribute to the governance and overall coordination of the Quantum Technologies Flagship.

Other issues to develop later in the call text

➔ Mention links to the governance and overall coordination of the QT Flagship

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe)

DIGITAL-EMERGING-31-2021/2022: Open testing, experimentation and first fabrication (production) capabilities for quantum technologies

Topic 1 (2021 FPA Call): Framework Partnership Agreements for open testing and experimentation and for pilot production capabilities for quantum technologies (FPA)

<u>Expected Outcomes</u>: Framework Partnership Agreements (FPAs) respectively for open testing, experimentation, and for pilot production capabilities for quantum technologies are expected to establish stable and structured partnerships between the EC and the institutions and organisations who commit themselves:

- To create long-term open, supportive and sustainable experimental and testing infrastructures in Europe that are openly accessible by European academia and industry; and,
- To develop and provide access to first European fabrication (production) capabilities for quantum technologies, building on and linking together existing infrastructures.

These partnerships will be set up through two FPAs, which will enable the completion of the research roadmap within the context of the agreements. The FPAs shall specify the objectives, the nature of the actions planned, and the procedure for awarding specific grants.

The first FPA ("supporting open testing, and experimentation for quantum technologies in Europe") is expected to contribute to the following outcomes:

- Establish a technology innovation roadmap through effective consultation with industry for linking early-stage capabilities to industry developments.
- Provide open testing, and experimentation capabilities for quantum technologies, that are available to scientists, engineers and users, and provide innovation support services to individual companies, in particular a broad spectrum of SMEs.
- Establish a well-connected network at European level and federate competences to increase European testing and experimentation capabilities of quantum technologies, and reduce their time-to-market.
- Provide services for the development of a European supply chain of quantum technologies, provide European industry, especially start-ups and SMEs, with the necessary innovation capacity, and make sure that critical IP remains within the EU.

The second FPA ("supporting experimental production capabilities for quantum technologies in Europe") is expected to contribute to the following outcomes:

- Establish a capability innovation roadmap for providing experimental (pilot) production capabilities and a roadmap for transferring such capabilities to an industrial production environment.

- Provide experimental production capabilities for quantum technologies in computing, communication and /or sensing available to users, including industry, in particular SMEs and contribute to developing European standards in the field.
- Provide services for the development of a European supply chain of quantum technologies, provide European industry, especially start-ups and SMEs, with the necessary innovation capacity, and make sure that critical IP remains within the EU.

<u>Scope</u>:

Proposals for both FPAs above are expected to establish well-networked lab facilities that interact and support each other. Proposals should federate key competences in the whole innovation value chain, from business-model development to promoting open-access to innovation and know-how, in order to provide access and support to European quantum technologies innovation actors.

Proposals should develop practical strategies in synergy with European academic and industrial players (especially start-ups and SMEs), and quantum technologies innovation actors in Europe to provide the quantum ecosystem with a ‘one-stop-shop’ to unique facilities, competences and know-how centred at various locations in Europe.

The consortia applying for the first FPA should include a balanced and inclusive network of RTOs and other excellent European institutes equipped with state of the art quantum experimental facilities, infrastructures and tools, and other key innovation players that can play a role in the implementation of sustainable open experimental and testing infrastructures in quantum technologies.

The consortia applying for the second FPA should include a balanced and inclusive network of RTOs and other excellent European institutes, small foundries, unique manufacturing providers, and other key innovation players that can play a role in building and providing experimental pilot production capabilities for quantum technologies.

The proposal for both FPAs should also cover: (i) the collaboration with other initiatives or programmes at regional, national, or European level; (ii) the eventual additional financial support they may receive in their activities from relevant national or regional initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

<u>Other issues to develop later in the call text</u>

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe)

Topic 2 (2022 Invitation to the selected FPA Consortia): Specific Grant Agreement for supporting open testing and experimentation for quantum technologies in Europe (SGA)

Within the Framework Partnership Agreement (FPA) awarded under topic 1 above, the selected consortium will be invited to submit a proposal that will implement the first 3 - 4 years (TBD) of the action plan related to the pan European provision of open testing and experimentation facilities defined in the FPA.

The proposal must progress the open testing and experimentation capability of European academic and industrial players, especially of start-ups and SMEs, in accordance with the technology/capability innovation roadmap as defined in the FPA. This covers in particular progress in establishing a well-connected network providing access to open testing, and experimentation facilities in Europe, as well as access to unique competences and know-how centred at various locations in Europe.

The network should be a 'one-stop-shop' to make state of the art hardware, experimental instrumentation and related facilities, technologies and tools as well as knowledge and expertise in quantum technologies available to European scientists, engineers and industry players, especially start-ups and SMEs, with the aim to establish an inclusive and effective quantum technologies lab-to-market ecosystem in Europe.

By enabling innovation experiments, the network will deliver improved design processes, better products and services, shorter time-to-market and improved innovation and competitiveness capabilities.

The proposal should also cover: (i) the collaboration with other initiatives or programmes at regional, national, or European level; (ii) the eventual additional financial support they may receive in their activities from relevant national or regional initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

Topic 3 (2022 Invitation to the selected FPA Consortia): Specific Grant Agreement for supporting experimental production capabilities for quantum technologies in Europe (SGA)

Within the Framework Partnership Agreement (FPA) awarded under topic 1 above, the selected consortium will be invited to submit a proposal that will implement the first 3 - 4 years (TBD) of the action plan for providing pilot fabrication capabilities defined in the FPA that would foster product development and rapid innovation especially for European industry, in particular start-ups and SMEs.

The proposal should aim to establish experimental (pilot) production capabilities for a first of their kind quantum technologies, where European companies, research centres and academic institutions can produce novel devices on a pilot scale based on a shared cost model between users and service providers.

Each of the targeted experimental (pilot) lines should have a simple baseline process ready in 2-3 years (TBD) from start of the project and the full flow should be ready during the lifetime of the FPA. The development and operation of each experimental pilot line will be coordinated closely with the core projects of the Quantum Flagship through a dedicated collaboration agreement.

The action will require expertise in the area of manufacturing flows for quantum technologies, in particular in quantum computing (for e.g. qubit fabrication) and sensing, and with issues regarding reliability, versatility, process control including integrated testing and minimizing lead times. Where necessary such expertise should be brought into the consortium under proper consideration of IP issues.

The action should demonstrate how it federates key competences in the whole innovation value chain, from business-model development to first fabrication, through a balanced and inclusive network of RTOs, small foundries, unique manufacturing providers, and other key innovation players, effectively acting as fabrication laboratories.

The proposal should also cover: (i) the collaboration with other initiatives or programmes at regional, national, or European level; (ii) the eventual additional financial support they may receive in their activities from relevant national or regional initiatives; and (iii) contribution to the governance and overall coordination of the Quantum Technologies Flagship initiative.

DIGITAL-EMERGING-32-2021 – International cooperation and Standardisation

Topic 1 (2021): International cooperation with Canada (RIA)

Expected outcomes: Joint EU – Canada projects are expected to contribute to the following outcomes:

- Advances in quantum technologies in specific areas of mutual EU – Canada interest, including Quantum Computing & Simulation, Quantum Networking & Communication, Quantum Sensing & Metrology.
- Reinforcement of the EU – Canada research excellence in the specific areas of mutual interest described above, including the establishment of strategic partnerships in research, education and training.

Scope:

Proposals are expected to address a mix of quantum technology challenges in the areas of quantum communication, computing, simulation and sensing and identify the added value and/or mutual benefit for both EU and Canadian partners. These should include the integration of different aspects like physics, engineering, computer science, theory, algorithms, software, manufacturing, control, infrastructures, etc.

Relevant challenges, include:

- Quantum computing and simulation co-design of hardware and software to accelerate applications; seamless interoperable software-to-hardware stack that can apply over multiple platforms, and theoretical and computer science foundations of quantum algorithms and architectures.
- Privacy and security concepts, proofs and applications for quantum communication, including QKD (quantum key distribution) and beyond; device independent protocols, quantum network/repeater protocols, including architectures and network stack;

development of satellite and space-based hardware, and certification/verification of states and correlations.

- Application-specific quantum sensor development covering: device fabrication, characterisation, e.g. for magnetometry, prospection, imaging, navigation, biomedical, and theoretical research optimising simple sensors, control, as well as advanced approaches (use of entanglement and error correction).

Proposals should address one or more of these challenges and clearly define the benefit the EU-Canada collaboration brings. In order to raise the Technology Readiness Level (TRL), support for holistic - software and hardware - engineering approaches across all areas are encouraged.

Topic 2: Standardisation support in quantum technologies (2021 CSA call)

Expected outcomes: The action is expected to contribute to the following outcomes:

- contribute to the development of international standards and regulations in quantum technologies and quantum applications, ensuring that Europe plays a leading role in global quantum standardisation initiatives.

Scope:

Proposals should address concrete standardisation activities in European and international standardisation fora where Quantum Technologies will play a major role in the near future and where standardisation can enhance existing capabilities and offer a competitive advantage to Europe. Examples are: quantum computing and quantum-enabled security such as QKD, QRNG, quantum sensing & metrology that include quantum enhanced medical imaging devices, quantum gravity sensing devices, quantum timing devices, etc.

For this, proposals should develop an active presence and leadership in the coordination and development of international standards and regulations in quantum technologies either in existing standardisation activities and bodies and where relevant, by contributing to creating new standardisation activities in existing groups and/or creation of new groups.

Proposals should bring together all the relevant stakeholders in the whole quantum technology standardisation value chain – research, standardisation and the industry sectors, and if relevant, public administrations/institutions. They should describe which players they will mobilise and how they will efficiently coordinate them at European level to achieve impactful results promoting the European interests in standardisation. Links to metrology aspects should also be included, wherever relevant.

DIGITAL-EMERGING-33-2022: Basic Science for Quantum Technologies (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Opening up new avenues for potential growth in the field of quantum technologies
- Novel concepts, leading to more advanced technologies continue to support the basic science research carried out by the Quantum Technologies Flagship, ensuring that it informs the Flagship's work in other quantum fields, and/or explores new directions within existing fields.

Scope:

Proposals should aim to explore new quantum effects and gain new knowledge that is not limited to the pillar activities, and which may contribute to new quantum technologies and applications in the long term. Areas of particular interest include quantum information theory, the identification of new laws and limits, understanding the mechanisms behind decoherence, the development of certification methods for quantum technologies, and research that goes beyond the field of pure quantum technologies, such as the study of quantum effects in thermodynamical or biological processes.

The technological resources include strategic components, ranging from fundamental properties to engineering quantum devices and systems (TRL 2-4) to interfacing these across different, always with a view towards end-user applications and their operation. Examples are: light sources, interfaces, and single photon detectors, which are compatible and interoperable. The development of new materials, single integrated solutions or hybrid integrated solutions that are miniaturised and scalable, fabrication and packaging solutions, are also key challenges, as is the development of new protocols, control approaches and algorithms.

Proposals should contribute to (i) the governance and overall coordination of the Quantum Technologies Flagship initiative, (ii) where relevant to inter-project cooperation, in particular with the 4 main pillars of the Quantum Technologies Flagship (quantum computing, quantum simulation, quantum communication and quantum sensing and metrology).

Other issues to develop later in the call text

➔ Mention specific security conditions for eligible partner participation + IP exploitation restrictions (in Europe)

DIGITAL-EMERGING-34-2021: Support the coordination and training activities of the Quantum Technologies Flagship (CSA)

Topic 1 (2021): Support the coordination of the Quantum Technologies Flagship activities (CSA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- support the efficient functioning of the Flagship and promote its activities to a wide public
- enable Flagship projects to find synergies in their work and share best practice

- publish a European research and industry community roadmap that provide the route from research to industrial exploitation
- foster a European quantum community and provide a forum for productive discussions on Research and Innovation strategies

Scope:

Proposals should ensure the smooth running and further development of the Flagship and raise the profile of its activities and of quantum technologies in general and update the European Strategic Research and Innovation Agenda, in particular by working on the following: support the operation of the Flagship's governance structure; conduct a community based process for preparing a Research and Innovation investment Roadmap and priorities by involving research and industry stakeholders, undertake wide dissemination of the Quantum Flagship results; organise outreach events and engage in discussions with the general public; provide research dissemination services to projects; identify relevant training, education and infrastructure needs.

Proposals should also encourage the Flagship's projects to find synergies in their activities and share best practice, and foster the growth of a European quantum community that links all academic and industry stakeholders, including by contributing to the coordination of activities between European, national and regional programmes and projects.

Finally, proposals should work on establishing dialogue with other international programmes in quantum technologies and in promoting international cooperation activities. In particular, they should be supporting collaborative discussions between the main international players, including countries such as the USA, Canada, Japan, Australia, and the EU, exploiting complementary strengths and challenges in collaborative research that ensures a clear win-win situation for both parties and ongoing leadership on the global stage.

Proposals should involve and be driven by representatives of the relevant actors of the field (e.g., academia, RTOs, and industry, including SMEs, and intermediaries).

Topic 2 (2021): Training and Education on Quantum Technologies (CSA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Define a European core curriculum for Quantum Technologies to prepare postsecondary students for the challenges arising in quantum industry and academic research.
- Facilitate access to services and training offered to interested postsecondary students, workforce and other potential users (from industry, academia or public sector)
- Addressing the skills gap in Quantum technologies related domains by specialised training to develop the human capital resources to address increased skills need in industry (including SMEs).
- Create training programme curricula in close cooperation with industry for the quantum workforce according to the specific skills required by the quantum and end user industry.

- Implement innovative research-based curricula in quantum technologies for the university and secondary school education levels in all European countries.

Scope:

Proposals should perform an extensive mapping of current and future requirements for education and training; define standards for implementing appropriate educational strategies; host existing and newly developed teaching materials and resources within a repository; develop strategies for scaling up advanced quantum technology training programmes across Europe; and, establish a network between science and industry to exchange ideas, needs, and human resources (e. g. in the form of student internships). In doing so, they should work in close cooperation with the Flagship project actors.

Proposals should also address the coordination of the education activities and strategies they would work upon with the relevant national actors.

Proposals should involve and be driven by representatives of the relevant actors of the field (e.g., academia, RTOs, and industry, including SMEs, and intermediaries).

Section: Graphene: Europe in the lead

[Expected impacts addressed: #15 (Green), #18 (Digital and emerging enabling technology sovereignty)

Objective: strengthen and accelerate the technology developments that would support a strong European supply and value chain in graphene and related materials and provide first-mover market advantages of scale.

Current status: The starting point is the Graphene Flagship, launched in 2013, which already reached European leadership in graphene and related 2D materials. The Flagships is now coming to a critical point where first simple products are being launched. R&I activities of the Flagship would now need to be pursued and accelerated in order translate achieved technology advances that are at TRL 4-5 into concrete innovation opportunities and into production capabilities in many industrial sectors (aviation, automotive, electronics, batteries, healthcare).

Achievements sought / targets:

- take advantage of the unique properties of graphene and 2D materials for drastically improving performance and creating new functionalities for **devices in a large number of industrial applications and sectors**, spanning from electronics to sensors, composite materials, energy generation (e.g. photovoltaics) and storage, biomedical technologies, and others;
- ensure consistent **high-quality production methods** for graphene and other 2D material**s, expand Europe's experimental pilot lines to reach** market-making capacity and ensure **first production capabilities in Europe** for high value-added products.

Means/Links: *Links to other clusters*: Graphene and related 2D materials' properties can significantly contribute to improving performance of batteries [cluster 5/partnership] and of biomedical technologies [cluster 1].

Links to other Partnerships: Graphene and related 2D materials' properties can significantly contribute to improving 'KDT' (photonics communication/sensors, next generation electronics) and advanced materials, Research on graphene and other 2D materials benefits from advances in Artificial Intelligence ('AI, data & robotics') and Advanced Computing ('EuroHPC').]

Proposals are invited against the following topic(s):

DIGITAL-EMERGING-38-2021: Uncover the 2D materials of tomorrow (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Establish a broad portfolio of innovative 2D materials (2DM) and multicomponent heterostructures, exhibiting a variety of functionalities and new physical phenomena, as started by the Graphene Flagship.

- Deliver controllable, reproducible and large-scale synthesis, fabrication methods and designs based on novel approaches, as well as new characterisation methods and reliable protocols synthesis of/for novel 2D materials and compounds. This topic will foster Europe's leading position in the 2D materials' cutting edge science and technology.

Scope: Proposals should create the basis for the exploitation of most promising 2DMs and 2DM technologies, namely develop controlled, ultra clean and large scale synthesis, fabrication methods and design of 2DM and heterostructures based on novel approaches e.g. Artificial Intelligence assisting material assembly and material simulation, robotics-based assembly, and advanced synthetic, preparation and growth methods combined with the help of modelling and simulation.

Proposals should develop high-quality materials and heterostructures that will demonstrate novel properties and enable to create a platform for developing new devices and new device concepts as well as reliable methods and protocols for improved synthesis, identification and exploitation of 2DM with novel properties.

DIGITAL-EMERGING-39-2021: New generation 2D materials-based component and devices.

Topic 1 (2021 call): New generation of/advanced (opto-) electronic and photonic 2D materials-based devices and sensors (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- New technological solutions with improved performance and reduced energy consumption providing significant advances towards the integration of 2D materials (2DM) technology in the semiconductor arena, and the emergence of competitive value chains in Graphene in Europe.

Scope: Proposals should cover the development of 2DM-based devices and systems bringing 2DM technology one step further towards the integration in current semiconductor technology and to the development of radically new prototypes and/or solutions for industry for a wide range of application areas overcoming integration cost, functionalities and/or power consumption challenges. The proposals should develop 2DM-based (opto-)electronic and photonic devices including ultrafast circuits, photodetector, and modulators, broadband detectors, switches, as well as sensors, advanced electronics, metamaterials, etc., serving applications such as 5G and 6G data communications, wireless connections, smart machine vision, autonomous robots and vehicles, internet of things, and neuromorphic circuitry and/or image applications. The 2DM-based devices and systems should demonstrate their added value in terms of e.g. functionality, integration, miniaturization, performances, power consumption, costs, etc. compared to current conventional technologies.

The proposals should also explore, develop and assess the route(s) for integration (e.g. wafer growth, transfer, wafer scale integration, co-integration) of 2DM into the devices and systems favouring industrial uptake in the longer-term.

Topic 2 (2021 call) : 2D materials-based devices and systems for energy storage and harvesting (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- New technology solutions for portable energy sources outperforming alternative technologies in terms of energy and power density, operational safety, long-term stability, mechanical flexibility, light weight, thin thickness, and low cost that will enable the rapid development of power-demanding smart devices, Internet of Thing (IoT) sensors and wearable electronics.
- Demonstrated added value of 2D materials (2DM) for energy storage devices and systems in applications where Europe can build competitive value chains.

Scope: Proposals should develop solutions demonstrating the potential added value of 2DM based energy storage like large energy storage technologies, beyond current Li-ion, for electric power grids/solar farms/wind farms with increased performances in terms of durability, safety, energy density and power density. Proposals should also work on structural batteries and structural supercapacitors and related production techniques, i.e. energy storage devices integrated in structural parts of e.g. airplanes or cars, to address the demand of distributed sensors and electronics, functional printed micro-flexible supercapacitors for e.g. IoT applications are included as well.

Proposals addressing energy harvesting should investigate/establish proof of concepts/develop 2DM-based devices for energy conversion that can produce electricity in response to e.g. light, moisture, flowing liquid, friction, pressure force, or heat with unprecedented characteristics or unique functionalities.

Topic 3 (2021 call): 2D materials-based devices and systems for biomedical applications (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- New technology solutions exploiting the unique properties of 2D materials (2DM) that would reduce cost and increase efficacy of therapies, or provide new therapies for which there is currently no solution, thus contributing to reducing hospitalization time.

Scope: Proposals should build on the multi-functionality allowed by 2DMs and demonstrate the advantages of combining e.g. biocompatibility, chemical stability, extreme recording, sensing and actuating, and integration with flexible electronic technologies, in addition to versatile surface chemistry (for interface with biology) to allow built-in pharmacological interventions.

Emphasis of the proposals should have a translational perspective, addressing how the devices and systems will reach the clinic, preferably led by European industry. Furthermore, the proposals should bring together multidisciplinary teams including engineers, material scientists, pharmacologists, biologists, clinicians, patients, and ethics experts. Potential application areas include: Engineering & bioengineering of bioelectronic therapeutic devices, sensors for digital health, Electronics for brain-computer interfaces, taking advantage of flexible devices, Medical imaging in combination with implantable devices (e.g. MRI), Graphene for drug delivery of therapeutics eg for neurological disorders.

DIGITAL-EMERGING-40-2021: 2D-material-based composites, coatings and foams (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- leading for instance to new multifunctional recyclable materials enabling solutions to environmental challenges.

Scope: Proposals should address 2D materials (2DM) composites, aero-gels and foams that can bring the full nanoscopic functionality of 2DM from nano- and microscale into the macroscopic world. They should target in particular the development of 2D materials and technologies mainly addressing environmental issues including e.g. oil spill removal from water, water purification with low energy consumption and improved water desalination. They should also target the development of next generation, lightweight, recyclable composites and coatings endowed with key functionalities like e.g., high temperature performance, structural health monitoring, etc and as enablers for structural batteries or hydrogen storage. They should address as well as Metal-2DM composites enabling ultralow friction surfaces, reducing energy loss in sliding mechanical and electrical parts and the development of 2DM foams enabling hydrogen economy through catalytic hydrogen generation and storage are also included.

Proposals must implement from the very beginning life cycle assessment (LCA) and end-of-life (EOL) materials management to fully capture the advantage and develop greener materials and processes.

Proposals should deliver prototypes with demonstrated and cost-effective added value in terms of performances, energy consumption and recyclability compared to alternative approaches.

DIGITAL-EMERGING-41-2021: Experimental pilot lines for 2D materials-based devices (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- broadly accessible experimental pilot line(s) fostering the creation of devices based on 2D materials (2DM) with applications in biomedical technologies, opto-electronic, spintronics and/or sensors, and/or quantumtechnologies) will lead to significant progress towards the adoption of the 2DM technology by demonstrating /producing specifically targeted small-volume of integrated systems in quality controlled way.

Scope: Proposals should aim to establish a 2D Material (2DM) experimental manufacturing facility[42], where European companies, research centres and academic institutions, can produce novel devices on a pilot scale based on a shared cost model between users and service providers. This pilot line would be used for all-on-chip applications in areas such as biomedical technologies, opto electronics, spintronics, sensors, quantum technologies, neuromorphic computing and should be able to cover the device requirements of most of these applications.

Proposals must include work for building the toolkit and design manuals necessary for creating prototype devices and integrated circuits, and assess their performance and their ability to cover the device requirements of the targeted applications. At the end of the project, the action should be capable of multiple wafer runs per year.

Proposals should describe a sustainable model of functioning beyond the project lifetime and include activities during the lifetime of the project that would pave the ground for transferring the pilot to an industrial production environment. Examples include addressing issues such as roadblocks to overcome for achieving a full industrial line, relevant cost issues and market perspectives, potential business partners; etc.

[42] A first experimental pilot line for 2d materials was established in 2020 under the Graphene Flagship initiative: see https://graphene-flagship.eu/news/Pages/Europe-developing-its-first-experimental-pilot-line-for-2D materials-.aspx#:~:text=Europe%20developing%20its%20first%20experimental%20pilot%20line%20for%202D%20materials,-%E2%80%8BBy%3A%20Rebecca&text=%E2%80%8BThe%20European%20Commission%20has,(GRMs)%20in%20semiconductor%20platforms

DIGITAL-EMERGING-42-2021: 2D materials production and manufacturing technologies (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Reliability, reproducibility and quality control of 2D materials (2DM) and production methods and processes for new coatings, composites and other 2DM-based materials.

Scope: Proposals should address the challenge of reaching reliability and reproducibility in 2DM materials and production processes.

For the material itself, proposals should target in particular the scalability in exfoliated 2DMs; the in-situ characterisation for improved synthesis; and the development of characterization and labelling protocols for qualifying 2DM along the value chain.

For the production, proposals should target in particular integrated direct crystal growth; low-defect large-scale graphene; and additive and hybrid manufacturing (i.e. Printed 2DM components that can be integrated into the product directly in the production process).

Proposal activities should cover the development of new manufacturing methods for 2DMs enhanced composites enabling the adoption of these advanced materials in many industrial sectors e.g. automobile, contruction, aerospace by addressing their respective requirements. This includes production methods for taking advantage of the 2DM properties that go beyond increasing strength, like electrical conductivity, fire retardancy, higher thermal and mechanical stability and inherent sensing properties. This also covers methods and tools for new production lines of advanced reinforced 2DMs composites.

Proposals should also cover the development of barrier, lubricant and anti-wear performance of 2DMs in nanocoatings and thick coatings for conventional use in metals (embedded in a matrix: paints, metallic coatings, etc).

DIGITAL-EMERGING-43-2021: Sustainable safe-by-design 2D materials technology (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- A set of robust and verified assays for toxicity and ecotoxicity testing of 2D materials (2DM), to support regulatory requirements for their registration and authorisation for use (OECD test guidelines, REACH compliance, authorisation pathways).

Scope: The increasing commercial exploitation of 2DM necessitates a comprehensive evaluation of their potential impact on human health and the environment. It is thus of utmost importance for 2DM technology development to understand the properties that underlie the potential toxicity of these materials. Since not all 2DMs are alike, it is essential to disentangle the structure-activity relationships for this class of materials.

Proposals should aim to ensure a safe development of 2DM technology and in the long term, a sustainable market entry/penetration of 2DM-based products.

They should critically examine 2DM health and environment issues, ranging from general toxicology, to occupational health and environmental impact. Studies and tests of biocompatibility and safety of 2DMs and composites along their lifecycle are also covered. Proposals should implement solutions to modulate potential risks by developing chemical approaches towards safer manufactured materials and nanomaterials (safe-by-design 2DMs).

Proposal should also assess the safety at different TRL levels to develop and test best practices along the product development process, from prototypes to product tested in relevant environments in order to guarantee the highest impact possible.

DIGITAL-EMERGING-44-2022: Supporting the coordination of the Graphene Flagship activities

Topic 1 (2022 call): Supporting the coordination of the Graphene Flagship (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- A strong and coherent Graphene Flagship initiative on 2D materials (2DM) by providing key support functions, enabling Flagship projects to find synergies in their work and share best practice, and favouring interactions and synergies with national and regional initiatives, projects and infratructures in the domain.

Scope: Proposals should address the need to guarantee a sustained European leadership in 2DM, capitalise upon the investments made so far in Graphene, exploit synergistically the scientific, technological and innovation outcomes of these investments and deliver benefits to the European society. Proposals should support the coordination of the Graphene Flagship initiative projects that would be selected under the call topics of the initiative. They should address all the coordination and support functions necessary to build a strong Flagship initiative, including: Governance, Community engagement, Dissemination, communication, outreach, dialogue with the public, etc. They should alsowork on creating new education and training curricula, promoting Innovation, developing Research and innovation roadmapping activities, liaising with and supporting the coordinating with relevant national and regional 2DM activities and establishing and supporting the dialogue with other international relevant programmes and initiatives in the field..

Proposals should involve and be driven by representatives of the relevant actors of the field (e.g., academia, RTOs and industry, including SMEs).

Topic 2 (2022 call): Synergy with national and regional initiatives in Europe (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Well coordinated Euorpean, national and regional initiatives in Graphene.

Scope:Proposals should support the coordination required between relevant national and regional public authorities in Graphene in working synergetically together with the aim to strengthen and complement the EU funded activities in the domain. Proposed activities should include maintaining an inventory of funding and scientific landscapes in the domain of 2D materials in Europe; analysing the gaps and overlaps; and contributing to topics that could be included in national/regional research agendas in the field. Such work may also include the support required for the national and regional actors to organise joint calls for proposals between their respective programmes and initiatives for supporting in Europe the further development of a strong innovation ecosystem in Graphene.

Proposals should involve and be driven by representatives of the relevant actors of the field (e.g., public authorities, academia, RTOs or industry, including SMEs).

DESTINATION 5 – Strategic autonomy in developing, deploying and using global space-based infrastructures, services, applications and data

In 2016, the European Commission published a 'Space Strategy for Europe', with the following main objectives: maximizing the benefits of space for society and the EU economy, fostering a globally competitive and innovative European space sector, reinforcing Europe's autonomy in accessing and using space, and strengthening Europe's role as a global actor. To implement this strategy, a proposal for a Space Programme for the period 2021-2027 was published in June 2018. The proposal includes the continuation of the flagships programmes Galileo, EGNOS and Copernicus, adds two new components Space Situational Awareness (SSA) and secure governmental satellite communications (GOVSATCOM).

The added-value of the space sector for EU economy and society, EU policies and EU citizens is obvious. Today we enjoy increasingly accurate global navigation services for all transport modes and users, extended Earth monitoring for land, marine, atmosphere and climate change, global meteorological observation and accurate cartographies of a wide number of variables. Space also makes important contributions to security crisis management and emergency services. These are key assets for the EU policies on climate, environment, transport, agriculture and secure society (e.g. Maritime Strategy, the Arctic Strategy, the Digital Agenda, the Common Security and Defence Policy, the Sustainable Development Strategy). Space technologies, data and services have also become indispensable in the daily lives of European citizens when using mobile phones and car navigation systems, watching satellite TV or withdrawing cash. Finally, the space sector is a source of economic growth, jobs and exports with the potential to spin-out a number of innovations in other sectors and to create a wealth of downstream applications and services.

With 43000 jobs, the upstream segment of the European space industry, i.e. manufacturing of launcher and spacecraft, represents 6% of the global space industry workforce and generates EUR 8.8 billion of consolidated revenues. Relying on these upstream space assets, much broader mid-stream and downstream sectors can develop a wealth of services. Today, it is estimated that 10% of the EU's GDP depends on the use of space services. The overall European space economy (upstream, mid-stream and downstream) is estimated to employ over 230 000 professionals generating a value of EUR 46-54 billion or 21% of the worldwide business in the sector[43].

This destination will directly support the following Key Strategic Orientations, as outlined in the Strategic Plan:

[43] Socio-economic impacts from Space activities in the EU in 2015 and beyond, PWC study, 2016. This figure only tracks the value of commercial space services and system procurement activities; it does not include the implicit value of free space services (such as the Galileo signal or the 16Tb of Copernicus data generated every year).

- A, '**Promoting an open strategic autonomy by leading the development of key digital, enabling and emerging technologies, sectors and value chains** to accelerate and steer the digital and green transitions through human-centred technologies and innovations.'
- B, **'Restoring Europe's ecosystems and biodiversity, and managing sustainably natural resources** to ensure food security and a clean and healthy environment.
- C, '**Making Europe the first digitally led circular, climate-neutral and sustainable economy** through the transformation of its mobility, energy, construction and production systems.'
- D, '**Creating a more resilient, inclusive and democratic European society,** prepared and responsive to threats and disasters, addressing inequalities and providing high-quality health care, and empowering all citizens to act in the green and digital transitions.'

Proposals for topics under this Destination should set out a credible pathway to contributing to the following expected impact:

> **Strategic autonomy in developing, deploying and using global space-based infrastructures, services applications and data,** including by reinforcing the EU's independent capacity to access space, securing the autonomy of supply for critical technologies and equipment, and fostering the EU's space sector competitiveness.

This expected impact is fully in line with the Space Strategy for Europe[44] and the proposal for the Space Programme[45].

Horizon Europe R&I funds will contribute to this expected impact along 2 main axes by:

- providing support with R&I funding to the EU space sector at large
- making a specific impact with the European Union action with i) R&I to prepare the future evolutions of the current EU flagship Space Programme components Galileo / EGNOS for positioning, navigation and timing and Copernicus for Earth observation ii) R&I to support the emergence of two new Space programme components to ultimately deliver services for Space Situationnal Awareness and for secured governmental communications GOVSATCOM; these are tangible assets which the EU puts at the disposal of governments, industry and citizens.

This Destination is therefore structured into the following sections:

1. Foster competitiveness of space systems

[44] COM(2016)705
[45] COM(2018)447

2. Reinforce our capacity to access and use space
3. Evolution of Space and ground infrastructures for Galileo/EGNOS
4. Evolution of services of the EU Space Programme components Galileo, EGNOS and Copernicus
5. Development of applications from the EU Space Programme components
6. Innovative space capabilities: SSA, GOVSATCOM, Quantum
7. Space entrepreneurship ecosystems (incl. New Space and start-ups) and skills
8. Targeted and strategic actions supporting the EU space sector

While sections 1, 2, 7 and 8 will support the EU space sector at large, sections 3), 4), 5), and 6) will be support the Space Programme components as well as the quantum emerging initiative.

All sections will contribute to the 'Strategic autonomy in developing, deploying and using global space-based infrastructures'. This is of course obvious when investing in R&I to ensure the future of exisiting space programme components infrastructures, services and applications (section 3) and with R&I to investigate new future services (sections 4 and 5). This autonomy would however not be complete if we would not have the capacity to access space and launch these infrastructures (section 2) and propose opportunities for In-Orbit Demonstration and In-Orbit Validation (section 8). We have also to recognise that the EU space sector can rely on a smaller share of institutional investment compared to other regions. This difference needs to be compensated by a more competitive sector (section 1). R&I and a strategy for critical technologies for non-dependence is another important axis of action (section 8). A guarantee for such autonomy is also to have a vivid and competitive entrepreneurship eco-sytems in the EU (section 7).

The following call(s) in this Work Programme contribute to this Destination:

The Destination structure and the allocation of topics to calls and year will be decided at a later stage.

Section: Foster competitiveness of space systems

[Objective: The European space sector and space economy needs to improve space-based capabilities, capture new markets, adapt to rapidly changing markets whilst staying competitive in the satellite communication, navigation and Earth observation sectors. This requires development of new competitive technologies for space and ground systems, such as very high throughput satellites, very high resolution sensors, radiation-hard electronics, on-board and ground AI, optical communication and quantum technologies, as well as contributions from robotics. We also need to prepare the ground for future modular, flexible and intelligent satellites (including distributed space systems), improve the survivability of satellites against unintentional (e.g. space debris) and intentional attacks, and increase the resilience of critical space-based missions. In the mid to long term, the future space ecosystem should include hybrid, smart and reconfigurable satellites, which can be manufactured, assembled and serviced directly on-orbit, and with a de-orbiting capacity.

Current status: Telecommunication systems is the main European commercial space segment and export market (EUR 3.5 billion sales in 2017), while Earth observation (EO) is the second commercial market for EU space industry. Ground segment aspects must be integrated in "end-to-end" approaches for telecom and Earth observation but aspects of ground control centres and operations, data handling and terminals need to be considered explicitly. Novel approaches to data chain aspects are needed to enable satellite missions with high productivity and growing data and service requirements.

Current space infrastructure is largely based on application-specific spacecraft design. Future space ecosystems will benefit from sustainable, resilient, secure, flexible, modular, highly-automated and maintainable space infrastructure. The availability of such economically viable infrastructure and related services will enhance commercial opportunities in space, also for challenges such as debris mitigation/removal further to the protection of the future in-space ecosystem and on-orbit servicing.

New user needs such as faster responsive mission, higher production volumes, on-demand flexible manufacturing and cost reduction call for major changes in the way Manufacturing, Assembly, Integration and Testing (MAIT) of space systems is performed.

A growing trend of technology spin-in and risk-taking approach is pervading the space sector and accelerating space business.

Achievements sought / targets:

Satellite telecommunication end-customers of Europe´s digital society and economy need ever increasing capacity, new end to end and plug and play applications and services owing to a quickly evolving digital context such as cloud network community, internet of things, the arrival of 5G, increasing competition and lowering costs.

The market demand for Earth observation is expected to grow on both high-end very high resolution satellite market (spatial) and lower end high resolution high revisit market (typically smaller satellites in constellations), as well as for new multispectral and hyperspectral sensors. Future systems should target cost efficient higher end-to-end performance, which can include multi sensor systems solutions (such as new advanced optical and radar sensors), and/or multi-layers capacity with various orbits and platforms.

Future satellite telecommunication and Earth Observation ground and space segments should handle a range of new needs, providing scalable and resilient solutions while reducing costs. These needs stems from the arrival of larger constellation of satellites, constellation interaction, multiple sensors, novel generation electronic devices, ever increasing data rates, more flexible payloads, active antennas and direct radiating arrays, on-board and on-ground autonomy (mission planning) and mission (re-)configurability. New tools and methodologies are needed to accelerate the validation of time critical software on a given hardware to increase reconfigurability capacities.

New technologies and systems for cost-effective, agile and high-speed data handling, processing, storage and transfer with an increasing role for artificial intelligence and autonomy both in space and ground segments.

New services including de-orbiting and active debris removal, on orbit servicing, assembly and manufacturing based on new systems concepts employing automated, flexible and sustainable space infrastructure, based on modular, adaptable and maintainable spacecraft.

Digitalisation and automation such as advanced design and manufacturing methods (including additive manufacturing) and "Digital Twins", plug-and-play modularity, as well as model based system engineering. Reductions in mass, cost, emission, energy consumption and development time as well as the development of alternative manufacturing routes, at the same time adhering to the stringent space requirements and specificities.

Disruptive technologies and concepts should be pursued to bring breakthrough innovation to the space sector, while at the same time furthering technology maturation in the view of qualification on ground or via In-Orbit Demonstration and Validation activities.

Means/links: Grants (RIA, IA and CSA).]

Proposals are invited against the following topic(s):

SPACE-01-2021: End to end satellite communication systems and associated services (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Contribute to capture 50% of global accessible Telecom satellite market by 2028.
- A European demonstrator mission for satellite telecommunication.
- Ultra and very high throughput from end to end.

- Reduce technology dependence from non-EU sources.

Scope: Maturation of technology building blocks for LEO broadband constellations and ultra and very high throughput satellites, such as end-user terminals, infrastructures and networks, optical and photonic systems, cyber-security, active antennas for LEO-MEO-GEO and large reflector antennas powerful broadband systems U/VHTS, data management and processing. Integrated demonstration of building blocks by 2026-2027.

SPACE-02-2021: End to end Earth observation systems and associated services (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Maintain the worldwide leadership for Earth Observation system by 2028 addressing (1) reactive very high resolution and (2) smart persistent (up to video) Earth observation.
- A European demonstrator mission by 2026-27 showcasing:
    - A reduction by 50% the cost of sub-metric missions by 2027
    - Image acquisition at below 50cm resolution anywhere in less than 1 hour
    - Drastic time reduction between user request and image availability

Scope: Technology studies for end-to-end system elements such as connectivity, security, autonomy and small series production. Ground segment elements including interoperability and resilience, data management and data fusion. Maturation of observation payload technologies including detectors and sensors, radar and optical, as well as satellite and platforms with on-board autonomy for data storage and processing. Preparation of a European demonstrator mission.

SPACE-03-2021: Future space ecosystems: On-Orbit Operations, new system concepts (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Maturation of key technologies for a European demonstrator mission for On-Orbit Servicing in 2025-2026 period.
- Preparing for a future space ecosystem, building on modularity and enabling on-orbit servicing, assembly, manufacturing and recycling.

Scope: Develop and demonstrate European capabilities in On-Orbit-Servicing, building on work done on Space Robotics in Horizon 2020 and A-B1 mission studies to be launched in 2020. Work will address maturation of required technologies for the demonstrator, including:

- European Standard Interfaces (EQM/QM), Refuelling Interface, Docking Interface
- Low cost European Robotic Manipulator (EQM/QM) (End-effector, joints, sensors)
- System Autonomy (Sensors, GNC, Operations)
- OBC & Bus architecture (computational power, communication, modularity, etc.)
- V&V methodology & Software (e.g. AI)
- Modules for De-Orbiting/transfering (e.g. modular space servicing kits)
- Key technology BB for assembly/manufacturing
- OOS procedures/scenarios (input for EOF updates)

SPACE-75-2022: Future space ecosystems: On-Orbit Operations, new system concepts (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- A European demonstrator mission for On-Orbit Servicing in 2025-2026 period that will demonstrate European know-how, open new business opportunities & foster international cooperation;
- Preparing for a future space ecosystem, building on modularity and enabling on-orbit servicing, assembly, manufacturing and recycling.

Scope: Develop and demonstrate European capabilities in On-Orbit-Servicing, building on work done on Space Robotics in Horizon 2020 and A-B1 mission studies to be launched in 2020. Work will address phase B2-D mission studies, building a European Operational Framework for on-orbit operations and contributing to international guidelines and standards, in particular addressing the following areas:

- Life-extension & Refueling (Refueling Interface, Berthing/Docking, Tugging);
- Modularity & Multi-Mission ability (Flexibility, Upgrade, Re-configuration);
- Orbit Maintenance (Payload exchange, Repair, End-Effectors);
- Orbit Assembly & Manufacturing (Modules, Standard Interfaces, Operations);
- On-Orbit Operations -> Verification OOS Guidelines & Standards (EOF).

SPACE-04-2022: Ground segment technologies for satellite communication and Earth observation (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Europe to become worldwide leader in in ground segments for any kind of mission.
- Support European demonstrator missions for satellite communication and Earth observation through a modern and competitive ground segment.

Scope: New trends that drastically increase the demand on future ground segments include increasing data rates and volumes, satellite constellations, higher frequencies, multi-mission data with increased needs for data fusion, AI techniques and infrastructure security.

Need to address both disruptive technologies and maturation of existing technologies to scale up TRL with a demonstration in an integrated environment by 2027.

SPACE-05-2022: Very low power Electrical Propulsion Systems (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To strengthen, in the mid-term, the European capacity to compete in the worldwide arena of electric propulsion satellites and missions in order to be in time and adapted to market.
- To develop the Incremental Technology Electric Propulsion System up to system demonstration in a space environment and ready for its qualification
- Matured technologies up to TRL 5/6 towards operational products

Scope: The Very Low power class (up to 300 W) is the class serving disruptive and emerging markets for satellite applications. The requirements vary a lot depending on the type of spacecraft (from cubesat to smallsat), depending on the on-board power available, the orbit of operations, and the application type. A wider portfolio of solutions needs to be investigated, only limited by the potential size of the demand. The core objective is to strengthen the maturity of technologies towards operational products. The aim is to achieve qualification at EP system level. This means that the required components shall be developed in close cooperation with the thruster developers, thus guaranteeing optimal interfaces, optimal performance and reduction of iteration costs. The components developers will be stimulated to take advantage of the different technologies and Generic Building Blocks developments achieved through Horizon 2020 to support the different types of EP applications and thrusters.

The scope of activities includes, when appropriate, the preparation of IOD/IOV demonstration(s).

SPACE-06-2022: Technologies and generic building blocks for Electrical Propulsion (generic line) – (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To strengthen, in the mid-term, the European capacity to compete in the worldwide arena of electric propulsion satellites and missions in order to be in time and adapted to market.
- Matured technologies up to TRL 5/6 at equipment level
- Matured industrialisation aspects for high TRL solutions
- Contribution to the preparation of the evolution of the 4 incremental power classes Electrical Propulsion systems (very low up to 0,3 kW; low: 0,3-1,5 kW; medium 3- 7 kW; high 12-20 kW)

Scope: In order to anticipate and adapt to future market and application needs of European EP products, the activities will focus on technologies and Generic Building Block Technologies towards products allowing to prepare the evolution of the 4 incremental power classes EP systems (including Hall Effect Thruster - HET, Grindded Ion Engine - GIE and Highly Efficient Multistage Plasma Truster technologies - HEMPT).

The activities shall also address the industrialisation aspects.

The scope of activities includes, when appropriate, the preparation of IOD/IOV demonstration(s).

For technology maturation, it shall address one or several of the following areas:

- Generic Building Blocks Technologies for thruster components (anode configuration, magnetic nozzle, cathode, materials),
- EP electric power architecture and products (PPU, direct drive, etc.),
- Fluidic management system and components.

For industrialisation, it shall address one or several of the following aspects for high TRL solutions:

- Standardisation
- Diagnostics
- Characterisation in orbit
- Manufacturing process

Section: Reinforce EU capacity to access and use space

[Objective: Two specific challenges stand out. Firstly, the highly competitive global launch service market landscape characterised by an increasing number of competitors with new capacities from USA, Japan, China, India, etc., proposing attractive launch service prices on the commercial market. Secondly, the emerging opportunities in space transportation that are not yet seized by European launch actors characterised by new uses of space (e.g. small satellites, larger constellations), new services (e.g. direct orbit injection, in-orbit servicing) and in-space transportation. This will require, amongst others, new concepts for reducing the production and operation cost such as reusability (including stage recovery and landing) of launcher components, and low cost, high thrust and green propulsion, modular avionics, autonomous systems, micro launchers and modern and flexible test and launch facilities.

Current status: Access to space is a key enabler and indispensable element in the overall space value chain without which, there is no space policy. In line with the Space Strategy for Europe, ensuring independent, reliable, flexible and cost-effective access to space is a political imperative for the EU to maintain its autonomy of decision, in particular for implementing the EU Space Programme.

It is necessary for EU launch service providers to balance and complement the limited demand from European institutional programmes with the capture of a significant share of the global commercial market in order to spread fixed costs on larger volumes and maintain the adequate launch rate for reliability.

The EU launcher sector has to bridge the innovation gap with its competitors in the US and China with the objective to reduce the cost of launch services by 50% by 2030. Some activities towards these objectives have been initiated by Space Agencies, Industry and Research Centers, including reusability concepts, low cost propulsion, but there are needs to accelerate the path to rapidly improve EU industry competitiveness.

Achievements sought / targets:

Matured technologies enabling operational capacities by 2030, using reusability concepts (including stage recovery and landing), high performance and green propulsion, next generation structural concepts, smart technologies, engineering tools, digitalisation, advanced data management, modular and affordable avionics (including GNC/AOCS), material and process modelling. Maturation shall go up to demonstrations (in flight for launcher technologies), in order to contribute to rapidly improve launch competitiveness and reduce the cost/price of launch services by 50% by 2030, for the benefit of EU Space Programme implementation (reliability, cost effectiveness, EU autonomy).

Readiness of new technologies and new options, in order to enable operational capacities by 2030 for new space transportation solutions/services such as micro launchers, test and associated launch facilities, rideshare, kick-stages, new types of space routes, re-entry solutions.

A highly scalable and versatile production system for launchers, allowing the manufacture of families of launchers in terms of a wide range of payloads, mission types, and different number scales.

Disruptive technologies, methodologies and concepts should be pursued to bring breakthrough innovation to the launcher systems sector towards cost reduction and contribute to the preparation of competitive European Space Transportation beyond 2030

Means/links: The complexity of the challenge at hand requires a mixture of implementation modes:

Main mode of implementation will be grants (RIA, IA and CSA).]

Proposals are invited against the following topic(s):

SPACE-07-2021: Launch service cost reduction with reusability for strategic space launchers - technologies and operation maturation including flight test demonstration (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Contribution to the overarching objective of launch cost/price reduction by 50% by 2030, for the benefit of EU Space programmes implementation and towards EU's non-dependence.
- Innovation acceleration of enabling technologies (maturing, assessing and practicing, through representative in flight experiments).
- Matured technologies up to TRL5/6, integration of demonstration vehicle, on-ground and low altitude demonstration tests by 2023 and contribution to the preparation of suborbital demonstration tests potentially in 2025.
- Cost reduction investigation and demonstration.

Scope: Access to space is an indispensable element of the entire value chain of space and has been recognised as an area of strategic importance towards the direction of Europe's non-dependence.

Access to space is also a matter of security of supply, industry capability and technology readiness and a sine qua non condition of the modern space knowledge-based economies.

The Space Strategy for Europe has confirmed that Europe shall maintain autonomous, reliable and cost-effective access to space.

Cost reduction and improving flexibility of European launch systems are the main challenges in order to foster European industry competitiveness on the global market.

Reusability concepts including required technologies have a strong potential for cost reduction, starting with the recovery of the most expensive components such as propulsion systems. It can also increase launch flexibility by reducing lead-time from order to launch by helping to adapt efficiently the launch rate and the performance to market variations. In addition, reusability would contribute to align space economy with the ecological transition to sustainability.

The activities address technologies and building blocks maturation up to TRL5/6 and subsystem/system demonstrations including prototyping, demonstration vehicle integration, ground tests, low altitude flight demonstration tests by 2023 and contribution to the preparation up to ground based system tests of suborbital flight demonstration tests by 2025. The execution of the suborbital tests is not part of the scope.

The developed enabling technologies and building blocks shall be applicable to strategic launchers able to launch EU Space Programme components, with the objective of enabling operational capacities by 2030. The demonstration vehicle shall be representative of a reusable 1st stage of a strategic European launcher. This vehicle shall be at a sufficiently large scale in order to be representative of the expected final capacities. The vehicle will be equipped with a reusable propulsion system.

The proposed activities shall also support EU non-dependence objective.

The activities will address enabling technologies maturation and demonstration in all of the following areas:

- low cost GNC and avionics (hybridation techniques, navigation sensors, modular, reconfigurable),
- maneuvering control devices,
- HMS (Health Monitoring System), propellant management
- aerodynamic devices,
- landing systems,
- on-ground servicing processes (refurbishment, check-out and repair),
- safety critical processes before launch and after landing

All the activities shall be complementary and coherent with the ESA on-going or future activities in particular those decided at the last ESA Ministerial held in November 2019.

Proposals under this topic may be subject to security scrutiny if they could potentially lead to security-sensitive results that should be classified (see guide for classification available at the Funding & Tenders Portal).

SPACE-08-2021: Launch service cost reduction with low cost high thrust propulsion for strategic space launchers - technologies maturation including ground tests (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Contribution to the overarching objective of launch cost/price reduction by 50% by 2030, for the benefit of EU Space programmes implementation and going towards EU's non-dependence
- Innovation acceleration of enabling technologies (maturing, prototyping, on ground tests)
- Identified and matured concepts up to TRL 3-4 for cost-reduction possibilities in the current European launchers, matured technologies up to TRL 5-6, prototyping and on ground tests at engine subsystem and system level
- Cost reduction investigation and demonstration

Scope: Access to space is an indispensable element of the entire value chain of space and has been recognised as an area of strategic importance towards the direction of Europe's non-dependence.

Access to space is a matter of security of supply, industry capability and technology readiness and a sine qua non condition of the modern space knowledge-based economies.

The Space Strategy for Europe has confirmed that Europe shall maintain autonomous, reliable and cost-effective access to space.

Cost reduction and improving flexibility of European launch systems are the main challenges in order to foster European industry competitiveness on the global market.

The propulsion systems represent a significant part of launch system costs. It is necessary to mature new or optimised low cost (lower number of parts, better operability), high performance (high thrust to weight ratio, high specific impulse) and green propulsion concepts, technologies and propellants for high thrust engines.

The activities shall address maturation of enabling technologies, building blocks, tools and processes including maintenance/overhaul and safety, up to TRL5/6 and subsystem/system demonstrations including prototyping and fonctional tests at subsystems level and on-ground demonstration tests at engine level.

The matured technologies, building blocks, tools and processes shall be applicable to strategic launchers able to launch EU Space Programme components, with the objective of enabling operational capacities by 2030 and preferably earlier for current launch solutions. The demonstration tests shall be appropriate to this objective.

The activities will address one or several of the following areas:

- low cost propulsion,

- throttability,
- reduced number of parts with extensive application of Additive manufacturing,
- maintenance/overhaul,
- associated fluidics,

All the activities shall be complementary and coherent with the ESA on-going or future activities in particular those decided at the last ESA Ministerial held in November 2019.

Proposals under this topic may be subject to security scrutiny if they could potentially lead to security-sensitive results that should be classified (see guide for classification available at the Funding & Tenders Portal).

SPACE-09-2021: Technologies maturation enabling new space transportations services (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Contribute to EU Green Deal objective through the reduction of the environmental impact of space transportation and to be prepared for the upcoming REACH regulations, especially with respect to the use of hydrazine and its derivatives, focussing on commercial market as a driver for business growth.
- Contribute to expand commercial space transportation offer and services with new space transportation solutions. The objective is contribute to double the accessible new space transportation service market to European industry by 2030.
- Design and performance studies as well as business cases.
- Matured technologies including functional and qualification test demonstrations on ground.

Scope: Access to space is an indispensable element of the entire value chain of space and has been recognised as an area of strategic importance towards the direction of Europe's non-dependence.

Access to space is a matter of security of supply, industry capability and technology readiness and a sine qua non condition of the modern space knowledge-based economies.

The Space Strategy for Europe has confirmed that Europe shall maintain autonomous, reliable and cost-effective access to space and identifies an action to encourage the development of commercial markets for new space activities.

There are emerging opportunities in space transportation that are not yet seized by European actors characterised by new uses of space (e.g. small satellites, larger constellations) new destinations (e.g. direct GEO).

The expected proposed activities shall contribute to the maturation of enabling new technologies and subsystems (including common building blocks) in the field of green propulsion, micro launchers and associated launch facilities, kick stage, orbital propulsion and distancing, attitude and landing, re-entry solutions for space transportation including new routes up to Lunar orbit or surface.

The maturation shall go up to Subsystem and system demonstrator level and may include one or several of the following areas:

- “low thrust” green and low cost propellant functional propulsion systems and vehicle system aspects of existing propulsion systems for use of green propellants
- Green engine, attitude control systems (RACS), thruster, ignition, fluid control equipment
- Actuation Systems and Pyrotechnic Systems, light weight structure concepts for micro launchers
- Smart dispenser for multi-satellites launch solutions,
- Attitude Orbital Module and re-entry module
- GNC, autonomous localization and termination, modern TM/TC data handling, low-cost and modular avionics, Automated Rendezvous and Capturing Technologies, Avionics and test-bed

Proposed developments should be a step in a new space transportation service development roadmap and well supported by a solid business case.

All the activities shall be complementary and coherent with the ESA on-going or future activities in particular those decided at the last ESA Ministerial held in November 2019.

Proposals under this topic may be subject to security scrutiny if they could potentially lead to security-sensitive results that should be classified (see guide for classification available at the Funding & Tenders Portal).

SPACE-10-2021: Technology maturation for multi sites flexible industrial platform and standardised technology for improving interoperability of EU access to space ground facilities (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Contribution to the overal objective of launch cost/price reduction by 50% by 2030, for the benefit of EU Space programmes implementation
- Improve cost efficiency of existing European test, production and space launch facilities
- Feasibility study of an industrial platform (perimeter, technologies, costs) and demonstration, including cost benefit assessment, of key technologies in representative conditions
- Matured technologies up to TRL 5/6 standardized technology for improving cost efficiency, interoperability of access to space ground facilities in EU, ground assets portability to speed-up deployments.

Scope: Access to space is an indispensable element of the entire value chain of space and has been recognised as an area of strategic importance towards the direction of Europe's non-dependence.

Access to space is a matter of security of supply, industry capability and technology readiness and a sine qua non condition of the modern space knowledge-based economies.

The Space Strategy for Europe has confirmed that Europe shall maintain autonomous, reliable and cost-effective access to space.

Cost reduction and improving flexibility of European launch systems are the main challenges in order to foster European industry competitiveness on the global market.

Europe needs to improve the cost efficiency of the ground facilities and of launch systems production and operations for the strategic launchers essential for the implementation of EU space programme. It could benefit from the industry 4.0 transformational wave, which has the potential to exploit digitalisation and advanced data management for lowering the cost of low production rate facilities and further improving quality

The activities adress technologies maturation applicable to strategic launch sytems able to launch EU Space Programme components, with the objective of enabling operational capacities by 2030.

The maturation will go up to TRL5/6 and include the prototyping.

The activities will address one or several of the following areas:

a) Multi sites flexible industrial platform:
    - Feasibility study and demonstrations of key technologies in representative conditions of a flexible platform as a tool for existing and future European space launcher products, to enable a cost-efficient approach including existing Manufacturing Assembly Integration and Testing capabilities as design constraints, to increase economical robustness against variable production rates in

the rocket industry and to optimise transfer from existing to new launcher productions

- o To explore, including from other industrial sectors, the use of a value-stream mapping (including the material- and information flow) in the field of Design to Manufacturing, Integration, Maintenance and Operation capabilities including improvements based on advanced data management and Artificial Intelligence. Maturation of technologies up to demonstration.

b) Develop standardised and cost effective innovative technologies to improve cost efficiency of existing Test and Launch facilities, their interoperability and compatibility/attractiveness for new users, including following areas:

- o modern data handling, data processing,
- o eco-friendly technologies,
- o automation and innovation controls,
- o mobile telemetry systems, mobile payload preparation facilities,
- o vacuum simulation test facilities,

All the activities shall be complementary and coherent with the ESA on-going or future activities in particular those decided at the last ESA Ministerial held in November 2019.

Proposals under this topic may be subject to security scrutiny if they could potentially lead to security-sensitive results that should be classified (see guide for classification available at the Funding & Tenders Portal).

SPACE-11-2022: Disruptive concepts/technologies for access to space (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Contribution to the preparation of competitive European Space Transportation beyond 2030.
- Disruptive ideas, technologies, concept, solutions with large potential and towards significant impacts on European Space Transportation capacities (e.g. payload size, time to destination, launch frequency) and competitiveness.

Scope: Access to space is an indispensable element of the entire value chain of space and has been recognised as an area of strategic importance towards the direction of Europe's non-dependence.

Access to space is a matter of security of supply, industry capability and technology readiness and a sine qua non condition of the modern space knowledge-based economies.

The Space Strategy for Europe has confirmed that Europe shall maintain autonomous, reliable and cost-effective access to space.

Cost reduction and improving flexibility of European launch systems are the main challenges in order to foster European industry competitiveness on the global market.

The proposed activities shall contribute to prepare globally competitive European Space Transportation beyond 2030, with a large potential to improve access to space.

The activities will initiate the development of disruptive concepts for access to space towards cost reduction and improvement of flexibility. This include technologies, components, system concepts for accessing space which would have a significant impact on capacity (e.g. payload size, time to destination) and competitiveness. They may incude, but not limited to, the following areas:

- Propulsion: detonation wave engine, new molecules for high performance green propellant, cross-feeding, development of a megawatt class Nuclear Electric Propulsion (NEP) reactor for deep space exploration, cargo & crewed missions, laser propulsion, combined/aerobie propulsion,
- Air-launching systems,
- Reusable winged (or not) upper stages,
- Optimised ground segment for highly frequent launches of micro-launchers,
- Single Stage to orbit,
- Smart Fault Detection, Identification and Recovery (FDIR),
- Disruptive Launch facilities.

Proposals under this topic may be subject to security scrutiny if they could potentially lead to security-sensitive results that should be classified (see guide for classification available at the Funding & Tenders Portal).

Section: Evolution of Space and ground infrastructures for Galileo/Egnos

[Objective: For Galileo/EGNOS, the international context, the competitive environment with emerging actors and novel techniques in the value chain, the increasing threats, and the evolution of the technologies, components and systems, including dual-use technology, call for a constant adaptation of the EU space infrastructure to these changing realities. To meet these challenges, sustained investments in R&D for innovative mission concepts, technology and systems are needed over time.

Current status: Today, the EU owns a unique operational space infrastructure providing precise positioning, navigation and timing (Galileo/EGNOS).

Achievements sought / targets:

The continuity of EGNSS service is ensured, the risks for technology inclusion in the infrastructure is minimized, the protection against modern threats is reinforced (cyber notably), and the strategic autonomy on key technologies is increased. Overall, keeping the EU´s position at the avant-garde of the Global Navigation Satellite Systems.

Means/links: Possible contribution agreements with ESA - European Space Agency and with EUSPA – European Space programme Agency. Actions to be implemented using grants and public procurement.

Implementation of this section is carried out under “Other actions”.]

Section: Evolution of services of the EU Space Programme components Galileo, EGNOS and Copernicus

[Objective: Copernicus core services must evolve and improve to better respond to new and emerging policy needs, such as anthropogenic CO2, GHG and pollutant monitoring, climate change mitigation and adaptation, EU arctic policy, coastal area, sustainable development goals, environmental compliance, protection of natural resources, ecosystems and biodiversity, food security, agriculture, fisheries, aquaculture, crisis management, safe transport, sustainable, clean energy, border management, cultural heritage, as well as other new domains that could bring key contributions to the European Green Deal and to other European Union priorities. Similarly, the Galileo service portfolio must be adapted to the evolution of the user needs and market trends by introducing new services and capabilities, so that EGNSS remains at the fore front of the provision of satellite navigation services.

Current status: With EGNSS and Copernicus, Europe enjoys an operational space infrastructure which can help tackle global challenges, contribute to economic growth and jobs, and provide more efficient emergency and security services.

Achievements sought / targets:

For EGNSS, Galileo will remain at the forefront of the provision of satellite navigation services and keep the pace with increasing competition in the sector (USA, China, 5G, etc). Extending Galileo services in various societal challenges and offering it as a complementary service to emerging markets like 5G, CCAM and AI.

For Copernicus, services related research will improve the Programme response to evolving EU policies and users' needs and the production of systematic and reliable data and information to keep Europe as a key actor in tackling global challenges in the environmental and security domains.

Means/Links: Grants (RIA, IA and CSA) and public procurement. Possible contribution agreement with EUSPA – European Space programme Agency.

Evolution of Galileo / EGNOS services can be found under Other Actions.]

Proposals are invited against the following topic(s):

SPACE-12-2021: Copernicus Marine Environment Monitoring Service evolution (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

1. New and innovative models for biogeochemistry and marine ecosystems monitoring toprepare Copernicus-based solutions for different policies areas and for the challenges related to pollution, and to exploit the dynamics of the biological component of the ocean in terms of 'fauna and flora', how this marine living component behaves in relation to the ocean physics (temperature, currents), its biochemistry composition (in particular the plankton-to-fish links), climate change and the man-made pressures (e.g. transport, pollution, fisheries, etc.).

2. New and innovative ocean modelling chains from the global ocean to coastal scales to enhance the Copernicus Marine Environment Monitoring Service with new products and services representative of high-resolution and high-dynamics phenomena and to prepare Copernicus solutions for coastal areas that are key for significant human activities.

Scope: The evolution of the Copernicus Marine Environment Monitoring Service (CMEMS) should ensure enhanced quality and enhanced efficiency of the current services in response respectively to policy and/or user requirements and to technological developments implementing the space regulation, but also complementing the challenges targeted by the Horizon Europe Mission: "Healthy oceans, seas, coastal and inland waters".

The baseline is to preserve continuity of what has been achieved while keeping the services modern and attractive through efficient and reliable new product chains, calling for new paradigms in data fusion, data processing and data visualisation. This is essential because the services are expected to handle more and more high-volume satellite data sets and product sets.

Furthermore, emerging space missions in the coming decade will provide new types of space observation data (being from new Sentinels or other contributing missions), which may allow the development of new products or the improvement of existing products, and which also may require new algorithms and processing chains to be developed. With an integrated modelling approach, the integration of new observational data becomes a driver for further enhancement and improved realism of the already existing production chains, assimilation systems and coupled models. The development of advanced processing and modelling techniques, as well as the exploitation of new sources of data, will be targeted to create new products or significantly improve the quality and performances of existing elements-components for the benefit of users. The projects should take into account the existing service and clearly define to what extent service will be improved with new elements or products, including the use of enhanced models, algorithms, tools and techniques to generate new products.

Proposals are expected to provide tangible results (new or improved products or service elements) for the Copernicus service within the period 2021-2027. The proposed research and development should be modular and scalable. For short-term outcomes, the project should provide a proof-of-concept or a prototype (e.g. system element targeting TRL7 at least) demonstrating the feasibility of the integration in the existing core service. For longer-term actions, the projects should demonstrate a strategic approach to the service, match Copernicus priorities and develop a roadmap over time to reach a mature state ready for transfer to operations when feasible.

Proposals may be submitted in any of the indicated outcomes or can propose a multi-mode approach covering all the outcomes. In the first case, up to maximum 2 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-13-2021: Copernicus Atmosphere Monitoring Service evolution (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

1. New and innovative data assimilation of atmospheric composition satellite observations to expand the use of satellite data streams in the Copernicus Atmosphere Monitoring Service (CAMS) operational global and regional production systems, to improve the quality of the CAMS global and regional reactive gases and aerosol information products (analyses, forecasts and reanalyses) and to deliver near-real-time observations-based emissions of reactive gases and aerosol at the global scale
2. New methods for quantifying uncertainties for atmospheric CAMS composition products in the context of decision-making as well as of environmental policies development and implementation to be directly useful for the users of the products
3. New integrated soil-vegetation-atmosphere modelling and data assimilation of deposition fluxes and of volatile organic compounds and pollen emissions to develop parameterizations that can consistently represent the budgets of energy and water together with the source and sinks of carbon (including Volatile Organic Compounds, VOCs).
4. New and advanced aerosols modelling and data assimilation at global and regional scales to advance substantially the representation of aerosol in CAMS global and regional systems and the modelling of secondary aerosols and their interlink with gas phase chemistry.

Scope: The evolution of the Copernicus Atmosphere Monitoring Service (CAMS) should ensure enhanced quality and enhanced efficiency of the current services in response respectively to policy and/or user requirements and to technological developments. The baseline is to preserve continuity of what has been achieved while keeping the services modern and attractive through efficient and reliable new product chains, calling for new paradigms in data fusion, data processing and data visualisation. This is essential because the services are expected to handle more and more high-volume satellite data sets and product sets.

Furthermore, emerging space missions in the coming decade will provide new types of space observation data (being from new Sentinels or other contributing missions), which may allow the development of new products or the improvement of existing products, and which also may require new algorithms and processing chains to be developed. With an integrated modelling approach, the integration of new observational data becomes a driver for further enhancement and improved realism of the already existing production chains, assimilation systems and coupled models. The development of advanced processing and modelling techniques, as well as the exploitation of new sources of data, will be targeted to create new products or significantly improve the quality and performances of existing elements-components for the benefit of users. The projects should take into account the existing service and clearly define to what extent service will be improved with new elements or products, including the use of enhanced models, algorithms, tools and techniques to generate new products.

The main output of the project shall be tools and methodologies that can be readily transferred for improving aerosol representation in CAMS operational global and regional systems. The proposal shall develop activities that will improve the quality of the aerosol variables in the CAMS global and regional analyses, forecasts and reanalyses, as well as of the CAMS solar radiation products.

Proposals are expected to provide tangible results (new or improved products or service elements) for the Copernicus service within the period 2021-2027. The proposed research and development should be modular and scalable.

For short-term outcomes, the project should provide a proof-of-concept or a prototype (e.g. system element targeting TRL7) at least demonstrating the feasibility of the integration in the existing core service. For longer-term actions, the projects should demonstrate a strategic approach to the service, match Copernicus priorities and develop a roadmap over time to reach a mature state ready for transfer to operations when feasible.

Proposals may be submitted in any of the indicated outcomes or can propose a multi-mode approach covering all the outcomes. In the first case, up to maximum 4 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-14-2021: Copernicus Climate Change Service evolution (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- coupled data assimilation to improve the next generation of global and regional reanalyses in the climate consistency of Earth-system reanalysis datasets
- underpinning science in predictability and multi-model product generation to improve the realism (including representation of extremes and teleconnection patterns) of the current generation of climate prediction models.

Scope: The evolution of the Copernicus Climate Change Service (C3S) should ensure enhanced quality and enhanced efficiency of the current services in response respectively to policy and/or user requirements and to technological developments implementing the space regulation, but also complementing the challenges targeted by the Horizon Europe Mission on “Adaptation to climate change including societal transformation”.

The baseline is to preserve continuity of what has been achieved while keeping the services modern and attractive through efficient and reliable new product chains, calling for new paradigms in data fusion, data processing and data visualisation. This is essential because the services are expected to handle more and more high-volume satellite data sets and product sets. Furthermore, emerging space missions in the coming decade will provide new types of space observation data (being new Sentinels or other contributing missions), which may allow the development of new products or the improvement of existing products, and which also may require new algorithms and processing chains to be developed. With an integrated modelling approach, the integration of new observational data becomes a driver for further enhancement and improved realism of the already existing production chains, assimilation systems and coupled models. The development of advanced processing and modelling techniques, as well as the exploitation of new sources of data, will be targeted to create new products or significantly improve the quality and performances of existing elements-components for the benefit of users. The projects should take into account the existing service and clearly define to what extent service will be improved with new elements or products, including the use of enhanced models, algorithms, tools and techniques to generate new products.

Proposals are expected to provide tangible results (new or improved products or service elements) for the Copernicus service within the period 2021-2027. The proposed research and development should be modular and scalable.

For short-term outcomes, the project should provide a proof-of-concept or a prototype (e.g. system element targeting TRL7) at least demonstrating the feasibility of the integration in the existing core service. For longer-term actions, the projects should demonstrate a strategic approach to the service, match Copernicus priorities and develop a roadmap over time to reach a mature state ready for transfer to operations when feasible.

Proposals may be submitted in any of the indicated outcomes or can propose a multi-mode approach covering all the outcomes. In the first case, up to maximum 2 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-15-2021: Copernicus Security and Emergency Services evolution (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- New and innovative methods and technologies to enhance the current services performance such as timeliness access to data, the need to reduce the gap between user needs and service provision, new paradigms in data fusion, automation and inclusion of wider sets of complementary, non-EO data and to demonstrate the viability of extending services to a broader range of users (from European to local users), to better monitor security and emergency threats at regional or local level.

- New and innovative methods and technologies to explore enlarged data sets for new emergency and security related applications to derive new, innovative products, addressing issues not currently tackled by the cores security and emergency services.

- New and innovative methods to increase the reach of emergency and security services towards new user communities and identify new opportunities for the deployment of services in new application domains currently not covered by the Copernicus core services and in response to local and regional needs.

Scope: Emergency and security applications have similar requirements in terms of resolution, detection capabilities and timely access to data, one of the main challenges being the provision of critical information as fast and accurate as possible. Emergency and security applications are also highly user-driven and need to provide data that often needs to be be fused with non-space data to be easily integrated along end-user intelligence supply chains to bring added value at operational level.

With a well-established community of users in both domains, Copernicus will firstly need to ensure continuity in service provision. Secondly, services will also have to evolve to handle an increasing volume of satellite data while keeping underlying technology up-to-date and include new paradigms in data fusion, processing and automation to match users increasing expectations in added-value, easiness of access and visualisation.

Upstream in the space segment, emerging EO missions in the coming decade will provide new types of space data (being new Sentinels or other contributing missions), which also require new algorithms and processing chains to be developed. Both the development of advanced processing and modelling techniques will be targeted and the exploitation of new sources of data, to create new products or significantly improve the quality and performances of existing elements-components for the benefit of users.

On data fusion, vast amounts of EO-data are now being available for applications in the security and disaster domains. Identification of complementary data sets development and testing of new and innovative ways to efficiently integrate them in emergency and security applications to generate added-value and new intelligence. Non-EO data could include in-situ observations, meteorological data, data from aerial platforms, social media or crowd-sourcing, as well as information generated from other Copernicus services.

Proposals may be submitted in any of the indicated outcomes or can propose a multi-mode approach covering all the outcomes. In the first case, up to maximum 3 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-16-2021: Copernicus evolution for cross-services thematic domains (RIA)

Expected outcomes: Projects results are expected to contribute to the following outcomes:

- prepare Copernicus-based solutions for an integrated monitoring and forecasting system for the Arctic regions
- prepare Copernicus-based solutions for an integrated approach to support the production of many SDGs indicators such as long-time series to monitor atmosphere composition and air quality, the ocean health, and regular mapping of land use ready to be used (in terms of content, compliance to methodology of calculation, consistency of time series, accuracy and veracity, formats and standards)
- prepare Copernicus-based solutions for an integrated approach in support of biodiversity conventions and natural protected areas
- prepare Copernicus-based solutions for an integrated approach in support of informing climate adaptation and resilience in different sectors and toContribute to the identification and quantification of climate-related risks to users provinding a series of climate service prototypes which should be sufficiently flexible to account for the possible integration of new data (e.g. foreseen space or no-space new missions/sensors, new service elements, etc.)

Scope: The objective of the Copernicus programme is to keep protecting the environment and the citizens by responding to emerging policies. This action collects topics useful to design and support the definition and development of new thematic and policy-related domains leveraging the different core services. The thematic and policy approach is part of the Copernicus evolution based on the identification of new policy(ies) or user need(s) and the corresponding observational and information gaps. This approach should be the starting point for integrating and expanding the Copernicus service portfolio from the user perspective and to better handle the evolution of the programme according to the Commission objectives.

This approach should foster the exploitation of space EO capabilities to close observation gaps in combination with ground-based infrastructure and innovative processing/modelling techniques.The proposed developments should be modular and scalable: the proposals should provide a proof-of-concept or a prototype that can be easily integrated into the service(s).

The proposals should propose the development of tools to support end users in their decision-making activities (e.g. decision support systems, assessments, decision processes) using Copernicus data and products and meeting the need for timely and quality long-term global/regional information. The proposals have the objective to increase the capabilities and capacity of end users to use Copernicus data and products. The involved end-user should provide feedback to the proposed tools on product efficiency, data access, new measurement needs, new applied research topics, societal benefits, and other factors if necessary.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

Proposals may be submitted in any of the indicated outcomes. Up to maximum 4 projects will be funded with aim of adressing all the outcomes.

SPACE-17-2021: Support to the Copernicus programme evolution with the preparation of a new collaborative approach for public authorities' pilot projects development (CSA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- A structured plan to support the Commission in setting up a coordinated and collaborative approach to develop pilot projects with and for national public authorities using the Pre-Commercial Procurement (PCP) tool.
- Prepare Copernicus-based solutions for an integrated approach to support national public authorities to concretely uptake Copernicus products and use them within their mandate and regulatory tasks and specifically helping them integrating Copernicus in their legacy systems, operational procedures and decision-making. For the Multi Annual Financial Framework 2021-2027, the main strategic objective for Copernicus 2.0 is to guarantee the continuity in providing high quality data and products to respond to major EU policies, especially the EU Green Deal and Digital Strategy.
- Improve the direct involvement of public institutions is a key aspect in fostering a larger Copernicus adoption levaranging the maturity of the Copernicus products and services and their increased accessibility and providing significant contribution to increase their uptake.

Scope: In Europe, end-users interested in the uptake of Earth Observation and Copernicus products are dedicated to performing their duty and are focused on their tasks. In general, however, practitioner organisations have little scope to free workforces from daily operations in order to allocate time and resources to monitor innovation and research that could be useful to them. They have few opportunities to interact with academia or with industry on such issues. All stakeholders – public services, industry, academia – recognize this as an issue.

Based on previous experience Pre-Commercial Procurement is potentially an interesting instrument to encourage the take-up of Copernicus products and services by public authorities. Public authorities are core users of Copernicus to implement EU and national policies. However, they are not used to work together across borders. Copernicus delivers core products that need to be further integrated in local practices, which can require knowledge and efforts. Therefore, more effort needs to be made to attract their interest and encourage collaboration.

Furthermore, the PCP instrument has very specific rules and can be difficult to implement for the first time. Expertise needs to be made available to future applicants and project participants to help them at the time of preparing the proposal as well as during the implementation of the project.

This can open new market opportunities for companies in Europe, can contribute to speeding up public sector modernisation and can help to tackle societal challenges with innovative/breakthrough solutions for the benefit of the citizens.

Since the use of PCP instrument is not straight-forward and to ensure a good success of such projects in the future, this CSA is a preparatory activity to organize the launch of new call(s) and prepare public authorities to foster demand-driven actions by public authorities, aiming at customising Copernicus applications for their specific needs.

Transnational cooperation has a key role to play in this context, as it can facilitate knowledge transfer and optimisation of resources for public authorities and is instrumental to develop harmonised and comparable practices between countries to implement EU policies or reporting.

Proposals should be building on procurement needs of the participating organizations and mainly addressing existing gap of knowledge and expertise and prepare the ground to move smoothly to the PCP phase.

The participants could already engage public procurers from each country represented in a consortium (at national, regional or local level) that have responsibilities and budget control in the relevant Copernicus domains. This approach will allow also to work with the public procurers since the beginning of the process, to better understand their needs (also administrative and procedural) and potential barriers in accessing and using the PCP tool.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

Up to maximum 1 project will be funded.

SPACE-18-2021: Support to the Copernicus programme evolution with design and impact studies on future observing systems to improve the Copernicus services (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- exploitation of the potentiality of the planned evolution of the Copernicus space component to directly improve the Copernicus services
- address the development of observing system impact and simulation studies/frameworks related to different Earth system domains (atmosphere, land, ocean, ice, lakes and rivers) that rely on modelling for producing information products.

Scope: For the Multi Annual Financial Framework 2021-2027, the main strategic objective for Copernicus 2.0 is to guarantee the continuity in providing high quality data and products to respond to major EU policies, especially the EU Green Deal and Digital Strategy, with leading-edge services and with the first generation of Sentinels fully deployed in space. Other objectives are to prepare the next generation of Sentinel satellites and play an important role in the EU digital strategy.

The Commission, with the support of the European Space Agency and EUMETSAT, is already planning the evolution of the Copernicus space component (still subject to funds availability), based on:

- The High Candidate Priority Missions: a CO_2 mission, a hyperspectral mission, a land surface temperate mission, two polar missions based on a passive micro-wave radiometer and an altimeter and an L-band SAR;
- The next generation of Sentinels 1, 2, 3, 4, 5 and 6 missions.

This evolution will address more user and policy needs ensuring the continuity of the Copernicus observations for the period 2030-2045. These satellites will embark sensors complementing the existing ones and enhancing the observational capabilities.

Specifically on technology and capability needs, services have different needs and requirements and all of these needs and requirements should find a proper response in the future Copernicus space component. The proposal should:

- assess and quantify the impact of the planned evolution of the Copernicus space component on the services combined with in-situ observing systems (ground, aerial) to assess their impact on the quality of the products (forecasts, reanalyzes, projections) that the Copernicus services deliver;
- investigate the best interplay between different satellites and in-situ observing network configurations therefore (orbit, resolution, swath, accuracy, data density, propagation of uncertainties);
- to assess the impact on the existing long-time series and their level of accuracy/uncertainties according to different scenarios of configuration and for different purposes (short-term or seasonal forecasts);
- propose guidance on the development of future Sentinel missions (e.g. sampling, accuracy, timeliness, product types, complementary between observing systems).
- Propose guidance on the development of additional in-situ systems complementary to space observations, and their contribution to the quality of Copernicus services products;
- propose recommendations for improvements in data assimilation methodologies that lead to better and more accurate products and services.

The results of these projects will help guide future evolution of publicly funded European and national Earth observation missions and should take into account both Sentinels and national or international missions from countries in which the European Commission is in agreement.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-19-2021: Support to the Copernicus programme evolution for international cooperation for future observing systems responding to EU policies (CSA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- exploitation of international cooperation for future observing systems for the Copernicus programme evolution
- exploitation of different future scenarios of global observing systems in the mid and long term, including in particular satellite observations and in-situ observations, but as well those emerging observation systems, such as airborne platforms
- exploitation of potential partnerships between the EU Space Programme and potential international and/or commercial partners.

Scope: For the Multi Annual Financial Framework 2021-2027, the main strategic objective for the Copernicus programme is to guarantee the continuity in providing high quality data and products to respond to major EU policies, especially the EU Green Deal and Digital Strategy, with leading-edge services and with the first generation of Sentinels fully deployed in space. Other objectives are to prepare the next generation of Sentinel satellites and continue to play an important role in the EU digital strategy.

The Commission, with the support of the European Space Agency and EUMETSAT, is already planning the evolution of the Copernicus space component (still subject to funds availability), based on:

- The High Candidate Priority Missions: a CO_2 mission, an hyperspectral mission, a land surface temperate mission, two polar missions based on a passive micro-wave radiometer and an altimeter and an L-band SAR;
- The next generation of Sentinels 1, 2, 3, 4, 5 and 6 missions.

This evolution will address more users' and policy needs ensuring the continuity of the Copernicus observations for the period 2030-2045. These satellites will embark sensors complementing the existing ones and enhancing the observational capabilities.

Specifically on technology and capability needs, services have different needs and requirement and all of these needs and requirements should find a proper response in the future Copernicus space component. The proposal should focus specifically in:

- the political boundary conditions,
- the potential additional capacity gained for Copernicus, in particular policy applications,
- the possible share of roles, risks and responsibilities in partnerships, and

- the cost benefit assessment.

Proposers are advised to consult information on the Copernicus programme in general at www.copernicus.eu. Up to maximum 1 project will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en. Up to maximum 1 project will be funded.

SPACE-20-2022: Copernicus Marine Environment Monitoring Service evolution (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- New and innovative ocean data assimilation and ensemble forecasting capabilities to support the evolution of the Copernicus Marine Environment Monitoring Service towards the development of a high-value Copernicus coastal, marine ecosystem and biology services
- New and innovative methods for regional seasonal predictions to multi-decadal projections of marine environment changes over European Seas for the ocean climate services on the ocean physical (incl. sea ice and waves) and biogeochemical states, ocean health and ecosystems.

Scope: The evolution of the Copernicus Marine Environment Monitoring Service (CMEMS) should ensure enhanced quality and enhanced efficiency of the current services in response respectively to policy and/or user requirements and to technological developments implementing the space regulation, but also complementing the challenges targeted by the Horizon Europe Mission: “Healthy oceans, seas, coastal and inland waters”.

The baseline is to preserve continuity of what has been achieved while keeping the services modern and attractive through efficient and reliable new product chains, calling for new paradigms in data fusion, data processing and data visualisation. This is essential because the services are expected to handle more and more high-volume satellite data sets and product sets.

Furthermore, emerging space missions in the coming decade will provide new types of space observation data (being new Sentinels or other contributing missions), which may allow the development of new products or the improvement of existing products, and which also may require new algorithms and processing chains to be developed. With an integrated modelling approach, the integration of new observational data becomes a driver for further enhancement and improved realism of the already existing production chains, assimilation systems and coupled models. The development of advanced processing and modelling techniques, as well as the exploitation of new sources of data, will be targeted to create new products or significantly improve the quality and performances of existing elements-components for the benefit of users. The projects should take into account the existing service and clearly define to what extent service will be improved with new elements or products, including the use of enhanced models, algorithms, tools and techniques to generate new products.

Proposals are expected to provide tangible results for the Copernicus service within the period 2021-2027. The proposed research and development should be modular and scalable.

For short-term outcomes, the project should provide a proof-of-concept or a prototype (e.g. system element targeting TRL7) at least demonstrating the feasibility of the integration in the existing core service. For longer-term actions, the projects should demonstrate a strategic approach to the service, match Copernicus priorities and develop a roadmap over time to reach a mature state ready for transfer to operations when feasible.

New technological tools should be considered and innovative solutions should be proposed for better data exploitation, processing and distribution, e.g.: move to cloud and HPC computing, distributed computing, Artificial Intelligence and machine learning (e.g. for automatic feature recognition), ensemble modelling, model coupling & nesting, software as-a-service.

Additionally, the transfer of research results to possible operations should receive active attention during the course of the project to strengthen the readiness for an operational deployment in the future, including the conditions for making available to, for re-use and exploitation of the results (including IPR) by the entities implementing the EU Copernicus programme. Software should be open licensed in order to use, copy, study, and change it in any way.

Proposals may be submitted in any of the indicated outcomes or can propose a multi-mode approach covering all the outcomes. In the first case, up to maximum 2 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-21-2022: Copernicus Climate Change Service evolution (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- New and innovative data processing and reprocessing methods for future Sentinels and other satellites as observational input for Earth-system reanalysis datasets, withimproved initialisation of all relevant Copernicus products (atmosphere, ocean, land) and for a better information about the climate record to be extracted from the available observations improving the overall monitoring of the climate and climate change.

- New and innovative multi-hazard systems for the identification of compound and cascading events to develop a robust methodologies for characterising the likelihood of their occurrence at present and in future climate.

- New and innovative method for extreme events and attribution science to underpin the development of a rapid climate change attribution service and of a new generation of climate models able to better characterise the extreme events trough an improvement of model realism in the short term.

Scope: The evolution of the Copernicus Climate Change Service (C3S) should ensure enhanced quality and enhanced efficiency of the current services in response respectively to policy and/or user requirements and to technological developments implementing the space regulation, but also complementing the challenges targeted by the Horizon Europe Mission on "Adaptation to climate change including societal transformation".

The baseline is to preserve continuity of what has been achieved while keeping the services modern and attractive through efficient and reliable new product chains, calling for new paradigms in data fusion, data processing and data visualisation. This is essential because the services are expected to handle more and more high-volume satellite data sets and product sets.

Furthermore, emerging space missions in the coming decade will provide new types of space observation data (being new Sentinels or other contributing missions), which may allow the development of new products or the improvement of existing products, and which also may require new algorithms and processing chains to be developed. With an integrated modelling approach, the integration of new observational data becomes a driver for further enhancement and improved realism of the already existing production chains, assimilation systems and coupled models. The development of advanced processing and modelling techniques, as well as the exploitation of new sources of data, will be targeted to create new products or significantly improve the quality and performances of existing elements-components for the benefit of users. The projects should take into account the existing service and clearly define to what extent service will be improved with new elements or products, including the use of enhanced models, algorithms, tools and techniques to generate new products.

Proposals may be submitted in any of the indicated outcomes or can propose a multi-mode approach covering all the outcomes. In the first case, up to maximum 2 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-22-2022: Copernicus Anthropogenic CO_2 Emissions Monitoring & Verification Support (MVS) capacity (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- New and innovative methodologies to improve the definition of the correlations between emissions of co-emitted species (CO_2, NO_2, CO, CH_4) in support of CO_2 fossil fuel emission estimation

- New and innovative method to better use of auxiliary observations such as ^{14}C (radiocarbon), SIF (Solar Induced Fluorescence), and APO (Atmospheric Potential Oxygen) to separate anthropogenic CO_2 emissions from the natural variability of CO_2
- New and innovative methods to estimate the impact of fires on vegetation and to improve the estimation of fire emissions in CAMS and the fire risk forecasting in CEMS.
- New and innovative methods to improve mass conservation estimations in transport models of atmospheric CO2

Scope: To enable the European Union (EU) to move towards a low-carbon economy and implement its commitments under the Paris Agreement a binding target to cut emissions in the EU by at least 40% below 1990 levels by 2030 was set and European Commission (EC) President von der Leyen committed to deepen this target to at least 55% reduction by 2030. This was further consolidated with the release of the Commission's European Green Deal on the 11th of December 2019, setting the targets for the European environment, economy and society to reach zero net emissions of greenhouse gases in 2050, outlining all needed technological and societal transformations that are aiming at combining prosperity and sustainability.

An important new element of the proposed Copernicus programme for 2021 - 2027 is the monitoring of anthropogenic CO2 emissions in support of all Parties' commitments to reduce CO2 emissions as agreed in the Paris Agreement. Designing and building the prototype systems for this anthropogenic CO_2 emissions Monitoring and Verification Support (CO2MVS) capacity was already started within the H2020 programme and it is foreseen to run a pre-operational service under Copernicus from 2023 onwards. The CO2MVS capacity is first of its kind, and worldwide unique and will require further new specific research activities to achieve its goals.

The main objective is to perform R&D activities identified as priorities for the Copernicus CO2MVS capacity as identified by the European Commission's CO2 monitoring Task Force[46] .

The activities shall support the further development of the foreseen European operational monitoring support capacity for fossil fuel CO_2 emissions. These activities shall complement or follow-up on the activities within the H2020-funded CO2 Human Emissions (CHE) project and the Prototype system for a Copernicus CO_2 service (CoCO2) project.

The activities, as described in the Guidance document, should address a series of scientific and critical system design issues, which were defined following outcomes of the CHE project and based on recommendations from the CO_2 monitoring Task Force.

[46] https://op.europa.eu/en/publication-detail/-/publication/51765498-c0d3-11e5-9e54-01aa75ed71a1; https://op.europa.eu/en/publication-detail/-/publication/0be8c94b-5912-11ea-8b81-01aa75ed71a1; https://op.europa.eu/en/publication-detail/-/publication/1c2a418c-216b-11ea-95ab-01aa75ed71a1.

More generally, this action should support the development of an integrated support capacity, enabling European experts to collectively share their knowledge and join forces on the multiple fronts required to develop such a system with operational capabilities.

The activities should fulfil the technological and scientific requirements for the development of this European operational capacity, to further improve the prototype system to better meet user requirements and to exploit synergies with other Copernicus services, the following research sub-topics need to be addressed. The proposal should tackle only one of the following sub-topics.

Proposals may be submitted in any of the indicated outcomes or can propose a multi-mode approach covering all the outcomes. In the first case, up to maximum 4 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-23-2022: Research activities for Copernicus Land Monitoring Service evolution (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- New and innovative methods to combine and explore data with different spatial and temporal characteristics and automatic processing for land cover and land cover status change assessment with a more dynamic approach (e.g. annual overviews or early warning or alert systems to responde to emerging European policy needs) and with the integration of various sensors with different temporal and spatial resolutions, and the development of specific automatic processing approaches capable of analysing data on real and near real time.
- New and innovative methods to integrate the current land products into land surface and land cover change models

Scope: The evolution of the Copernicus Land Monitoring Service (CLMS) should ensure enhanced quality and enhanced efficiency of the current services in response respectively to policy and/or user requirements and to technological developments.

The baseline is to preserve continuity of what has been achieved while keeping the services modern and attractive through efficient and reliable new product chains, calling for new paradigms in data fusion, data processing and data visualisation. This is essential because the services are expected to handle more and more high-volume satellite data sets and product sets. Furthermore, emerging space missions in the coming decade will provide new types of space observation data (being new Sentinels or other contributing missions), which may allow the development of new products or the improvement of existing products, and which also may require new algorithms and processing chains to be developed. With an integrated modelling approach, the integration of new observational data becomes a driver for further enhancement and improved realism of the already existing production chains, assimilation systems and coupled models. The development of advanced processing and modelling techniques, as well as the exploitation of new sources of data, will be targeted to create new products or significantly improve the quality and performances of existing elements-components for the benefit of users.

The project should take into account the existing service and clearly define to what extent the service will be improved with new elements or products, including the use of enhanced models, algorithms, tools and techniques to generate new product(s).

Since 2013, CLMS has developed core products for the monitoring of natural resources and the assessment of land cover and land use changes, including land cover conditions. At European level, land cover mapping is carried out on a regular basis, every 6 years for CORINE and every 3 years for the thematic 'High Resolution Layers" (HRL). The local component dealing with land cover mapping on specific areas like riparian areas, urban zones and natural 2000 sites, is following the same approach with a 6 years cycle but at very high resolution. At Global level, an annual land cover mapping has been proposed since 2015 at mid resolution, the evolution to high resolution is also envisaged.

Vegetation, Inland Water and Cryosphere conditions are also monitored but on a regular basis, mainly ten-daily basis at mid-resolution for the Global and European levels.

These mapping and monitoring approaches were partly conditioned by the availability of satellite data. The deployment of the full Earth Observation capacities of Copernicus and the complementarities between the instruments, including outside Copernicus environment, allows to rethink of the approach including for providing a better answer to the policy needs.

Proposals may be submitted in any of the indicated outcomes or propose a multi-mode approach. Up to maximum of 2 projects will be funded.

Proposals may be submitted in any of the indicated outcomes or can propose a multi-mode approach covering all the outcomes. In the first case, up to maximum 2 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-24-2022: Copernicus evolution for new emerging cross-services thematic domains (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Specific and well-targeted applications using products and services coming from different core services and responding to emerging policy needs
- Enable Copernicus services to better serve cross-cutting applications on European, regional and local scale;

- Reinforce the link with academic and scientific sector for scientific exploitation of Copernicus data and products.

Scope: The objectives of the Copernicus programme are to reinforce its capacity (both space and services) to keep protecting the environment and the citizens by responding to emerging policies while maintaining the key factors that made its strength.

Copernicus produces a wealth of data and information regarding the Earth sub-systems (land, atmosphere, oceans) and cross-cutting processes (climate change, emergency and security). The wealth of information delivered by the Copernicus operational programme is not fixed but needs to evolve further with recognised and emerging user requirements and state of the art methodologies. The potential for new products and applications needs to be exploited, especially as regards cross-cutting cases not yet realised.

This action collects topics useful to design and support the definition and development of new thematic and policy-related domains leveraging the different core services. The thematic and policy approach is part of the Copernicus evolution based on the identification of new policy(ies) or user need(s) and the corresponding observational and information gaps. This approach should be the starting point for integrating and expanding the Copernicus service portfolio from the user perspective and to better handle the evolution of the programme according to the Commission objectives. This approach should take into consideration synergies, complementarities and harmonisation across core services.

Proposals shall demonstrate the technical operational feasibility of the selected application. The proposers are expected to demonstrate that their proposal is relevant for the enhancement of Copernicus core services and capitalise from the corresponding product portfolio. These applications may concern areas in relation to domains such as energy, health, resilience of built environment and urban planning, cultural heritage, waste flows, disaster prevention (especially early alert on earthquakes or other disasters) and others. Areas such as Arctic regions, SDGs monitoring, biodiversity and natural protected areas, climate adaptation actions, food security and compliance to EU regulation should be avoided, because already addressed in other specific topics in HE.

Proposals may be submitted in any of the indicated application areas. Up to maximum 3 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

SPACE-25-2022: Copernicus evolution for cross-services thematic domains (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

- Prepare Copernicus-based solutions to develop a specific cross-services element to support food security policies integrating climate change impact on the models used for describing the soil-water-vegetation interactions.

- Prepare Copernicus-based solution to support the promotion, monitoring, inspection/verification and enforcement of compliance with EU environmental legislation and rules:

Scope: The objectives of the Copernicus programme are to reinforce its capacity (both space and services) to keep protecting the environment and the citizens by responding to emerging policies while maintaining the key factors that made its strength.

This action collects topics useful to design and support the definition and development of new thematic and policy-related domains leveraging the different core services. The thematic and policy approach is part of the Copernicus evolution based on the identification of new policy(ies) or user need(s) and the corresponding observational and information gaps. This approach should be the starting point for integrating and expanding the Copernicus service portfolio from the user perspective and to better handle the evolution of the programme according to the Commission objectives. This approach should take into consideration synergies, complementarities and harmonisation across core services.

This approach should also foster the exploitation of space EO capabilities to close observation gaps in combination with ground-based infrastructure and innovative processing/modelling techniques. The proposed developments should be modular and scalable: the projects should provide a proof-of-concept or a prototype that can be easily integrated into the service(s). The project should also propose the development of tools to support end users in their decision-making activities (e.g. decision support systems, assessments, decision processes) using Copernicus data and products and meeting the need for timely and quality long-term global/regional information. The project(s) have also the objective to increase the capabilities and capacity of end users to use and apply Copernicus data and products. The involved end-user should also provide feedback to the proposed tools on product efficiency, data access, new measurement needs, new applied research topics, societal benefits, and other factors if necessary.

Depending on the selected area(s), user communities should be involved in the proposal. They are mainly public authorities from national to local scale, operators of protected areas that need to be monitored, administration in charge of planning and services in charge of law enforcement. The community ranges from the fisheries or maritime authorities to land managers, foresters and park managers, environmental agencies but also administration of cultural site or universities. It also includes many of the actors that have to comply with environmental rules from the business sector.

New digital tools should be considered and innovative solutions should be proposed for an optimal exploitation of the data, improved processing and distribution chains, e.g.: cloud and HPC computing, distributed computing, Artificial Intelligence, machine learning, ensemble modelling, model coupling & nesting, software as-a-service.

Additionally, the transfer from research to operations should receive full attention during the course of the projects to strengthen the readiness for an operational deployment in the future, including the conditions for making freely available, for re-use and exploit the results (including IPR) to the entities implementing the EU Copernicus programme. The software should be open licensed in order to use, copy, study, and change it in any way.

Proposals may be submitted in any of the indicated outcomes. All the outcomes should be covered. Up to maximum 2 projects will be funded.

Proposers are advised to consult information on the Copernicus programme in general at https://www.copernicus.eu/en and further details on the topic in the Guidance document.

Section: Development of applications from the EU Space Programme components

[Objective: We need to make the best use of EGNSS and Copernicus capacities for EU citizens, companies and society. Research and innovation should therefore foster the development of EGNSS downstream applications and promote their adoption in the EU and worldwide, in particular in long lead-time markets (e.g. maritime, rail, aviation), and in areas where Galileo offers unique differentiators (high accuracy, authentication, Search and Rescue, PRS). Copernicus based applications and services can serve, for example, polar research, monitoring of the environment, maritime and coastal monitoring, natural disasters, migration, agriculture and can bring, with EMODnet and EGNSS, a key contribution to the European Green Deal and to the sustainable management of natural resources. The public sector should be supported as customer of space based technologies via innovation procurement. Synergies between Galileo/EGNOS and Copernicus, as well as synergies with non-space programmes, leveraging the combination of space data with non-space data, will open new avenues for a wealth of new and innovative applications and services, still to be invented.

Current status: With EGNSS and Copernicus, Europe enjoys an operational space infrastructure, which can help tackle global challenges, contribute to economic growth and jobs, provide more efficient emergency and security services and pave the way for new space-based applications and products serving all sectors of society.

Achievements sought / targets: Copernicus data and information products are key tools to support specific activities worldwide where needs are identified, e.g. such as the Paris Agreement, 2030 Sustainable Development Goals (e.g. life on land, climate, life below water). It will create the enabling conditions for European researchers, industry, products and services in third countries and support the uptake of European-developed downstream applications, services and products outside Europe.

EGNSS based applications are needed to foster the European Green Deal, enable smart mobility, foster safety and crisis management, making best use of the Public Regulated Service (PRS) to serve public authorities needs. Applications should be fit for the digital age, complementing other technology trends such as 5G or AI, and innovative EGNSS receivers and chipsets should be developed responding to global macro-trends. Moreover, interoperability between space data and non-space data will be pursued taking into interoperability frameworks such as INSPIRE.

Means/Links: Most of the applications using the EU space programme components, primarily EGNSS and Copernicus are expected to be developed in the Horizon Europe Clusters addressing Climate, Mobility, Food and Natural Resources, Security societies. Therefore synergies with those clusters must be maximised. Possible contribution agreement with EUSPA – European Space Programme Agency, and using both grants and public procurement.]

Proposals are invited against the following topic(s):

SPACE-26-2021: EGNSS applications fostering the European Green deal (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Development of innovative EGNSS based solutions that contribute to the implementation of the European Green deal.
- EGNSS solutions can play a major role in the transformation of the EUs economy into a climate-neutral economy by 2050, environmental protection, biodiversity etc.
- Uptake of Galileo's specific features and differentiators in areas such as zero-pollution, clear and renewable energy and circular economy; sustainable and smart mobility; building and renovation, and digital farming supporting the farm to fork strategy.

Scope: Proposals shall focus on the development of innovative EGNSS applications that support the Green Deal objectives and its related policies and may be submitted in any of the following areas :

- **Zero-pollution ambition, clear and renewable energy and circular economy**: EGNSS solutions which contribute to C02 reductions and a toxic free environment, through better monitoring and preventing pollution from the air, water, soil and consumer products. EGNSS solutions which support the supply of clean, affordable and secure renewable energy. EGNSS solutions which limit the damage from fires, floods or other natural hazards. Examples of emerging applications include : EGNSS solutions for waste management within smart cities,''authenticated'' CO2 tracking, infrastructure monitoring, wind turbine blade inspection using drones, soil moisture, air quality or water quality monitoring using IoT, flood mapping and water level monitoring, oil spills mapping, data from GNSS CORS (Continuously Operating Reference Stations) used for meteorology, seismology or landslide monitoring, location-based services with GNSS geo-tagged photos of incidents.
- **Sustainable and smart mobility:** EGNSS solutions which enable or contribute to the development of new sustainable mobility services and which reduce congestion, emissions and pollution especially in urban areas, while keeping costs at an effective level. Examples of emerging applications include: automated and connected multimodal transport, mobility as a service, autonomous driving, IoT solutions for efficient mobility, road maintenance. The applications shall be focused on non-regulated road services.
- **Building and renovation:** EGNSS based solutions which contribute to the digitisation, smart monitoring and tracking of building and renovation processes. Examples of emerging applications include EGNSS based augmented or mixed reality for construction, special mapping solutions for making digital twins of buildings, utilities and infrastructure using Building Information Modelling (BIM), location-based applications for governmental processes, e.g. energy labelling of buildings leveraging the authentication

feature, sensors for smart monitoring, drones with thermal camera to detect water and thermal leaks.

- **Space based farming supporting the farm to fork strategy.** EGNSS based solutions which provide for food traceability across the entire supply chain. Precision or digital EGNSS farming solutions which reduce significantly the use of chemical pesticides and fertilisers. Innovative EGNSS based tools that support the digitisation of post-2020 Common Agricultural Policy or other agri-environmental policies. Examples of emerging applications include: EGNSS based autonomous machinery or automatic guidance, variable rate applications, swarm robotics, farm management systems, crowdsourcing, drones, geo-tagged photos, livestock and food tracking, virtual fencing, etc.

The developed solutions for all four areas shall leverage the EGNSS differentiators, e.g. High Accuracy Service, authentication features or Galileo Open Service with multi-frequency capability and may integrate other space components such as Copernicus or technologies like IoT, big data, artificial intelligence, drones, 5G, augmented/mixed reality etc.

Developed applications shall have a clearly defined commercial potential and should respond to user needs. The expected final TRL of the solution developed shall be between 7-9.

Proposals should deliver new innovative applications, with commercial impact and a clear market uptake. Where a combination of EGNSS with other technologies, such as Copernicus, satellite communication or other sensors is required to make the application(s) work, this can be included in the scope.

For proposals under this topic:

- Participation of industry, in particular SMEs, is encouraged;
- Participation of non-space countries is encouraged;
- Involvement of post-graduate researchers (engineers, scientists, and others) is also encouraged, for example through professional work experience or through fellowships/scholarships when applicable;
- A Business Plan and evidence of user engagement shall be compulsory and shall be provided as part of the proposal, to demonstrate the user need and sustainability of the project.

Proposals addressing PRS (Public Regulated Service) related applications are not in the scope of this action.

SPACE-27-2021: EGNSS applications for Safety and Crisis management (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Development of innovative EGNSS based solutions contributing to a resilient and more stable Europe that protects citizens.

- Development of innovative EGNSS solutions addressing safety concerns, to support the implementation of EU policy priorities relating to the safety of citizens, improved disaster risk management, improved border protection, better security and reslience of infrastructure and vital societal functions, cybersecurity, crisis management and fighting crime and terrorism more effectively.

Scope: Proposals may be submitted in any of the following areas:

- **Improved emergency disaster risk management and societal resilience**s. EGNSS solutions for critical services related to preparedness, response, recovery and mitigation of emergencies and disasters, introducing synergies between satellite navigation, earth observation and communications. EGNSS solutions that leverage Search and Rescue service for resilience and management in crisis situations, following a disaster where conventional means, e.g. telecommunications, are no longer existant. Further promising areas include mapping and high accuracy navigation for response and recovery, drone operations for disaster response, GNSS-based earthquake early warning system, Helicopter Emergency Medical Services.

- **Timing and synchronisation applications** focussing on emerging network synchronisation needs of critical infrastructures (electricity, telecommunications, financial etc.) in terms of accuracy and robustness, while reducing EU dependency from other GNSS. Proposals may e.g. focus on increasing receiver resilience to interference, increasing resilience and reliability in the reception of GNSS signals, tighter and more accurate time/phase requirements, timing precise synchronisation between financial platforms, Critical Assets Monitoring and Data Center resistance against spoofing data; telecommunication networks' operation; small cell synchonisation and 5G; Energy distribution and Phasor Measurement Units for smart grids.

- **Improved security, including**
    - **Management of air, land and sea EU external borders**, leading to better monitoring of movements across external borders and reduction of illegal movements of people and goods across those borders;
    - **Protection of citizens from violent attacks in public spaces**, through more effective prevention, preparedness and response while preserving the open nature of such spaces;
    - **Resilience of infrastructure and vital societal functions**, such as healthcare, law enforcement, energy, mobility, public services, and logistics infrastructures/networks, so as to minimise disruptions including from hybrid threats;
    - **Fighting crime and terrorism more effectively**, particularly through better prevention of criminal acts and enhanced investigation capabilities notably as concerns cybercrime;

- **Cybersecurity and a secure online environment**, with citizens, public bodies and companies empowered to protect their data and online activities.

Proposals shall exploit EGNSS differentiators such as Galileo Open Service multifrequency, Galileo High Accuracy Service (HAS), Galileo Open Service Navigation Message Authantication (OS-NMA), Galileo Signal Authentication Service and Galileo Search and Rescue Service (SAR) for the development of new innovative applications.

Developed applications shall have a clearly defined commercial potential and should respond to user needs. The expected final TRL of the solution developed shall be between 7-9.

Proposals should deliver new innovative applications, with commercial impact and a clear market uptake. Where a combination of EGNSS with other technologies, such as Copernicus, satellite communication or other sensors is required to make the application(s) work, this can be included in the scope.

For proposals under this topic:

- Participation of industry, in particular SMEs, is encouraged;
- Participation of non-space countries is encouraged;
- Involvement of post-graduate researchers (engineers, scientists, and others) is also encouraged, for example through professional work experience or through fellowships/scholarships when applicable;
- A Business Plan and evidence of user engagement shall be compulsory and shall be provided as part of the proposal, to demonstrate the user need and sustainability of the project.

Proposals addressing PRS (Public Regulated Service) related applications are not in the scope of this action.

SPACE-28-2021: EGNSS applications for the Digital Age (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Foster the adoption of EGNSS in mass markets
- Create applications that will make the best use of EGNSS innovative features such as better multipath resistance, authentication etc.
- Contribute to the competitiveness of the European GNSS industry in the area of mobile applications, with special focus on the innovative role of SMEs, and non-space countries.

- maximise public benefits by supporting the development of EGNSS applications that will address major societal challenges in focus areas such as health, citizen safety, mobility and the sharing economy.

Scope: Proposals may be submitted in any of the following areas:

- **Internet of Things:** Within Internet of Things solutions, there is a clear trade-off in terms of accuracy and battery life that prevents users to rely on GNSS in any situation. EGNSS solutions should demonstrate how power reduction techniques can effectively deliver GNSS-level accuracy in IoT devices and develop IoT solutions able to demonstrate the EGNSS compositeness in the IoT domain, to be used in application fields such as food geo traceability, blockchain and Artificial Intelligence
- **Mobile solutions.** Development of new EGNSS enabled solutions which exploit the EGNSS differentiators such as High Accuracy Service and authentication feature,s or which leverage the availability of GNSS raw measurements in smartphones.
- **mHealth-solutions for silver economy, robotics.** With the ageing population growing fast in EU, governments will be increasingly challenged in meeting the needs of older people in a cost-effective manner. EGNSS can support the silver economy by satisfying the specific needs of elderly and disabled persons. The innovations brought by EGNSS - together with technologies such as robotics or enhanced home automation – should be exploited to develop innovative solutions.
- **Artificial intelligence- Big Data, Geo-tagging, optimisation for multiple sensors.** Advances in AI will improve the capabilities of applications and services, providing improved experiences to all users.AI-enabled machine learning can be used to improve the GNSS data processing to provide even greater performances thanks to the optimization of multiple sensors. Proposals shall explore synergies between EGNSS and Artificial intelligence, also in the frame of applications relaying on big data and geo-tagging techniques. Synergies with earth observation data can be also exploited.
- **Cybersecurity- solutions that are stimulating privacy, security of location data, exploiting synergies with quantum**. In a digitalised world, privacy and cybersecurity are of utmost importance for individuals who are increasingly relying on digital applications to perform day-to-day task and activities. EGNSS solutions shall enhance the security of location-based applications. Additionally, synergies with quantum can be leveraged as well.
- **Sharing economy- solutions for logistics, mobility services, goods and food, wellness and beauty.** Sharing economy covers a great variety of sectors and is rapidly emerging across Europe. Within this trend, GNSS is a key technology for all service models requiring geographic information. EGNSS solutions in the field of logistics, mobility services, food industry and wellness should be developed that capitalise on enhanced accuracy and the innovative features provided by EGNSS.
- **Sports and fitness- smart wearables.** Wearables represent the beginning of the separation between smartphones and end users, as an increasing number of smartphone services and apps are now accessible via new interfaces (smartwatches, fitness trackers, smart glasses, clothing, etc.). Currently, wearables are mostly used for fitness, health and

entertainment. Proposals should ensure the use of EGNSS innovative features and differentiators in the smart wearables domain.

Synergies with other space components and other non-space technologies are applicable to this topic.

Developed applications shall have a clearly defined commercial potential and should respond to user needs. The expected final TRL of the solution developed shall be between 7-9.

Proposals should deliver new innovative applications, with commercial impact and a clear market uptake. Where a combination of EGNSS with other technologies, such as Copernicus, satellite communication or other sensors is required to make the application(s) work, this can be included in the scope.

For proposals under this topic:

- Participation of industry, in particular SMEs, is encouraged;
- Participation of non-Space countries is encouraged;
- Involvement of post-graduate researchers (engineers, scientists, and others) is also encouraged, for example through professional work experience or through fellowships/scholarships when applicable;
- A Business Plan and evidence of user engagement shall be compulsory and shall be provided as part of the proposal, to demonstrate the user need and sustainability of the project.
- Proposals addressing PRS (Public Regulated Service) related applications are not in the scope of this action.

SPACE-29-2021: Public sector as Galileo user (PCP)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Stimulate the public sector in Europe to use space downstream products, involving SMEs.
- Support to public stakeholders through specific funding tools, to develop, via pre-commercial procurement (PCP) innovative EGNSS solutions
- Encourage the public sector to be the “first customer” for innovative space based applications and contribute to speeding up the public sector modernisation.
- Enable public procurers to collectively implement PCPs in order to close the gap between supply and demand for innovative solutions that require e.g. precise location (from EGNOS/Galileo), spatial data and earth monitoring capabilities (from Copernicus).

- Bring radical improvements to the quality and efficiency of public services by encouraging the development and validation of breakthrough space-based solutions

- Decrease of the prices of EGNSS products/services, a smart use of the procurement budget to remove supplier lock-in and obtain more open, standardized solutions, shorter time-to-market facilitating the access of SMEs to the procurement market and increased exploitation of IPRs and R&D results

Scope: This topic is open to proposals for PCP actions in all areas of public sector interest requiring innovative solutions in different market segments that exploit space data. It is open both to proposals requiring improvements mainly based on one specific downstream space technology (e.g Galileo, Copernicus, GovsatCom), as well as to proposals requiring end-to-end solutions that need combinations of different space components.

The topic is dedicated for public administration to procure research that exploits space data and services (e.g. Galileo and/or Copernicus) and that meets their needs. In addition, the proposals should build on the procurement needs of the participating organizations, supporting the EGNSS market take-up across Europe and demonstrating a sustainability of solutions beyond the lifespan of the proposed project. Promising areas of activities are the following, however, the choice of market segment and application is left to the proposer:

- EGNSS for mobility as a service, cooperative ITS, public transport and smart cities,

- Integration of EGNSS into U-Space concept for drones,

- Monitoring of infrastructure with EGNSS and Copernicus (rail, road, critical infrastructure)

- Copernicus and EGNSS for crisis management.

Activities covered shall reinforce the national policy frameworks and mobilise substantial additional national budgets, as well as awareness raising, technical assistance and/or capacity building to other procurers beyond the project to mainstream PCP implementation and to remove obstacles for introducing the innovative solutions to be procured into the market.

Proposals addressing PRS (Public Regulated Service) related applications are not in the scope of this action.

SPACE-30-2021: Innovative EGNSS receivers, chipsets and antennas (RIA or procurement tbc)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Development of EGNSS receivers, chipsets and antennaes in non-mature markets with a low EGNSS penetration (e.g. critical infrastructure), in long lead term markets (e.g. rail), or the development of prototype receivers or chipsets which leverage new EGNSS services.

Scope: Proposals shall target the development of EGNSS receivers, chipsets and antennaes in non-mature markets with a low EGNSS penetration (e.g. critical infrastructure), focus on long lead term markets (e.g. Rail), or the development of prototype receivers or chipsets which leverage new EGNSS services.

Proposals shall build on the operational implementation of current differentiators such as OS-NMA, HAS and triple frequency to ensure the successful development and leverage new and enhanced Galileo services introduced by its evolutions. In parallel, the commercial implementation of new differentiators as CAS (Commercial Authentication Service) or ARAIM (Advanced Receiver Autonomous Integrity Monitoring) should be explored.

The development of emerging, disruptive technologies should continue to be fostered in new areas of applications such as advanced robotics, automation, artificial intelligence, machine learning, safety and liability critical transport etc.

While at application level synergies between EGNSS & Copernicus or GovSatCom are more evident, the synergies between other space systems on user technology should be increased.

Moreover, company consortia should be accompanied after the project duration to scale-up their business and create synergies with other business partners together with other entrepreneurship initiatives. The participation of start-ups and SMEs is encouraged.

SPACE-31-2022: EGNSS applications for Smart mobility (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Development of EGNSS based safety-and liability-critical applications in long lead time market segments such as aviation, maritime, rail, road transportation and multi modal domains.
- EGNSS response to the increasing mobility demands and emerging transport solutions, such as those enabled by autonomous or unmanned platforms.
- The action aims at fostering the EGNSS market uptake in transport. Applications shall demonstrate the advantage of Galileos and EGNOS specific features and differentiators for their use in smart and green mobility, and shall contribute to a resource efficient, safe, climate and environmentally friendly transport, that will be for the benefit of citizens, the economy and society.

Scope: Proposals may be submitted in any of the transport areas or propose a multi-mode approach:

- **Aviation**: EGNSS solutions for modernising and improving air operations and traffic management technologies, addressing Communication, Navigation and Surveillance, targeting new navigation operations powered by EGNSS (e.g. 4D, GBAS DFMC, surveillance), increased airport efficiency (e.g. leveraging SWIM), critical airport infrastructure management (e.g. synchronization, monitoring, surveying) and facilitating integration of drones in the airspace (drone operations, U-Space services leveraging EGNSS and Earth observation data, dynamic maps), as well as new entrants in the airspace, scuh as high altitude flights.

- **Maritime**: EGNSS solutions that reduce emissions in shipping and increase efficiency of operations (e.g. ports operations and logistics, intelligent routing), safety (e.g. fisheries, navigation at sea, coastal and inland waters, surveillance and accident investigation, search and rescue at sea), and resilience, and drive the modernization of the sector (e.g. Internet of boats, automation, GNSS contribution to marine communication networks).

- **Rail**: EGNSS for cheaper, smarter, higher performance, safer and emission-efficient solutions (e.g. contributing to the the deployment of EGNSS based signaling and its inclusion into the evolution of the European Train Control System (ETCS), efficiency-focused innovations enabling cost savings, capacity increase and automation, infrastructure management, dangerous goods transport, autonomous trains). EGNSS based train localization for critical applications as well as the use of Copernicus for infrastructure related operations shall ensure that the EU railways sector keeps pace with rest of the world, where the adoption of space-based services already started.

- **Road**: EGNSS solutions for regulated markets that reduce traffic, optimise fuel consumption, lower emissions, and foster cheaper, smarter, safer and greener transportation. EGNSS solutions to support the development of connected and autonomous driving, new capacities for vehicles, e.g.intelligent speed adaptation, and the use of integrated space data for road safety and environment, such as monitorization of road infrastructures (e.g. land slides and bridge infrastructure). EGNSS solutions that valorize of EGNSS regulations such as the eCall system (e.g. GNSS Tolling for passengers cars, congestion charging in Smart Cities, eParking, traffic information), or of the Smart Tachograph in commercial vehicles (e.g. custom control and cross-border enforcement, cabotage and freight activities).

Proposals should be built on the exploitation of the distinguishing features of EGNOS and Galileo.

The action focuses on the development of close to market EGNSS transport applications and mobility services through the realisation of large scale demonstration and implementation projects.

Developed applications shall have a clearly defined commercial potential and should respond to user needs. The expected final TRL of the solution developed shall be between 7-9.

Proposals should deliver new innovative applications, with commercial impact and a clear market uptake. Where a combination of EGNSS with other technologies, such as Copernicus, satellite communication or other sensors is required to make the application(s) work, this can be included in the scope.

For proposals under this topic:

- Participation of industry, in particular SMEs, is encouraged;
- Involvement of post-graduate researchers (engineers, scientists, and others) is also encouraged, for example through professional work experience or through fellowships/scholarships when applicable;
- A Business Plan and evidence of user engagement shall be compulsory and shall be provided as part of the proposal, to demonstrate the user need and sustainability of the project.

Proposals addressing PRS (Public Regulated Service) related applications are not in the scope of this action.

SPACE-32-2022: Innovative governmental EGNSS receiver, chipsets and antennaes (PRS) (IA or procurement, tbc)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- The development of PRS receivers, chipsets and antennaes for the first generation of Galileo, and the preparation of PRS technology adaptations for the second generation of Galileo (G2G).
- The development or evolution of additional PRS tools required for the qualification of these PRS items shall be addressed.
- Stimulate the downstream PRS market uptake via the delivery of accredited PRS equipment, promote the integration of secure services in other space components, such as GovSatCom and Copernicus, and to increase and disseminate knowledge and support cross border EU cooperation between Member States, so as to deliver concrete solutions for EU strategic challenges such as safety and the competitiveness of the EU industry.

Scope: The action shall focus on the development of innovative technologies in the following areas, considering that each equipmen will have to fulfill the EU security requirements:

- **PRS tools (G2G):** The adaptation of already existing PRS tools, or the development of new PRS tools, enabling the development of PRS items for the 2nd generation of Galileo.
- **PRS space grade receivers.** The development of PRS space grade receivers on board the satellites, to ensure a higher protection against interferences of GNSS services and the service provider infrastructure, and maintain the availability and continuity of the service.

- **Secondary Channel:** The development of user equipment and technology, required to provide secure ground communication between secure PRS items of the user segment. The knowledge gathered under this action is of benefit also to other Space Programmes.

- **Innovative protection schemes:** The development of new innovative technologies in the field of protection and distribution of sensitive materials, including e.g. the use of quantum technology for the creation of more powerful cryptographic algorithms. The knowledge gathered under this action is of benefit also to other Space Programmes.

Any development of equipment shall have a clear target of intended application, shall be justified by its commercial potential and shall respond to the user needs. The expected final Technology readiness level (TRL) of the solution developed shall be between 8 and 9 again with the view that these EU made in solutions shall support competitiveness and company's growth.

SPACE-33-2022: Public sector as Galileo user (governmental applications, PRS) (PCP)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Stimulate the public sector of Member States to jointly test activities to verify the PRS functioning on the field, and to use PRS related applications.
- Encourage the public sector to be the "first customer" for innovative space based PRS applications and contributing to speeding up the public sector modernisation.

Scope: The action is targeting the joint development of innovative PRS applications, the integration of PRS with other already existing non-PRS applications and technological components, and the development and testing of prototypes which demonstrate the added value of using PRS in critical market segments (e.g. timing, aviation, command and control services).

The action aims at addressing the governmental user needs expressed in priority market segments, increasing the knowledge around PRS use, supporting cross border EU cooperation, maximising the benefits for European citizens and manufacturers and increasing the EUs safety and industry competitiveness (including SMEs and universities).

Promising areas of activities are the following, however, the choice of market segment and application is left to the proposer:

- Joint testing activities of Member States to verify the PRS functioning on the field, e.g in the area of timing and synchronization, control and command, aviation.

- Activities related to the development of standardized PRS user technology, involving as well GovSatCom.

- The joint development of PRS related applications in key public regulated areas such as police operations, search and rescue, border surveillance, emergency response, public safety, disaster relief etc.

Activities covered shall reinforce the national policy frameworks, as well as awareness raising, technical assistance and/or capacity building to other procurers beyond the project to mainstream PCP implementation and to remove obstacles for introducing the innovative solutions to be procured into the market.

SPACE-34-2022: Governmental downstream applications (PRS) (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Stimulate the development and market uptake of PRS governmental downstream applications.
- PRS market uptake including the preparation of G2G market uptake for EU governments.
- Stimulate the development of innovative PRS applications and the integration of PRS with other already existing non-PRS applications and technological components

Scope: The action is intended to serve the need of governmental users.

The actions shall focus on the development of innovative PRS applications or inclusion of PRS capacity evolution into existing applications capable to serve the need of the EU governments, including authorized EU Agencies. The action covers evolution of the applications according to the Galileo system developments and evolutions.

The scope of action shall ensure but not be limited to the development of the following application:

- Monitoring and timing application for authorized users;

Each of developed applications shall seek for the synergies with other Programmes intended for EU Governments.

SPACE-35-2022: EGNSS applications for the Digital Age (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Foster the adoption of EGNSS in mass markets
- Create applications that will make the best use of EGNSS innovative features such as better multipath resistance, authentication etc.

- Contribute to the competitiveness of the European GNSS industry in the area of mobile applications, with special focus on the innovative role of SMEs and non-space countries

- maximise public benefits by supporting the development of applications that will address major societal challenges in focus areas such as health, citizen safety, mobility and the sharing economy.

Scope: Proposals may be submitted in any of the following areas:

- **Internet of Things:** Within Internet of Things solutions, there is a clear trade-off in terms of accuracy and battery life that prevents users to rely on GNSS in any situation. EGNSS solutions should demonstrate how power reduction techniques can effectively deliver GNSS-level accuracy in IoT devices and develop IoT solutions able to demonstrate the EGNSS compositeness in the IoT domain, to be used in application fields such as food geo traceability, blockchain and Artificial Intelligence
- **Mobile solutions.** Development of new EGNSS enabled solutions which exploit the EGNSS differentiators such as High Accuracy Service and authentication feature,s or which leverage the availability of GNSS raw measurements in smartphones.
- **mHealth-solutions for silver economy, robotics.** With the ageing population growing fast in EU, governments will be increasingly challenged in meeting the needs of older people in a cost-effective manner. EGNSS can support the silver economy by satisfying the specific needs of elderly and disabled persons. The innovations brought by EGNSS - together with technologies such as robotics or enhanced home automation – should be exploited to develop innovative solutions.
- **Artificial intelligence- Big Data, Geo-tagging, optimisation for multiple sensors.** Advances in AI will improve the capabilities of applications and services, providing improved experiences to all users.AI-enabled machine learning can be used to improve the GNSS data processing to provide even greater performances thanks to the optimization of multiple sensors. Proposals shall explore synergies between EGNSS and Artificial intelligence, also in the frame of applications relaying on big data and geo-tagging techniques. Synergies with earth observation data can be also exploited.
- **Cybersecurity- solutions that are stimulating privacy, security of location data, exploiting synergies with quantum**. In a digitalised world, privacy and cybersecurity are of utmost importance for individuals who are increasingly relying on digital applications to perform day-to-day task and activities. EGNSS solutions shall enhance the security of location-based applications. Additionally, synergies with quantum can be leveraged as well.
- **Sharing economy- solutions for logistics, mobility services, goods and food, wellness and beauty.** Sharing economy covers a great variety of sectors and is rapidly emerging across Europe. Within this trend, GNSS is a key technology for all service models requiring geographic information. EGNSS solutions in the field of logistics, mobility services, food industry and wellness should be developed that capitalise on enhanced accuracy and the innovative features provided by EGNSS.

- **Sports and fitness- smart wearables.** Wearables represent the beginning of the separation between smartphones and end users, as an increasing number of smartphone services and apps are now accessible via new interfaces (smartwatches, fitness trackers, smart glasses, clothing, etc.). Currently, wearables are mostly used for fitness, health and entertainment. Proposals should ensure the use of EGNSS innovative features and differentiators in the smart wearables domain.

Synergies with other space components and other non-space technologies are applicable to this topic.

Developed applications shall have a clearly defined commercial potential and should respond to user needs. The expected final TRL of the solution developed shall be between 7-9.

Proposals should deliver new innovative applications, with commercial impact and a clear market uptake. Where a combination of EGNSS with other technologies, such as Copernicus, satellite communication or other sensors is required to make the application(s) work, this can be included in the scope.

For proposals under this topic:

- Participation of industry, in particular SMEs, is encouraged;
- Participation of non-Space countries is encouraged;
- Involvement of post-graduate researchers (engineers, scientists, and others) is also encouraged, for example through professional work experience or through fellowships/scholarships when applicable;
- A Business Plan and evidence of user engagement shall be compulsory and shall be provided as part of the proposal, to demonstrate the user need and sustainability of the project.

Proposals addressing PRS (Public Regulated Service) related applications are not in the scope of this action.

SPACE-36-2022: Copernicus downstream applications and the European Data Economy (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Actions under this topic should be instrumental to help European companies innovate, develop and bring to market new or improved products and services by exploiting Copernicus data assets and, whenever relevant, the link with European satellite positioning/navigation/timing technologies.

Copernicus data will be at the core of the data value chains and integration activates needed to fulfil the industrial requirements that will drive the proposals.

Project proposals should adopt state-of-the-art ICT technologies (such as, for example, big data and AI technologies), and make use of existing European data infrastructures, such as Copernicus DIAS platforms, European open data portals, industrial data platforms and contribute to European data spaces.

The participation of industry is required to define the project's industrial requirements from the very beginning of the action and to take ownership of the results.

Scope: Copernicus, the Union's Earth observation and monitoring programme produces a wealth of data and information services on the Earth, its lands, atmosphere, oceans and inland waters, as well as on climate change and in support of disaster management and security. Copernicus data and information services are available with a free and open data licence.

Copernicus data are an integral part of the European Data Economy. Europe needs to strengthen its position as provider of products and services based on data, enabling new market opportunities.

The integration of Copernicus data assets with data contributed by other vertical domains (i.e. not necessarily from the space/geospatial sector) will greatly enhance Copernicus downstream market. Likewise, many vertical domains, other than space, will benefit from the use of Copernicus.

SPACE-37-2022: Large-scale Copernicus data uptake with AI and HPC (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Development of big data technologies and analytics, and AI methodologies addressing industrial requirements and/or societal challenges with Copernicus earth observation data at their core, scaling up to the increased data volumes of Copernicus' archives.

Proposers shall aim to develop new, enabling, operational solutions to improve capabilities and performance of the Copernicus value chain: from access and discovery of data and information to integration with other data sources and analysis to delivery and applications. Proposals can address individual elements of the value chain or the value chain as a whole, and should provide quantitative measures of the progress beyond the state of the art.

Scope:Copernicus is producing increasingly large data volumes that require specific Big Data technologies and Artificial Intelligence (AI) methods to analyse it and manage it. The adoption of Big Data technologies in the space industry represents a significant opportunity to innovate.

New and innovative products and services having Copernicus data assets at their core require solving technological challenges related, for example, to the adoption of Artificial Intelligence paradigms and to the big data management of integration with other distributed data sources from other industrial domains.

Copernicus data are part of the European Data Economy and its value chains. As such, this call is promoting the collaboration of ICT actors, both from industry and academia, with the earth observation/space stakeholders.

SPACE-38-2022: AI for Space Data Infrastructures (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Project proposal should address the technological building blocks and Artificial Intelligence paradigms, required to fully integrate Earth Observation data archives, including Copernicus data and information assets, into the wider web of data and connect to European Data Spaces.

Proposers shall aim to develop new, enabling, operational solutions making machine to machine operations possible with the goal to foster earth observation data exploitation at Petabyte scale and industrial uptake.

Scope: The data infrastructures offering archiving and distribution services for Earth Observation data, including Copernicus, are often data silos that offer today limited discoverability, querying and linking possibilities.

The full exploitation of the archives and data stores require specialized Artificial Intelligence technologies, Linked Open Data paradigms and semantic archives able to scale to the full archives data volumes.

Enhancing those cloud infrastructures with technological paradigms that are now typical of other data intensive domains (such as multimedia), will contribute to facilitate the development of new products and services with earth observation data at their core, and connect earth observation data to European Data Spaces.

Section: Innovative space capabilities: SSA, GOVSATCOM, Quantum

[Objective: Space Situational Awareness (SSA) and GOVSATCOM innovative components will be developed in the EU Space programme fostered by Horizon Europe R&I. Quantum Technologies, as an emerging field with great potential to be applied in the EU Space programme, requires foundational research and validation activities for its space component.

Space Situational Awareness (SSA) will provide services to European users including spacecraft owners/operators and governmental entities that will reinforce the protection and resilience of European space and ground infrastructures against various threats and risks (collisions in/from space, Near Earth Objects or space weather events). New challenges are posed by the ever increasing orbital population of smaller satellites and space debris and the associated increased risk of orbital collisions and re-entry. R&I activities shall address these challenges by developing novel architectures and technical solutions for ground/space sensors, data processing, networking and operation centers (including critical technological elements for the realization of crucial future space weather applications and services) to ensure safety and sustainability of space operations in Europe as well as by implementing improved and new services (mitigation; remediation; modelling; space weather services). The **GOVSATCOM** initiative, in order to ensure reliable, secured and cost-effective satellite communications services, will provide the EU and Member State authorities with an infrastructure supporting secure critical missions, with the ability to exchange sensitive information in a hybrid threats environment worldwide (including the Arctic) Research and innovation activities will foster the development of European satcom security related technologies and increase European independence from foreign critical technologies and exploiting synergies with Copernicus and Galileo.

Space will pave the way for **quantum technologies** in EU space infrastructure and for space-based services. It is of highest strategic importance for the EU and its industry to be competitive and to become a global leader in this area. Satellites and space-based applications are playing an increasing role in quantum technologies (e.g. quantum inter-satellite communication, next generation atomic clocks or quantum sensors) and will provide enhanced services to EU citizens and allow to overcome limitations and challenges of the current generation of quantum technologies. Therefore, R&I shall foster the development and use of EU sourced space qualified quantum components, including mission design, integration and in-orbit demonstration and validation. In addition, the availability of adequate ground segment infrastructure for testing and validation the quantum space mission needs to be ensured. Synrgies with GOVSATCOM will be ensured.

Current status:

The EU is currently implementing a Space Surveillance and Tracking (SST) support framework in order to provide initial SST services to registered users through a network of Member States' sensors (radars, telescopes and lasers) and operational centres.

An operational satcom space infrastructure already exists in Europe, and its capacity will initially contribute to new GOVSATCOM initiative, which is based on pooling and sharing of resources. The EU GOVSATCOM R&I actions – expanding further the existing commercial and governemental systems - will allow industry to also respond to the needs of the national and global market.

Europe has an excellent research pool dedicated to quantum technologies; currently the transformation from science and research into industrial applications in and for space is weak. By supporting and bridging in both areas the EU will be able to ensure the availability of non-dependent industrial sources for critical components, including through the EuroQCI initative. Boosting the quantum technology ecosystem in space and for space applications (including SME and start-up support) will allow Europe to bring quantum in space to the next level.

Achievements sought / targets:

SSA: Improving European strategic autonomy in ensuring the protection and resilience of critical European space infrastructures.

Govsatcom: Improving European resilient and secured satellite communication services, increasing the strategic technology autonomy in the infrastructure required, and reinforce protection against modern threats, exploiting the synergies between civilian and defence /security space and infrastructure assets, in order to reduce cost, increase resilience and improve efficiency.

Quantum: The EU will be a non-dependent global leader in space-based quantum technologies and be able to provide the EU space programme and consequently its citizen with the most beneficial services and usage of state of the art technologies applied.

Means/Links: Grants (RIA, IA and CSA) and public procurement. Possible contribution agreements with ESA - European Space Agency and with EUSPA – European Space programme Agency. Actions to be implemented using grants and public procurement.]

Proposals are invited against the following topic(s):

SPACE-41-2021: Next & Improved EUSST Missions and Services (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

In the coming years, an increase in the number of active objects in orbit is foreseen (e.g. deployment of mega-constellations, increased number of non-manoeuvrable small objects – CubeSats for research and scientific purposes, etc.). Additionally, the number of objects (active and inactive) to be handled by SST systems will also increase due to the use of sensors with a higher detection capability. For example, the US Space Fence radar, declared operational in March 2020, is capable of detecting and tracking objects smaller than 10 centimetres and is expected to considerably increase the size of space objects catalogue of the US Space Surveillance Network.

Consequently, the provision of services by the EUSST operation centres, as well as the strategy used to protect the European active satellites will have to be adapted to the arising needs. The need for the development of automated concepts becomes more relevant in order to reduce response times, reduce costs and simplify coordination activities amongst operators.

Therefore, R&I projects on "*new and improved EUSST missions and services*" are expected to contribute to the following outcomes:

- Keep the knowledge and capabilities of Europe on the Space Surveillance and Tracking domain at the leading edge.
- Adapt, improve and evolve the current EUSST initial services (Collision Avoidance; Fragmentation; Re-entry) portfolio to future user needs and space environment.
- Improve the overall performance of the EUSST services and ensure, in the long-term, a high level of performance and appropriate autonomy at Union level.
- Identify and define new missions and services (e.g. debris mitigation; debris remediation).
- Explore the implementation of new services, in complement of the three existing ones.
- Support the pre-developments and end-to-end early demonstration of new SST services.

<u>Scope</u>:

- Evolution of the Collision Avoidance service towards a higher responsiveness in the case of risks (e.g. Automatic warning service).
- Evolution of the EUSST system for **debris mitigation** in order to reduce the space debris generation, as for example:
  - Extended computation of conjunctions and risks;
  - Automatic risk estimation and mitigation measures, (e.g. ground or on-board processes and using AI techniques);
  - Support to satellite O/O in case of spacecraft anomalies;
  - Design of innovatives solutions for the detection and characterisation of malfunctioning satellites;
- Evolution of the EUSST System for space **debris remediation** by managing the existing space debris. The analysis of potential remediation focused services at European level, the feedback of O/O and the monitoring of the international arena in the coming years are needed inputs prior to define the content of this topic in detail.
  - Stimulation of the use of removal and disposal techniques through regulatory initiatives;

  - Design associated to removal/servicing technology demonstration;
  - Development and demonstration of passivation, disposal and active removal technologies;

- Evolution of the EUSST Service Provision Portal in line with the evolution of the existing services (CA, RE, FG) and the inclusion of additional ones (Debris mitigation / remediation). R&I activities will be required to cope with an expected increased number and heterogeneity of users and spacecraft, evolution of the SST Consortium/Partnership, etc. Reporting activities must continue evolving, as to provide actionable "Key Performance Indicators" supported by the development of the necessary tools/applications.

SPACE-42-2021: SST & STM system (architecture / evolutions / lab & test beds) (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

The environment on which the EUSST system performs its mission and delivers its services is in constant evolution (e.g. technological or political factors changing the way on which the space is used, orbital environment …).

EUSST system architecture engineering & evolutions: the analysis of the EU SST system architecture needs to continuously progress to evaluate how the system has to evolve at medium and long term, not only at network level (type, performance, number, geographical localisation... of assets) but also at data processing and at services level. Other aspects like data flow, security constraints, interconnectivity between EU assets but also complementarity and cooperation with other SST systems, etc. need to be considered as well.

- Foster European cooperation in the SST domain and improve the EUSST performance towards larger autonomy.
- Highlight and propose solutions to fill the gaps in the current EUSST architecture.
- Pave the way on which the EUSST system has to evolve towards a higher level of performance (e.g. precision; number of catalogued objects...), quality of service (e.g. timeliness of information...) and autonomy.
- Ensure the complementarity, coherence and added-value of each element of EUSST system towards a more autonomous, interoperable SST system.
- Look for higher complementary to other SST systems such as the US one which is of paramount importance to develop long-term cooperation.

Space debris and Orbital Environment R&D; SSA Lab & testbeds

- Increase the accuracy of the modelling tools and the modelling studies.

- Improvement of algorithms to model the space environment in a way that can respond to the challenges of the future (large constellations, small satellites, on-orbit servicing, activities on defence of space, big data management, use of orbital indexes, etc.)..

Solutions (ground & space based) for EU Space Traffic Management implementation: the reliance on space-based data and services, in particular thanks to the success of Copernicus and Galileo European programmes, for our society, economy, security and defence has been rapidly growing. At the same time, the emergence of new type of actors and business models (e.g. mega constellation) increases the number of satellites and debris in orbit. For this reason, space becomes more and more congested, posing a threat to the sustainability and safety of space operations and infrastructures, with a higher risk of collision and of radiofrequency interferences.

The importance of SST / Space Traffic Management (STM) is thus growing, in a context where there is lack of a clear definition at international level and no global regime and system is in place, neither are flight rules and the associated monitoring means.

- Raise the main issues and propose relevant answers to questions posed by all those developments in various technical, operational and legal domains.

- Propose adaptation to the new changes and solutions for their possible integration into the existing standards, practices, technological means, governance, regulatory and policy frameworks.

Scope:

- EUSST architecture engineering.

- Define the future EUSST architecture and associated development roadmap offering the best value for money

- Architecture studies and system design to validate the added-value of all the layers of the EUSST system.

- Define and set up efficient and relevant performance criteria, “metrics”, “Key Performance Indicators” and “critical success factors” (e.g. accuracy of European catalogue; expected increase of the number of objects into the catalogue; timeliness of service provision...)

- Orbital population modelling at different time horizons

- Various simulation tools

- Laboratory equipment and testbeds for orbital environment modelisation

- Activities / studies in the area of manoeuvre coordination, interference management, collision avoidance automation.

- Activities / studies in space objects life cycle and risk assessment.

- Assessment and pre-development of technology for rendez-vous and close proximity operations.
- Develop and promote spacecraft / constellations "Clean_design".
- Preparation and demonstration of technologies for in-orbit servicing.
- Assessment and pre-development of technology for object identification, for navigation aids and for servicing interfaces.
- Technical standardisation activities in these areas.

SPACE-43-2021: Space-based SST (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

With the increase of the orbital population and with the need of observing smaller objects to better protect the EU space assets, the need and added-value of developing **Space-Based Space Surveillance** (SBSS) missions in complement to ground SST networks shall be studied in Europe.

Space-based SST missions and sensors network: Based on the experience of SBSS missions launched and operated outside Europe (e.g. by US and Canada), this type of mission may potentially increase the EU ability to observe and catalogue objects on various orbits, and compensate for the limitation linked to the geographical location of ground sensors.

- Study and assess several technical solutions for the development of a future European capability of SBSS.
- Explore of small satellites solutions to reduce CAPEX and OPEX
- To develop in the mid-term the European capacity to operate independently SBSS.
- R&I SST exploratory payloads & IOD missions: space based sensors (co-financed with IOD support): in order to allow Europe to develop a SBSS capability aiming to enhance its capability to protect European space assets from space debris threats, Research and Innovation activities on payloads and space-based sensors are required.
- Study and assess several technical solutions for the development of a future European payloads and sensors for SBSS missions
- As the SBSS mission is not just a concept (cf. Saphire - Canada, ORS mission - USA), Europe has to develop in short term in orbit demonstrations / validations to test missions concepts (e.g. microsat, CubeSat, constellation) and payloads (e.g. dedicated, opportunistic)

Non-dependent EU Technology sources for critical components of space based SST systems and sensors: in order to achieve Europe's strategic autonomy of a future European SBSS system, Europe needs non-dependent access to critical space technologies. "Non-dependence" refers to the possibility for Europe to have free, unrestricted access to any required space technology. Reaching non-dependence in certain technologies will also open new markets to our industries and will increase the overall competitiveness of the European Space sector.

- To reduce the dependence on critical SBSS technologies and capabilities from outside Europe,
- To develop in a timely manner reliable and affordable SBSS space technologies,
- Complement with focus on SBSS needs, the R&I activities in technologies for European non-dependence and competitiveness undertaken within the frame of the past space research programmes (e.g. Commission-ESA-EDA Joint Task Force (JTF) on Critical Technologies for European non-Dependence list of actions...).
- Develop complementary and create synergy with other European activities in the same technological domain (e.g. optical sensors; on-board pre-processors ...) either in the space or non-space fields.

Scope: With the development of SBSS missions, new challenges have to be solved, at payloads and on-board sensors as for the following examples. Non-dependent technologies for European SBSS have also to be ensured.

- Study of various mission configurations (e.g. orbit regime, orbit plan, …) and payload location to maximize the number of observed and catalogued objects,
- Study of coordination strategy and techniques among the satellites of the SBSS mission and the terrestrial SST system.
- Develop algorithms allowing going from detection to cataloguing (e.g. IOD, correlation …) taking into account ground based SST system and payload performance (i.e. observable magnitude).
- Exploration of the use of non-dedicated sensors (“opportunistic” solutions) to reduce cost of operation is also an aspect to develop.
- Security issues related to the link between SBSS and ground SST network.
- R&I activities shall include as well as the launch of small (microsat, CubeSat) platforms equipped with payloads to test at lowest cost the capability of European payloads and technology to observe and catalogue space objects from space.
- Payloads and missions may include the use of non-dedicated sensors (e.g. star trackers) to analyse their capability to characterize the space environment
- Analysis of relevant available technological roadmaps,
- Develop specific technological roadmaps for SBSS systems,

- Study and assess SST space-based sensors
- Enhance the TRL of the technologies identified in the list.
- [other TBD with preliminary results of SBSS payloads design]

SPACE-44-2021: SST Sensors and Processing (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Supporting the upgrade and development of assets, in particular radars and telescopes as well as data processing.

SST radiofrequency & optical sensors (radars, telescopes…) technological research & innovation: due to the increased number of objects (both active and debris) to be handled, as well as the evolution and inclusion of services in the future, R&I activities are necessary in the sensor domain, both for radiofrequency (e.g. passive ranging, radars, etc.) and optical sensors (e.g. telescopes, lasers). New promising technologies like sensors based on the use of infrared will also be considered.

- Contribution to a consolidated and efficient EUSST sensor function.
- Improve coverage area, geographical location and performance they can offer: e.g. field of view, limiting magnitude, frequency-band...
- Ensure an optimum evolution of the configuration and use of the EUSST sensors network, including the necessary raw data processing required to provide measurement data.

Improved integration and connectivity of value added sensors, ensuring their compliance to the minimum quality requirements (including protocols, procedures, formats and calibration status)SST data processing research & innovation (e.g. Artificial Intelligence…): the changes and evolution in the space environment impose the need of adapting the current algorithms and data processing methods and tools, as well as to look for new one.

- Include or at least explore the possibility to use Artificial Intelligence (AI) in any SST data processing (e.g. Improvement of object detection capability; of probability of collision accuracy ...)
- Development of automatic tasking and data processing functions

Scope: To ensure that the data processing used in the SST domain can properly address the upcoming requirements in all aspects, such as:

- Technologies already in use, like radars, telescopes and lasers, need to be adapted to the new environment.

- Improvement of sensors performances (e.g. measurements quality (noise; bias; measurements rates ...); tracks accuracy (track noise; track duration...)).
- Specification, development, testing and pre-integration of a improved sensors.
- Innovations need to be developed to allow detection of smaller objects, higher processing capabilities (e.g. networked telescopes for LEO coverage, tracking by lasers in daylight ...).
- New detection strategies to cope with an increased number / size of objects in the sensors' Field of Regard / Field of View.
- Additionally, new technologies will be explored for the development and implementation of potential new services developed in CAP_SSA-01 topic (e.g. support to manoeuvre, detection of malfunctioning spacecraft, etc.)
- Improved algorithms (e.g. Initial Orbit Determination, OD, covariance estimation...) for a more agile cataloguing of the increasing space objects population.
- Algorithms for data fusion for a more efficient use of the data and information from the same object coming from different sensors.
- Improvement of correlation measurements algorithms.
- mprovement of orbit and covariance estimation, for example for support to manoeuvres and identification of in-orbit anomalies, etc...
- Improvement of computation models of collision probability.
- Development of evaluation methods of collision probability that could be applied to constellations (e.g. multiple encounters).
- Improvement or development of new objects propagation models for efficient propagation of the orbital population (e.g. cloud propagation models to propagate the debris cloud generated after a fragmentation ...).
- Evolution of coordinated scheduling of sensors to progress towards a more efficient use of multiple available resources at system level.
- Any promising technology for precise tracking and data processing.

SPACE-45-2021: SST Networking, Security & Data sharing (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

The topic "SST Networking, Security & Data sharing" aims to support the upgrade, development and security issues of EUSST infrastructure based on the European network of assets (sensors, operation centres, front desk …).

Although the EUSST infrastructure is supposed to stay under national control (meaning mainly sensors and operation centres), an increased coordination is needed due to the increased number of assets contributing to the European SST system. Without this interconnection and coordination, it is impossible to ensure an efficient use of the resources and an appropriate response to the challenges pose by the changing space environment.

As concrete aspects of the EUSST network (e.g. pooling of data from multiple sensor sources; exchange between multiple operations centres of Member States) shall be considered in highly detailed case studies, modelling ..., this topic shall be limited to the members of the EU SST Consortium/Partnership in order to protect security-sensitive information.

SST networking of sensors & operation centres (European Union SST network Command & Control): considering the increased number of objects to be handled, an increased number of events and users is expected. The European SST system has to evolve to a coordinated scheduling of the resources and assets, ensuring that the events are covered in an optimum way, while the current survey and tracking of the space objects population continues to be performed. Evolution of the European SST network includes the Front Desk in charge of the interaction with the users (users' needs, monitoring of the service performance, etc.).

- Raise the main issues and propose relevant answers to the increasing complexity and missions constraints of the EUSST network.
- Connectivity and interface consolidation of network function between sensors / database / operating centres / front desk (reliability, maintainability and agility).
- Develop EUSST network in order to include a future new SBSS segment.

Research on EUSST network hardening against external threats: the research concerns security-critical aspects of the existing EU SST network. Various external threats shall be considered in the research activity (e.g. cyber threats or other malicious activity). Research specifically applying to the hardening of the EU SST network could add value to existing research on network hardening that looks at computer networks and other related networks more generally.

- A secured and resilient EUSST infrastructure.

Next generation exchange protocols / solutions for SSA enhancing interoperability and security (robustness, information assurance, intrusion detection…)

- A secured and resilient EUSST infrastructure
- Define the need for SST-specific tools and solutions with regard to enhanced data interoperability and data security.

Scope: With the development of, among others:

- Update operation centres to improved current services (Collision Avoidance; Fragmentation; Re-entry) adapted to future user needs and space environment.

- Update operation centres to new missions and services (e.g. debris mitigation; debris remediation).
- Adapt the European SST network to a more efficient coordinated scheduling of the resources and assets.
- Develop new data sharing and fusion strategies and techniques adapted to both ground based and space based SST assets.
- Develop threats analysis and associated counter measures.
- Adapt EUSST operation centres for increasing security and resiliency.

SPACE-46-2021: Space Weather (type of action tbc)

Expected outcomes: Projects are expected to contribute to the following outcomes:

Commonly occurring space weather events (SWE) have the potential to affect the performance of critical space and ground infrastructure by disrupting operations and communications in multiple sectors of society. In addition, “extreme SWE” could have devastating societal and economic consequences with potential costs for disruptions and damages estimated in tens or even hundreds of billions of Euros.

Space weather technological research for new precursor services: the worldwide goal of space weather activities should be to monitor and forecast SWE just like terrestrial weather. However, direct physical simulation is currently not achievable for an operational Sun to Earth system, due in part to the lack of measurements and to the complexity of the involved processes, as well as different timescales involved. Current space weather models are generally not capable of forecasting events over several days. A longer forecasting horizon would require access to data from new observation infrastructure coupled with new and improved modelling capabilities. Research and innovation activities shall address application domains that may include space as well as terrestrial infrastructure. Proposals shall include architectural concepts of possible European space weather services in relation to the application domains addressed and they shall demonstrate complementarity to Space Weather services developed through the Space Situational Awareness component of the EU Space Programme.

- Prepare Europe for a full exploitation of space weather data by a renewed effort on modelling and forecasting using currently available data.
- Improve scientific understanding of the origin and evolution of space weather phenomena.
- Improving SWE restitution and prediction capabilities using artificial intelligence / deep learning techniques.

Space weather exploratory payloads studies & predevelopments

- Acceleration innovation of enabling technologies (maturing, prototyping, on ground tests)
- Identified and matured concepts up to TRL 3-4
- Matured technologies up to TRL 5-6, prototyping and on ground tests

Scope:

- New modelling and forecasting techniques capable of improving the restitution quality and extending the time horizon of a future space weather forecasting capability to several days.
- Proposals shall address the development of modelling capabilities and/or the delivery of prototype services able to interpret a broad range of observations of the Sun's corona and magnetic field, of the Sun-Earth interplanetary space and of the Earth magnetosphere/ionosphere coupling relying on existing observation capacities.
- Training of models using deep-learning techniques based on existing large aggregated databases from space measurements.
- Inventory of potential early indicators of extreme space weather events.
- Complementary and coherent activities with the ESA on-going or future activities in particular those decided at the last ESA Ministerial held in November 2019.
- Maturation of technologies, building blocks, tools and processes that will address SWE
- On ground demonstration tests
- Complementary and coherent activities with the ESA on-going or future activities in particular those decided at the last ESA Ministerial held in November 2019.

SPACE-47-2021: Near Earth Objects (type of action tbc)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

It is fundamental to improve our understanding of Near-Earth Objects (NEOs) through scientific modelling as well as the development of spacecraft instruments and data exploitation, both for the design of asteroids impact mitigation missions and the assessment of the associated effects.

At present, our knowledge of the physical characteristics of the NEO population is limited. In order to conduct spacecraft close proximity operations to NEOs and undertake mitigation demonstration missions, it is necessary to have a number of specific technologies and instruments readily available to conduct missions to asteroids with very weak gravitational fields. In addition, ground-based observations also represent an essential means to investigate the physical and dynamical properties of the NEO population as a whole, thus leading to further strengthening the science return of a mission, as well as optimising the choice of mission targets.

Proposals shall seek and demonstrate complementarity and synergy with NEO activities developed through the Space Situational Awareness component of the EU Space Programme, and with international coordination efforts such as those undertaken by ESA or in the framework of the UN.

- The proposed project shall also coordinate with existing surveys devoted to NEO discovery and radar facilities in order to provide a rapid response system for quickly characterize a small asteroid flying-by or in route of collision with the Earth (imminent impactor).The proposed project shall: improve the capability of timely detection and characterization of potential imminent impactors of Earth.
- Advance our understanding of the dynamical and physical states of a target NEO and their changes due to the effects of a kinetic impactor;
- Advance payload technology, and associated performance simulators, for the thorough characterization of asteroid properties affecting planetary defence missions;
- Foster international collaboration focused on timely follow-up observations of potentially hazardous objects.

<u>Scope</u>:

- The capability to network large telescopes, as well as radar facilities, with wide-field assets will be key for physical characterization.
- Efficient use and pooling of existing large aperture telescopes, radar facilities and data processing capabilities;
- Performing high-quality physical observations and calculation;
- Developing methods for rapid orbit estimation of an object and characterization of its physical and dynamical properties;
- Maturation or adaptation to specific use case of existing modelling capabilities
- Development of instruments, technologies and associated data exploitation models in support of missions to asteroids.
- Algorithms and simulators for close-proximity operations and payload data analyses

SPACE-48-2021: GOVSATCOM Technology Development and implementation of system innovative features (type of action tbc)

<u>Expected Outcomes</u>: Projects are expected to contribute to the following outcomes:

Future preparations, advanced technologies up to TRL level 4/5 (technology development/demonstration; product developments up to flight readiness) for:

- security-related technologies,
- technologies required for increased European non-dependence/critical technologies

e.g.: advanced coding, modulation and cryptography, key management solutions, anti-jamming, secure TM/TC including secure hosted payload solutions, inter-satellite links (including data relay solutions), optical feeder link

EU GOVSATCOM supporting technologies include, e.g.

- Flexible phased array antennas providing multi-beam and beam-forming capabilities, digital signal processing, SW-defined Radio, and related flexible payloads programmable in response to changing needs such as capacity flexibility and geographic coverage and distribution of traffic,
- Ground segment technologies for satellite control systems, mission planning systems, user terminals including multi-satellite and multi-band support and for beam hopping, and in support to the different security levels required by the different EU GOVSATCOM services and user categories.
- Implementation of future ground and space segment components, including innovative features of the EU GOVSATCOM planned and future space segment, such as LEO and Arctic constellations, optical space communications for data relay, planned satellite-based air-traffic management solutions, future implementation for 5G and of Very High Throughput Satellites.

<u>Scope</u>: Contribute to the preparation of the GOVSATCOM component of the EU Space Programme

SPACE-49-2021: Quantum technologies for space gravimetry (RIA)

<u>Expected Outcomes</u>: Projects are expected to contribute to the following outcomes:

- Support the EU space policy and the green deal by paving the way for the deployment of a future EU Earth observation mission making use of quantum gravimetry
- Ensure EU non-dependence for the development of capacities leading to the availability of quantum space gravimetry
- Enhance the TRL of all (critical) components necessary to build quantum gravimetry for space

<u>Scope</u>: The scope of this topic is the development of EU technologies and components for space quantum gravimeters and gradiometers (including hybrid sensors, relying both on

quantum and classical technologies). The enhancement of the TRL for cold atom interferometry components is a key objective of this call. The scope also covers the development of software simulation tools to analyse the different mission concepts linked to these sensors or processing and analysis of the sensor data. This also includes the development and/or use of testbeds such as the Einstein elevator or any other system used to recreate or simulate the space environment to test quantum graviemeters technology components. A major priority for this topic is the development of the technology leading to the deployment of a gravimeter mission based on cold atom interferometry.

SPACE-50-2021: Quantum technologies for space communication networks (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Support the EU space policy and end-to-end secure communication by paving the way for the deployment of a future EU secure and global satellite quantum communication capacity
- Ensure EU non-dependence for the development of quantum communication technology in space
- Enhance the TRL of the components necessary to build a quantum satellite communication capacity using EU technology

Scope: The scope of this topic is the development of EU quantum communication technologies for space. It comprises the development of components for quantum satellite communication systems, the development of space technology components and systems necessary for Quantum Key Distributions (QKD) (e.g. space compatible QRNGs, single or entangled photon sources, decoy state systems, associated electronics, systems for key management and storage, single photon detectors and super accurate pointing mechanisms). The elements of the corresponding ground segment such as components of the QKD optical ground segment are also included. The scope of this topic also covers different QKD protocols and standards, quantum specific on-board computers as well as novel user authentication mechanisms. The orbits considered as a matter of priority are LEOs, and in a later stage MEOs and GEOs. This topic also includes the tools necessary to simulate, control and monitor the space quantum information networks as well as the high-accuracy pointing mechanisms for quantum applications. This also includes the development and/or use of testbeds or any other system used to recreate or simulate the space environment to test quantum satellite communications technology components.

SPACE-51-2021: Fundamental research in quantum technologies for space-based applications (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Contribute to the academic leadership of the European Union in the field of quantum science for space-based applications
- Develop, foster and sustain the European Union's academic network of scientists specialised in quantum technologies for space

Scope: This topic includes the fundamental research activities performed by academia in the field of quantum communication and quantum sensing for space applications.

SPACE-52-2021: International lab-to-lab cooperation on quantum technologies for space-based applications (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Foster international lab-to-lab cooperation in the field of quantum in space
- Allow EU academia, scientists, researchers and engineers to collaborate with international partners

Scope: This topic aims at developing international lab-to-lab cooperation between:

- EU and Australia
- EU and Japan

on specific quantum applications in space, in particular quantum communication and quantum gravimetry. The EU will fund the EU participants to the call for grants, the international partners will fund their own.

SPACE-53-2022: Next & Improved EUSST Missions and Services (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

In the coming years, an increase in the number of active objects in orbit is foreseen (e.g. deployment of mega-constellations, increased number of non-manoeuvrable small objects – CubeSats for research and scientific purposes, etc.). Additionally, the number of objects (active and inactive) to be handled by SST systems will also increase due to the use of sensors with a higher detection capability. For example, the US Space Fence radar, declared operational in March 2020, is capable of detecting and tracking objects smaller than 10 centimetres and is expected to considerably increase the size of space objects catalogue of the US Space Surveillance Network.

Consequently, the provision of services by the EUSST operation centres, as well as the strategy used to protect the European active satellites will have to be adapted to the arising needs. The need for the development of automated concepts becomes more relevant in order to reduce response times, reduce costs and simplify coordination activities amongst operators.

Therefore, R&I projects on "*new and improved EUSST missions and services*" are expected to contribute to the following outcomes:

- Keep the knowledge and capabilities of Europe on the Space Surveillance and Tracking domain at the leading edge.
- Adapt, improve and evolve the current EUSST initial services (Collision Avoidance; Fragmentation; Re-entry) portfolio to future user needs and space environment.
- Improve the overall performance of the EUSST services and ensure, in the long-term, a high level of performance and appropriate autonomy at Union level.
- Identify and define new missions and services (e.g. debris mitigation; debris remediation).
- Explore the implementation of new services, in complement of the three existing ones.
- Support the pre-developments and end-to-end early demonstration of new SST services.

Scope:

- Evolution of the Collision Avoidance service towards a higher responsiveness in the case of risks (e.g. Automatic warning service).
- Evolution of the EUSST system for **debris mitigation** in order to reduce the space debris generation, as for example:
    - Extended computation of conjunctions and risks;
    - Automatic risk estimation and mitigation measures, (e.g. ground or on-board processes and using AI techniques);
    - Support to satellite O/O in case of spacecraft anomalies;
    - Design of innovatives solutions for the detection and characterisation of malfunctioning satellites;
- Evolution of the EUSST System for space **debris remediation** by managing the existing space debris. The analysis of potential remediation focused services at European level, the feedback of O/O and the monitoring of the international arena in the coming years are needed inputs prior to define the content of this topic in detail.
    - Stimulation of the use of removal and disposal techniques through regulatory initiatives;
    - Design associated to removal/servicing technology demonstration;
    - Development and demonstration of passivation, disposal and active removal technologies;

Evolution of the EUSST Service Provision Portal in line with the evolution of the existing services (CA, RE, FG) and the inclusion of additional ones (Debris mitigation / remediation). R&I activities will be required to cope with an expected increased number and heterogeneity of users and spacecraft, evolution of the SST Consortium/Partnership, etc. Reporting activities must continue evolving, as to provide actionable “Key Performance Indicators” supported by the development of the necessary tools/applications.

SPACE-54-2022: SST & STM system (architecture / evolutions / lab & test beds) (RIA)

<u>Expected Outcomes</u>: Projects are expected to contribute to the following outcomes:

The environment on which the EUSST system performs its mission and delivers its services is in constant evolution (e.g. technological or political factors changing the way on which the space is used, orbital environment …).

EUSST system architecture engineering & evolutions: the analysis of the EU SST system architecture needs to continuously progress to evaluate how the system has to evolve at medium and long term, not only at network level (type, performance, number, geographical localisation... of assets) but also at data processing and at services level. Other aspects like data flow, security constraints, interconnectivity between EU assets but also complementarity and cooperation with other SST systems, etc. need to be considered as well.

- Foster European cooperation in the SST domain and improve the EUSST performance towards larger autonomy.
- Highlight and propose solutions to fill the gaps in the current EUSST architecture.
- Pave the way on which the EUSST system has to evolve towards a higher level of performance (e.g. precision; number of catalogued objects...), quality of service (e.g. timeliness of information...) and autonomy.
- Ensure the complementarity, coherence and added-value of each element of EUSST system towards a more autonomous, interoperable SST system.
- Look for higher complementary to other SST systems such as the US one which is of paramount importance to develop long-term cooperation.

Space debris and Orbital Environment R&D; SSA Lab & testbeds

- Increase the accuracy of the modelling tools and the modelling studies.
- Improvement of algorithms to model the space environment in a way that can respond to the challenges of the future (large constellations, small satellites, on-orbit servicing, activities on defence of space, big data management, use of orbital indexes, etc.)..

Solutions (ground & space based) for EU Space Traffic Management implementation: the reliance on space-based data and services, in particular thanks to the success of Copernicus and Galileo European programmes, for our society, economy, security and defence has been rapidly growing. At the same time, the emergence of new type of actors and business models (e.g. mega constellation) increases the number of satellites and debris in orbit. For this reason, space becomes more and more congested, posing a threat to the sustainability and safety of space operations and infrastructures, with a higher risk of collision and of radiofrequency interferences.

The importance of SST / Space Traffic Management (STM) is thus growing, in a context where there is lack of a clear definition at international level and no global regime and system is in place, neither are flight rules and the associated monitoring means.

- Raise the main issues and propose relevant answers to questions posed by all those developments in various technical, operational and legal domains.

  Propose adaptation to the new changes and solutions for their possible integration into the existing standards, practices, technological means, governance, regulatory and policy frameworks.

Scope:

- EUSST architecture engineering.
- Define the future EUSST architecture and associated development roadmap offering the best value for money
- Architecture studies and system design to validate the added-value of all the layers of the EUSST system.
- Define and set up efficient and relevant performance criteria, “metrics”, “Key Performance Indicators” and “critical success factors” (e.g. accuracy of European catalogue; expected increase of the number of objects into the catalogue; timeliness of service provision...)
- Orbital population modelling at different time horizons
- Various simulation tools
- Laboratory equipment and testbeds for orbital environment modelisation
- Activities / studies in the area of manoeuvre coordination, interference management, collision avoidance automation.
- Activities / studies in space objects life cycle and risk assessment.
- Assessment and pre-development of technology for rendez-vous and close proximity operations.
- Develop and promote spacecraft / constellations “Clean_design”.

- Preparation and demonstration of technologies for in-orbit servicing.
- Assessment and pre-development of technology for object identification, for navigation aids and for servicing interfaces.
- Technical standardisation activities in these areas.

SPACE-55-2022: Space-based SST (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

With the increase of the orbital population and with the need of observing smaller objects to better protect the EU space assets, the need and added-value of developing Space-Based Space Surveillance (SBSS) missions in complement to ground SST networks shall be studied in Europe.

Space-based SST missions and sensors network: Based on the experience of SBSS missions launched and operated outside Europe (e.g. by US and Canada), this type of mission may potentially increase the EU ability to observe and catalogue objects on various orbits, and compensate for the limitation linked to the geographical location of ground sensors.

- Study and assess several technical solutions for the development of a future European capability of SBSS.
- Explore of small satellites solutions to reduce CAPEX and OPEX
- To develop in the mid-term the European capacity to operate independently SBSS.

R&I SST exploratory payloads & IOD missions: space based sensors (co-financed with IOD support): in order to allow Europe to develop a SBSS capability aiming to enhance its capability to protect European space assets from space debris threats, Research and Innovation activities on payloads and space-based sensors are required.

- Study and assess several technical solutions for the development of a future European payloads and sensors for SBSS missions
- As the SBSS mission is not just a concept (cf. Saphire - Canada, ORS mission - USA), Europe has to develop in short term in orbit demonstrations / validations to test missions concepts (e.g. microsat, CubeSat, constellation) and payloads (e.g. dedicated, opportunistic)

Non-dependent EU Technology sources for critical components of space based SST systems and sensors: in order to achieve Europe's strategic autonomy of a future European SBSS system, Europe needs non-dependent access to critical space technologies. "Non-dependence" refers to the possibility for Europe to have free, unrestricted access to any required space technology. Reaching non-dependence in certain technologies will also open new markets to our industries and will increase the overall competitiveness of the European Space sector.

- To reduce the dependence on critical SBSS technologies and capabilities from outside Europe,
- To develop in a timely manner reliable and affordable SBSS space technologies,
- Complement with focus on SBSS needs, the R&I activities in technologies for European non-dependence and competitiveness undertaken within the frame of the past space research programmes (e.g. Commission-ESA-EDA Joint Task Force (JTF) on Critical Technologies for European non-Dependence list of actions...).
- Develop complementary and create synergy with other European activities in the same technological domain (e.g. optical sensors; on-board pre-processors ...) either in the space or non-space fields.

Scope: With the development of SBSS missions, new challenges have to be solved, at payloads and on-board sensors as for the following examples. Non-dependent technologies for European SBSS have also to be ensured.

- Study of various mission configurations (e.g. orbit regime, orbit plan, …) and payload location to maximize the number of observed and catalogued objects,
- Study of coordination strategy and techniques among the satellites of the SBSS mission and the terrestrial SST system.
- Develop algorithms allowing going from detection to cataloguing (e.g. IOD, correlation …) taking into account ground based SST system and payload performance (i.e. observable magnitude).
- Exploration of the use of non-dedicated sensors (“opportunistic” solutions) to reduce cost of operation is also an aspect to develop.
- Security issues related to the link between SBSS and ground SST network.
- R&I activities shall include as well as the launch of small (microsat, CubeSat) platforms equipped with payloads to test at lowest cost the capability of European payloads and technology to observe and catalogue space objects from space.
- Payloads and missions may include the use of non-dedicated sensors (e.g. star trackers) to analyse their capability to characterize the space environment
- Analysis of relevant available technological roadmaps,
- Develop specific technological roadmaps for SBSS systems,
- Study and assess SST space-based sensors
- Enhance the TRL of the technologies identified in the list.
- [other TBD with preliminary results of SBSS payloads design]

SPACE-56-2022: SST Sensors and Processing (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

Supporting the upgrade and development of assets, in particular radars and telescopes as well as data processing.Expected Outcomes: Projects are expected to contribute to the following outcomes:

SST radiofrequency & optical sensors (radars, telescopes…) technological research & innovation: due to the increased number of objects (both active and debris) to be handled, as well as the evolution and inclusion of services in the future, R&I activities are necessary in the sensor domain, both for radiofrequency (e.g. passive ranging, radars, etc.) and optical sensors (e.g. telescopes, lasers). New promising technologies like sensors based on the use of infrared will also be considered.

- Contribution to a consolidated and efficient EUSST sensor function.
- Improve coverage area, geographical location and performance they can offer: e.g. field of view, limiting magnitude, frequency-band...
- Ensure an optimum evolution of the configuration and use of the EUSST sensors network, including the necessary raw data processing required to provide measurement data.

Improved integration and connectivity of value added sensors, ensuring their compliance to the minimum quality requirements (including protocols, procedures, formats and calibration status) SST data processing research & innovation (e.g. Artificial Intelligence…): the changes and evolution in the space environment impose the need of adapting the current algorithms and data processing methods and tools, as well as to look for new one.

- Include or at least explore the possibility to use Artificial Intelligence (AI) in any SST data processing (e.g. Improvement of object detection capability; of probability of collision accuracy ...)
- Development of automatic tasking and data processing functions

Scope: To ensure that the data processing used in the SST domain can properly address the upcoming requirements in all aspects, such as:

- Technologies already in use, like radars, telescopes and lasers, need to be adapted to the new environment.
- Improvement of sensors performances (e.g. measurements quality (noise; bias; measurements rates ...); tracks accuracy (track noise; track duration...)).
- Specification, development, testing and pre-integration of a improved sensors.

- Innovations need to be developed to allow detection of smaller objects, higher processing capabilities (e.g. networked telescopes for LEO coverage, tracking by lasers in daylight ...).
- New detection strategies to cope with an increased number / size of objects in the sensors' Field of Regard / Field of View.
- Additionally, new technologies will be explored for the development and implementation of potential new services developed in CAP_SSA-01 topic (e.g. support to manoeuvre, detection of malfunctioning spacecraft, etc.)
- Improved algorithms (e.g. Initial Orbit Determination, OD, covariance estimation...) for a more agile cataloguing of the increasing space objects population.
- Algorithms for data fusion for a more efficient use of the data and information from the same object coming from different sensors.
- Improvement of correlation measurements algorithms.
- Improvement of orbit and covariance estimation, for example for support to manoeuvres and identification of in-orbit anomalies, etc...
- Improvement of computation models of collision probability.
- Development of evaluation methods of collision probability that could be applied to constellations (e.g. multiple encounters).
- Improvement or development of new objects propagation models for efficient propagation of the orbital population (e.g. cloud propagation models to propagate the debris cloud generated after a fragmentation ...).
- Evolution of coordinated scheduling of sensors to progress towards a more efficient use of multiple available resources at system level.
- Any promising technology for precise tracking and data processing.

SPACE-57-2022: SST Networking, Security & Data sharing (RIA)

Expected outcomes: Projects are expected to contribute to the following outcomes:

The topic "SST Networking, Security & Data sharing" aims to support the upgrade, development and security issues of EUSST infrastructure based on the European network of assets (sensors, operation centres, front desk …).

Although the EUSST infrastructure is supposed to stay under national control (meaning mainly sensors and operation centres), an increased coordination is needed due to the increased number of assets contributing to the European SST system. Without this interconnection and coordination, it is impossible to ensure an efficient use of the resources and an appropriate response to the challenges pose by the changing space environment.

As concrete aspects of the EUSST network (e.g. pooling of data from multiple sensor sources; exchange between multiple operations centres of Member States) shall be considered in highly detailed case studies, modelling ..., this topic shall be limited to the members of the EU SST Consortium/Partnership in order to protect security-sensitive information.

SST networking of sensors & operation centres (European Union SST network Command & Control): considering the increased number of objects to be handled, an increased number of events and users is expected. The European SST system has to evolve to a coordinated scheduling of the resources and assets, ensuring that the events are covered in an optimum way, while the current survey and tracking of the space objects population continues to be performed. Evolution of the European SST network includes the Front Desk in charge of the interaction with the users (users' needs, monitoring of the service performance, etc.).

- Raise the main issues and propose relevant answers to the increasing complexity and missions constraints of the EUSST network.
- Connectivity and interface consolidation of network function between sensors / database / operating centres / front desk (reliability, maintainability and agility).
- Develop EUSST network in order to include a future new SBSS segment.

Research on EUSST network hardening against external threats: the research concerns security-critical aspects of the existing EU SST network. Various external threats shall be considered in the research activity (e.g. cyber threats or other malicious activity). Research specifically applying to the hardening of the EU SST network could add value to existing research on network hardening that looks at computer networks and other related networks more generally.

- A secured and resilient EUSST infrastructure.

Next generation exchange protocols / solutions for SSA enhancing interoperability and security (robustness, information assurance, intrusion detection…)

- A secured and resilient EUSST infrastructure
- Define the need for SST-specific tools and solutions with regard to enhanced data interoperability and data security.

<u>Scope</u>: the development of, among others:

- Update operation centres to improved current services (Collision Avoidance; Fragmentation; Re-entry) adapted to future user needs and space environment.
- Update operation centres to new missions and services (e.g. debris mitigation; debris remediation).

- Adapt the European SST network to a more efficient coordinated scheduling of the resources and assets.
- Develop new data sharing and fusion strategies and techniques adapted to both ground based and space based SST assets.
- Develop threats analysis and associated counter measures.
- Adapt EUSST operation centres for increasing security and resiliency.

SPACE-58-2022: Space Weather (Type of action tbc)

Expected outcomes: Projects are expected to contribute to the following outcomes:

Commonly occurring space weather events (SWE) have the potential to affect the performance of critical space and ground infrastructure by disrupting operations and communications in multiple sectors of society. In addition, “extreme SWE” could have devastating societal and economic consequences with potential costs for disruptions and damages estimated in tens or even hundreds of billions of Euros.

Space weather technological research for new precursor services: the worldwide goal of space weather activities should be to monitor and forecast SWE just like terrestrial weather. However, direct physical simulation is currently not achievable for an operational Sun to Earth system, due in part to the lack of measurements and to the complexity of the involved processes, as well as different timescales involved. Current space weather models are generally not capable of forecasting events over several days. A longer forecasting horizon would require access to data from new observation infrastructure coupled with new and improved modelling capabilities. Research and innovation activities shall address application domains that may include space as well as terrestrial infrastructure. Proposals shall include architectural concepts of possible European space weather services in relation to the application domains addressed and they shall demonstrate complementarity to Space Weather services developed through the Space Situational Awareness component of the EU Space Programme.

- Prepare Europe for a full exploitation of space weather data by a renewed effort on modelling and forecasting using currently available data.
- Improve scientific understanding of the origin and evolution of space weather phenomena.
- Improving SWE restitution and prediction capabilities using artificial intelligence / deep learning techniques.

Space weather exploratory payloads studies & predevelopments

- Acceleration innovation of enabling technologies (maturing, prototyping, on ground tests)

- Identified and matured concepts up to TRL 3-4
- Matured technologies up to TRL 5-6, prototyping and on ground tests

Scope:

- New modelling and forecasting techniques capable of improving the restitution quality and extending the time horizon of a future space weather forecasting capability to several days.
- Proposals shall address the development of modelling capabilities and/or the delivery of prototype services able to interpret a broad range of observations of the Sun's corona and magnetic field, of the Sun-Earth interplanetary space and of the Earth magnetosphere/ionosphere coupling relying on existing observation capacities.
- Training of models using deep-learning techniques based on existing large aggregated databases from space measurements.
- Inventory of potential early indicators of extreme space weather events.
- Complementary and coherent activities with the ESA on-going or future activities in particular those decided at the last ESA Ministerial held in November 2019.
- Maturation of technologies, building blocks, tools and processes that will address SWE
- On ground demonstration tests
- Complementary and coherent activities with the ESA on-going or future activities in particular those decided at the last ESA Ministerial held in November 2019.

SPACE-59-2022: Near Earth Objects (type of action tbc)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

It is fundamental to improve our understanding of Near-Earth Objects (NEOs) through scientific modelling as well as the development of spacecraft instruments and data exploitation, both for the design of asteroids impact mitigation missions and the assessment of the associated effects.

At present, our knowledge of the physical characteristics of the NEO population is limited. In order to conduct spacecraft close proximity operations to NEOs and undertake mitigation demonstration missions, it is necessary to have a number of specific technologies and instruments readily available to conduct missions to asteroids with very weak gravitational fields. In addition, ground-based observations also represent an essential means to investigate the physical and dynamical properties of the NEO population as a whole, thus leading to further strengthening the science return of a mission, as well as optimising the choice of mission targets.

Proposals shall seek and demonstrate complementarity and synergy with NEO activities developed through the Space Situational Awareness component of the EU Space Programme, and with international coordination efforts such as those undertaken by ESA or in the framework of the UN.

The proposed project shall also coordinate with existing surveys devoted to NEO discovery and radar facilities in order to provide a rapid response system for quickly characterize a small asteroid flying-by or in route of collision with the Earth (imminent impactor).

- Improve the capability of timely detection and characterization of potential imminent impactors of Earth.
- Advance our understanding of the dynamical and physical states of a target NEO and their changes due to the effects of a kinetic impactor;
- Advance payload technology, and associated performance simulators, for the thorough characterization of asteroid properties affecting planetary defence missions;
- Foster international collaboration focused on timely follow-up observations of potentially hazardous objects.

Scope:

- The capability to network large telescopes, as well as radar facilities, with wide-field assets will be key for physical characterization.
- Efficient use and pooling of existing large aperture telescopes, radar facilities and data processing capabilities;
- Performing high-quality physical observations and calculation;
- Developing methods for rapid orbit estimation of an object and characterization of its physical and dynamical properties;
- Maturation or adaptation to specific use case of existing modelling capabilities
- Development of instruments, technologies and associated data exploitation models in support of missions to asteroids.

Algorithms and simulators for close-proximity operations and payload data analyses.

SPACE-60-2022: GOVSATCOM Technology Development and Implementation of System innovative features (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Future preparations, advanced technologies up to TRL level 4/5 (technology development/demonstration; product developments up to flight readiness) for:

- security-related technologies,
- technologies required for increased European non-dependence/critical technologies

e.g.: advanced coding, modulation and cryptography, key management solutions, anti-jamming, secure TM/TC including secure hosted payload solutions, inter-satellite links (including data relay solutions), optical feeder link

EU GOVSATCOM supporting technologies include, e.g.

- Flexible phased array antennas providing multi-beam and beam-forming capabilities, digital signal processing, SW-defined Radio, and related flexible payloads programmable in response to changing needs such as capacity flexibility and geographic coverage and distribution of traffic,
- Ground segment technologies for satellite control systems, mission planning systems, user terminals including multi-satellite and multi-band support and for beam hopping, and in support to the different security levels required by the different EU GOVSATCOM services and user categories.
- Implementation of future ground and space segment components, including innovative features of the EU GOVSATCOM planned and future space segment, such as LEO and Arctic constellations, optical space communications for data relay, planned satellite-based air-traffic management solutions, future implementation for 5G and of Very High Throughput Satellites.

Scope: Contribute to the preparation of the GOVSATCOM component of the EU Space Programme

SPACE-61-2022: GOVSATCOM Service Developments and demonstrations (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Consolidation of security-related services, demonstrations in a user context and in particular for civilian users and synergies with the services provided by the other components of the Space Regulation (e. g. services for civil protection with Copernicus images).
- This topic address service developments in support to all High Level User Needs, including direct involvement of users and with emphasis on civilian users. This should include Pooling & Sharing demonstrations, in particular on services enabled by new technology developments such as ground segment, RPAS, optical communications or Internet of Things. Service development should include an element of awareness building and outreach.

Scope:

Prepare and foster to the adoption of the GOVSATCOM services

SPACE-62-2022: Quantum & new concepts for space (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Develop new space mission concepts based on quantum technologies in space.
- Assess the feasibility of these new space missions from an industrial/implementation point of view
- Develop the transfer of know-how between academia and industry in the field of quantum technologies for space-based applications and ensure cross-fertilization.

Scope: The scope includes the creation and development of new mission concepts using quantum technologies in space. Ideally, these new mission concepts will be born from academia or research laboratories.Their feasibility will be verified through mission analysis or phase 0 in close cooperation with industry and/or national research / space agencies.

Section: Space entrepreneurship ecosystems (incl. New Space and start-ups) and skills

[Objective: The development, incubation and upscaling of start-ups will be fostered across all space areas. Moreover, support will be provided to foster business and innovation-friendly ecosystems, including strengthening space related skills. We want to increase the number of innovative start-ups in the EU doing business using Copernicus and Galileo data and/or developing space technologies. We want to improve their ability to work with customers and their capacity to expand. The objective is to make them investment-ready and able to secure VC funding.

Current status: Initial activities (i.e. competition for innovative ideas, voucher for incubation) have already kicked off, hackathons and mentoring for 2021-23 are in the procurement pipeline, plans for business acceleration/seed funding and prizes for disruptive innovation are under development.

Achievements sought / targets: Increase in the number of start-ups using EU Space technologies and improve their success rate. Increase the number of space-based SMEs that scale up.

Means/Links: Actions implemented via grants, prizes and strong synergies with the InvestEU programme and the Space programme.]

Proposals are invited against the following topic(s):

SPACE-63-2021: CASSINI Business Accelerator (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- CASSINI aims to promote commercial use cases for the EU's space programme by providing qualified business development support. The objective is to increase the number of space-based companies that achieve high revenue growth. This will allow the companies to attract investments and capture new market shares.
- The expected economic benefits include an increase in the number of successful start-ups and scale-ups using space data and space technology, through an increase in sales, market share growth and staff hiring. These outcomes will allow the companies to attract larger amounts of financing through bank loans and equity investments.

Scope:

- The CASSINI Business Accelerator will target early-stage limited companies in both upstream and downstream space segments.

- Applying companies should be able to present a functioning prototype, an early phase product for market testing or a market validated product, as well as a clear value proposition for their customers.
- During the Business Accelerator programme, entrepreneurs will receive high quality support to develop their market development plan and an accompanying plan for financing operations and up-scaling of the company. Matchmaking with investors and large companies will be organized.

SPACE-68-2022: CASSINI Hackathons & Mentoring (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To stimulate the spur-of-the-moment development of innovative applications based on data and information coming from Copernicus satellite images and EGNOS and Galileo positioning signals and services.
- To develop prototypes further into viable business propositions.
- To provide training opportunities on how to access and use data from Copernicus and EGNOS/Galileo with data analytics tools and artificial intelligence.
- To promote the EU’s space programmes Copernicus and EGNOS/Galileo to a broader audience.

Scope:

- The CASSINI Hackathons & Mentoring Business Accelerator will target students, researchers and start-up companies with technical experience and knowledge in data analytics, artificial intelligence, machine learning, earth observation and geographical information systems, global positioning systems and internet of things.
- Applying participants shall display a motivation to develop “close to market” solutions or prototypes, a motivation to become an entrepreneur, and adequate technical competence.
- The Hackathons events shall be widely advertised to attract a large group of participants and shall be organized to get wide coverage in social media and other communication channels. The events shall help to promote the EU Space Programme overall. The Coordinator and Local Organisers shall use both paid advertising space and earned media to achieve these goals.
- The three overall winners from each Hackathon event qualify for a mentoring scheme with selected industry experts designed to help them advance development of their solution, do market research and design a viable business model. The aim is to encourage more products making use of EU space data to enter the market.

SPACE-69-2022: Education and skills for the EU space sector (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Structured overview of the educational offer in the EU, including continuing education for the EU space sector. In-depth quantitative analysis of the 'stocks & flows' across EU-27 of students at the different levels eventually employed in the space sector at large (academia, government agencies, upstream industry, downstream industry). Comparative analysis of the cost/time to achieve a degree.
- Socio-economic analysis of the space-oriented student population (e.g. educational background, family income, parents' education, residence geography, etc.), to identify gaps/shortcomings and excellences across the EU-27.
- Identification of the needs for education and skills in the EU space sector and of potential new educational knowledge answering emerging and future needs
- Assessment of the adequacy between curricula and sector needs; benchmarking of the careers opportunities for space-oriented graduates issued of different universities across EU-27 (e.g. time to first employment, average salary after 3-5-7 years, etc.). Measurement & tracking of intra-EU and international mobility. Monitoring of net inflows/outflows within EU27 and with non-EU countries.
- Actions for the promotion of space jobs and career in Bachelor and Master courses

Creation of educational material for jobs related to Earth observation and Positing Navigation and timing, in particular downstream.

Scope: Competitiveness and innovation of the EU space sector depends on the availability of high educational standards and skilled professionals across a range of qualifications and the possibility for these professionals to upgrade and update their skills. This is also in the interest of the research and innovation community where the quality of the results and the impact of EU-funded research is a precursor of the future space sector. The EU also plays a role in the aligning with educational degrees to provide more opportunities and promote mobility of professionals and researchers across countries and sectors.

The scope of this action encompasses:

- The analysis of the main curricula and courses available and existing educational standards across the EU27 at bachelor, master and post-graduate levels as well as continuing education (training and staff qualification / certification). In short, a complete overview of the 'supply' of space-oriented education and of the 'demand' for it across EU27, supported by extensive, in-depth quantitative and fact-based time-series evidence.
- The analysis of the skills required and reskilling needs of the R&I and the industrial community (across the entire supply chain, ranging from upstream space to downstream

space) will be performed and structured, presumably along existing educational modules (e.g. electrical, mechanical, telecommunication, system engineering, physics, psychology, medicine). The analysis should engage both industry and educational institutions, as well as not be limited to technical / scientific, engineering disciplines skills needed in an innovating world such ability to work in a diverse multidisciplinary team, to communicate efficiently, to create new activities and businesses, etc. An assessment of the number of professionals needed in the different sectors will be produced, based on fact-based and in-depth quantitative analysis of the demographics across EU-27, the current/projected enrolment rate into space-oriented disciplines, the success rate, etc. This will also include an exploratory look at future skills which the space sector might need in the future. The analysis should take into consideration results stemming from existing activities funded under Horizon 2020, e.g. the EO4GEO project (http://www.eo4geo.eu/) and the PERSEUS project https://cordis.europa.eu/project/id/640211

- The analysis of the match between needs and offer across the whole of EU-27 will be analysed and recommendations made to ensure improved adequacy between the needs and the offer in the coming years.
- Action will be undertaken for the promotion of the space sector jobs and careers (in particular where there is a strong demand for qualified workforce) and information about the different curricula and disciplines of interest for such careers in Bachelor and Master courses.
- Action will be undertaken for the creation of course modules in relation to the 2 EU flagship constellations Copernicus and Galileo for jobs related earth observation and PNT, in particular for the downstream sector.

Section: Targeted and strategic actions supporting the EU space sector

[Objective: Development of associated technologies and actions of key importance to the sections described above will be pursued. These actions will at the same time contribute to foster the competitiveness of the EU space sector to reinforce our capacity to use and access space and to R&I for the Space Programme. In addition, actions to promote European scientific missions and planetary robotics as well as to collect, process and disseminate the data collected from these missions are also key contributions to the European competitiveness in space.

Current status: There is an urgent and growing need to strengthen EU sovereignty by securing strategic non-dependence in specific critical space technologies. These have been an important priority in Horizon 2020 and previous programmes. The identification of technologies to be developed is carried out regularly and jointly with Commission, ESA and EDA and the cooperation of European space industry and EU Member States. Potential synergies with development work undertaken trough the EU defence fund is to be explored. Regular opportunities to enable in orbit demonstration/validation of new technologies and concepts in real conditions are needed for de-risking before first operational utilisation. Actions on In-orbit validation ("IOV") and in-orbit demonstration ("IOD") have started under Horizon 2020 in cooperation with ESA. This work will be pursued and further extended in Horizon Europe to enhance the competitiveness of European space industry, including SMEs which do not have ready access to space flight heritage for their innovations. Excellence in space science contributes to the mid to long-term competitiveness in the space sector by developing new concepts and tools pushing the technical envelopes to answer major scientific challenges. The EU can also bring a useful contribution to space science in particular for a better exploitation of data gathered from space missions, the development of new scientific instrumentation and other technologies for future space missions. Heritage of targeted cooperation with 3rd countries addressing Copernicus applications, EGNSS awareness and in space science and space weather research.

Achievements sought / targets:

Development of critical technologies for EU non-dependence and strengthening of relevant supply chains (components, materials and processes).

Establishment of regular and cost-effective flight opportunities for IOD/IOV will contribute to de-risk new technologies, concepts and applications.

The open availability of space data from European and international space missions contribute to advances in space science which in turn feed back to new space based services and next generation space systems. Targeted space science activities will be encouraged and augmented with outreach and education activities (e.g.. development of cutting-edge scientific instrumentation in support of space missions).

Space R&I provide ample opportunities for mutually fruitful international cooperation with likeminded countries, primarily in climate research and sustainable development and in space science.

Means/Links: Grants (RIA, IA and CSA).

In terms of perspectives for co-creation within cluster 4 and with other clusters, the following domains have been identified

- AI, HPC, Big data, Robotics
- Manufacturing & Materials
- EEE components
- Transport, Smart Cities, critical infrastructure
- Environment, climate (including GEOSS/EuroGEO), agriculture, fishery
- Cultural Heritage
- Security, emergency

IOV/IOD activities can be found under "Other actions"]

Proposals are invited against the following topic(s):

SPACE-70-2021: Critical technologies for non-dependence (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To reduce the dependence on critical technologies and capabilities from outside Europe for future space applications;
- To develop or regain in the mid-term the European capacity to operate independently in space;
- To enhance the technical capabilities and overall competitiveness of European space industry vendors on the worldwide market;
- To open new competition opportunities for European manufacturers by reducing dependency on export restricted technologies that are of strategic importance to future European space efforts;

To improve the overall European space technology landscape and complement and/or create synergy with activities of European and national either in the space or non-space fields.Scope: Actions from the JTF List of Actions 2021-2023 shall be implemented in 2021 as the following technology lines.

[TBD. 6-7 technology lines to be addressed each year are currently under discussion in the EU-EDA-ESA Joint Task Force on critical space technologies for non-dependence]

Context information and high-level requirements, including description of scope, initial and target TRLs, and, where applicable, references and information of related activities, are provided in the JTF List of Actions 2021-2023. Accordingly, a technical guidance document, based on the JTF List of Actions 2021-2023, is published on the Funding & Tenders Portal outlining all relevant information to the selected actions.

Activities shall be complementary and create synergy with other European activities in the same domain either in the space or non-space fields. Technological spin in and/or bilateral collaborations should be enhanced between European non-space and space industries, including technology research institutes and academia.

With a view to achieving the non-dependence objective, applicants must

- Describe the technologies and/or technology processes to be used and show that they are free of any legal export restrictions or limitations, such as those established in the International Traffic in Arms Regulations (ITAR) or equivalent instruments applicable in other jurisdictions;
- Set up a suitable technology development process aiming at avoiding export restrictions of non-EU states.

SPACE-71-2021: Space science (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To strengthen the interaction between the areas of education-research-industry in Europe,
- To consolidate a strong downstream space knowledge,
- To leverage on high quality research and education, as well as on areas of excellence in the field of downstream space in order to improve Europe's competitiveness with respect to other regions of the world.
- To focus on European areas where the potential of space is not yet fully exploited.
- To develop the leading edge research and technology in the industrial world in the field of space.
- To support entrepreneurial culture among researchers through encouraging them to join research groups in the commercial sector
- The projects should activate a minimum of XX two-year long PhD scolarships in space-related disciples (potentially 1 per Member State, either as participant students or hosting entities).
- PhDs students should conduct their research with/within an EU or eligible third country industrial entity in the space domain (either a startup, a SMEs or a big

company), therefore facilitating/accelerating the application of advanced scientific concepts to commercial operations.

Scope: cientific disciplines (e.g. engineering, physics, astronomy) underlying any component of the EU Space programme (e.g. satellite communication, including secure one, navigation & positioning, Earth observation, space situational awareness, …)

The new space applications, ideas, knowledge and techniques need more than ever highly trained researchers ready to propagate them, enrich them and make them effective.

The actions shall connect the various research and innovation environments with space developing industry. The actions under this topic shall enable circulation of ideas, the exchange of concepts, transfer of knowledge, learning of new skills and the dissemination of techniques.

Initiatives supporting cross-links between the universities and the industry, and interactions between space students and space industries.

SPACE-72-2022: Space science and exploration technologies (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Enable breakthroughs in technologies and scientific instrumentation for space science and exploration missions.
- Validation of novel human spaceflight and robotic space technologies and instrumentation through analogue tests.
- Increased collaboration of scientific, engineering and industrial teams both within and outside Europe across different domains;

Scope: The development of instrumentation and technologies enabling space science and exploration missions may address technology development associated with future space science and exploration missions, including robotic exploration technologies, early stage scientific instrumentation and technologies for space resources utilisation. The development of new and innovative approaches, such as the use of Cubesats and other small space platforms, including planetary entry probe, or the use of Commercial off-the-shelf (COTS) components is encouraged as long as it contributes to the implementation of space science and exploration missions with significant scientific outputs.

Advances are expected in support to on-site activities such as landing, planetary navigation, sample collection and processing or in-situ analysis.

Activities should target primarily European and European-led space science and exploration missions or internationally-led missions where the participation of European partners provides demonstrated added-value in terms of technological development and scientific output.

SPACE-73-2022: Critical technologies for non-dependence (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To reduce the dependence on critical technologies and capabilities from outside Europe for future space applications;
- To develop or regain in the mid-term the European capacity to operate independently in space;
- To enhance the technical capabilities and overall competitiveness of European space industry vendors on the worldwide market;
- To open new competition opportunities for European manufacturers by reducing dependency on export restricted technologies that are of strategic importance to future European space efforts;
- To improve the overall European space technology landscape and complement and/or create synergy with activities of European and national either in the space or non-space fields.

Scope: Actions from the EU-EDA-ESA joint task force list of Actions 2021-2023 shall be implemented as the following technology lines.

[TBD. 6-7 technology lines to be addressed each year are currently under discussion in the EU-EDA-ESA Joint Task Force on critical space technologies for non-dependence]

Context information and high-level requirements, including description of scope, initial and target TRLs, and, where applicable, references and information of related activities, are provided in the JTF List of Actions 2021-2023. Accordingly, a technical guidance document, based on the JTF List of Actions 2021-2023, is published on the Funding & Tenders Portal outlining all relevant information to the selected actions.

Activities shall be complementary and create synergy with other European activities in the same domain either in the space or non-space fields. Technological spin in and/or bilateral collaborations should be enhanced between European non-space and space industries, including technology research institutes and academia.

With a view to achieving the non-dependence objective, applicants must

- Describe the technologies and/or technology processes to be used and show that they are free of any legal export restrictions or limitations, such as those established in the International Traffic in Arms Regulations (ITAR) or equivalent instruments applicable in other jurisdictions;
- Set up a suitable technology development process aiming at avoiding export restrictions of non-EU states.

SPACE-74-2022: International Cooperation - Designing space-based downstream applications with international partners (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Maximise and spread the benefits of EU space-based applications and solutions (i.e. enabled by EGNOS/Galileo satellite positioning, by Copernicus Earth observation), to leverage downstream space excellence in particular of SMEs and universities, to facilitate downstream space investments and to foster market uptake.
- Develop cooperation with partner countries to foster using Copernicus data to jointly develop algorithms, services and/or products which serve local user needs and/or enhance the Copernicus global product quality.
- Establish sustainable supply chains for innovative EO value added products and/or EGNSS solutions and services with demonstrated commercial value with international client communities;
- Lead to new or improved products, processes or services on the market – using EU space technologies (Copernicus, EGNOS/Galileo) as enabler - that are capable of generating within 3 years after the end of public funding a significant turnover for the participants, and create new jobs;
- Creation of strategic partnership with non-EU entities towards commercialization, to attract investment from Europe and beyond by enhancing the European downstream space industry's potential to take advantage of market opportunities and establish leadership in the field and to boost business activity;
- Capacity building and awareness raising around EGNOS/Galileo and Copernicus based applications and solutions.
- Develop and share expertise with public and/or private entities to introduce EU-space based applications/solutions leveraging their innovative, unique features (e.g. Galileo High Precision, Authenticated services) and EU know-how, in both regulated and unregulated domains.

Scope: The actions should focus on technical developments of EU-space based applications/solutions, dissemination, awareness-raising and communication, as well as provide opportunities for the creation of networks of European industry with international partners, or among public entities. By doing so the action should be achieving a critical mass of space based-application success stories, demonstrating the advantages and differentiators of EU space based solutions and services and making it an attractive option for public authorities, private industries and private investors in Europe and globally.

Cooperation with international partners is key to promoting the uptake of Copernicus globally, exploiting possibilities for integrating in-situ, space data and information technologies. Building the Copernicus full, free and open data policy, the Commission seeks to facilitate access to Copernicus data and information for interested international partners. Administrative cooperation arrangements on Copernicus data access and earth observation data exchange have already been signed with the United States, Australia, Ukraine, Chile, Colombia, Serbia, African Union, India and Brazil. Discussions towards similar cooperation have been started with other countries and regions (including United Nations Agencies and Asia-Pacific countries).

Tasks shall include joint calibration and validation activities or integration of local in-situ systems to enhance the quality of data and service products. It is important to exploit the added value of integration of EO observation technologies (both satellite, airborne and ground based) with positioning ones, and ICT (enhancing new frontiers opened by cloud computing) from international partner countries through the development of applications, and encourage their insertion into the market.

International cooperation is similarly important in satellite navigation and positioning domain to enable non EU countries to benefit from the advanced and unique features offered by EGNOS and Galileo, particularly in transport and regulated domains.

Technology promotion activities can include incentive schemes in the form of financial support to third parties, that will promote the uptake of space downstream applications across Europe and globally.

For proposals under this topic:

- When dealing with Copernicus based applications, participation of at least one partner from a country that has signed a Copernicus Cooperation Arrangement is required;
- Participation of industry, in particular SMEs, is encouraged;
- Involvement of public authorities is encouraged, if relevant;
- Involvement of post-graduate scientists, engineers and researchers is encouraged, for example through professional work experience or through fellowships/scholarships as applicable;
- Participation of partners involved in international GEO initiatives is encouraged.

Proposals are encouraged to use the Copernicus Data and Information Access Services (DIAS), or other existing data access solutions instead of setting up their own download and processing infrastructure. They are also encouraged to integrate third-party data (including in-situ data) and envisage data assimilation into models and products made available on the Copernicus platform of the Copernicus services. Proposals dealing with EGNOS/Galileo are encouraged to involve the relevant players on the European side whenever relevant (e.g. ESSP for EGNOS Safety of Life service to aviation and other transports).

DESTINATION 6 – A human-centred and ethical development of digital and industrial technologies

As Europe takes the lead in the green and digital transition, workers, regions, and societies are faced with extremely fast transformations, and will be differently affected by these changes. The rapid adoption of new technologies offers an immense potential for improved standards of living, safer mobility, better healthcare, new jobs, or the personalisation of public services. At the same time, it presents risks such as skills mismatches, digital divides, user lock-in, or serious breaches of security or privacy.

As Europe sets off on its path to recovery towards a greener, digital and more resilient economy and society, the need to improve and adapt skills, knowledge and competences becomes all the more important. Developments in industry, in digital and enabling technologies have the potential to enhance social inclusion, can inform up-skilling training programmes and ensure a two-way engagement with society with regard to developing technologies.

The issue of trust has become central in the use of technologies, following revelations about the exploitation of personal data, large-scale cybersecurity and data breaches, and growing awareness of online disinformation. For AI technologies, trust requires in particular improving transparency (explainability, expected levels of performance); for the Internet: increasing trust requires new tools and services to ensure that GDPR is a reality for end-users. These aspects will be the focus of technology development under this Destination.

It is also an opportunity for Europe to re-gain presence on the consumer electronics market, by developing new interactive applications in various sectors with systems meeting European values and requirements in terms of privacy and security. The COVID-19 crisis has also shown how important distance and innovative learning is for society. Actions under this Destination will therefore develop digital educational solutions, applications and tools based on emerging technologies such as AI, data analytics, immersive and interactive applications, for personalised, innovative, efficient and inclusive learning, for learners of all age and condition.

Actions under this Destination will support EU objectives of inclusiveness and resilience, by supporting a human-centred approach to technology development that is aligned with European social and ethical values, as well as sustainability. These actions will further contribute to addressing the challenges faced by European industry and support the creation of sustainable, high-quality jobs by targeting skills mismatches, the need to empower workers, and ethical considerations relating to technological progress.

Proposals for topics under this Destination should set out a credible pathway to contributing to the following expected impact:

> A human-centred and ethical development of digital and industrial technologies, through a two-way engagement in the development of technologies, empowering end-users and workers, and supporting social innovation.

This Destination is structured into the following sections:

- Leadership in AI based on trust
- An Internet of Trust
- New digital interactions, 3D, augmented and virtual reality
- Digital learning technologies, including upskilling of the workforce
- Cross-cutting topics

The following call(s) in this Work Programme contribute to this Destination:

The Destination structure and the allocation of topics to calls and year will be decided at a later stage.

Section: Leadership in AI based on trust

[Expected impacts addressed: #18 (Digital and emerging enabling technology sovereignty), #20 (Human-centred), #15 (Green), #21 (Data).

Objective: ensure sovereignty and autonomy for Europe in AI, leading the way in research, development and deployment of world-class technologies that are beneficial to humans both individually and societally, and that adheres to European ethical values, values, such as the principles reflected in our fundamental rights and environmental sustainability. One priority will be the development of top-performing technologies that industries and citizens will trust and that will be applied in a wide range of applications and industrial sectors. Trustworthy AI is particularly key in application such as healthcare for helping professionals

Current status: Europe's scientific community is leading in AI. However Europe lags behind in AI diffusion, and less than half of European firms have adopted one AI technology, with a majority of those still in the pilot stage. 70% of these adopter companies, are only capturing 10% of full potential use, and only 2% percent of European firms in healthcare are using those technologies at 80% of potential[47]. Moreover, as demonstrated during the COVID-19 crisis, many AI and robotics solutions exist today but only a limited number of them reaches the level of autonomy necessary to solve the problems at hand. Therefore, there is room for large improvement for adoption, which requires drastic improvements in trust, reflected through increased performance (accuracy, robustness, etc.) and explainability, as well as adopting the 'ethics-by-design' approach, with a view of reaching 'ethical-by-design' AI systems capable of "understanding" humans, adapting to complex real-world environments, and appropriately interacting and collaborating with humans in complex social settings.

Achievements sought / targets:

Develop **trustworthy AI** technology, key for acceptance, to take full advantage of the huge benefits such technology can offer, and demonstrate the benefit in particular applications. This will require improvement in transparency: explainability, accountability and responsibility, safety, expected levels of technical performance (accuracy, robustness, level of 'intelligence' and autonomy, etc.) which are guaranteed/verifiable and with corresponding confidence levels.

Make sure that AI solutions aimed at industry meet the industrial requirements in terms of safety, repeatability and robustness. Build the **next level of "intelligence" and autonomy**, essential to scale-up deployment, in solving wider set and more complex problems, adapting to new situations and context knowledge, addressing real-time performance requirements and data and energy efficiency, also for greener AI and robotics solutions. This will require a.o. integration of both learning and reasoning, causality, contextualization and knowledge discovery, human-in the loop approaches for truly mixed human-AI initiatives combining the best of human and machine knowledge and capabilities.

[47] See https://www.mckinsey.com/featured-insights/artificial-intelligence/tackling-europes-gap-in-digital-and-ai (based on data from 2017 and 2018)

Build the next level of **perception, interaction and collaboration** between humans and AI systems working together as partners to achieve common goals, sharing mutual understanding of each other's abilities and respective roles.

Build AI systems that are socially aware: able to anticipate and cope with the consequences of complex network effects in large scale mixed communities of humans and AI systems interacting over various temporal and spatial scales. This includes the ability to balance requirements related to individual users and the common good and societal concerns, including sustainability, equity, diversity etc..

Make sure that developed AI and robotics solutions meet the requirements of Trustworthy AI, based on the respect of the ethical principles, the fundamental rights, including privacy. 'Ethics-by-design' approach needs to be adopted from early stages of AI development. Propose standardisation methods to foster AI industry, helping to create, and guarantee trustworthy and ethical AI, and in support of the EC regulatory framework.

Means/links: A co-programmed Partnership ('AI, Data and Robotics') is currently proposed to as the necessary instrument to enable European industrial and academic stakeholders to design and implement common strategic research and innovation agendas and roadmaps, and develop synergies with Member States initiatives and funding.

Links to other clusters: AI technologies are general-purpose enabling technologies that can be developed in any context and economic sector, such as manufacturing, healthcare, agrifood, energy, water supply, security, climate/energy/mobility, space, mining, humanitarian challenges, creative and cultural industries addressed in various Horizon Europe clusters, as well as most of the Horizon Europe missions (cancer, food, smart cities, healthy water/oceans); therefore the link with corresponding Partnerships will be established to maximise synergies (meet the needs of the application sectors) which could possibly be implemented by joined calls.

Links to other Partnerships: Smart Network and Services, High Performance Computing, KDT, Smart Networks and Services, Space/Copernicus, Made in Europe and EIT-KIC Digital. Regarding synergies with other enabling technologies: AI will be used to optimise the Next Generation of Internet, Cybersecurity, and vice versa, HPC optimised for AI, and progress in IoT, advanced and distributed sensors, photonics, edge /cloud computing, and neuromorphic computing will be exploited in this section, to increase the performance of AI-based solutions.]

Proposals are invited against the following topic(s):

HUMAN-01-2021: Verifiable robustness and transparency for Trustworthy AI (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- World-class transparent, explainable and trustworthy AI, based on smarter, safer, secured and accurate, robust, reliable and dependable solutions, integrating European values by design.
- Further developing the operationalisation of 'Ethics-by-design' approach, including reducing bias in the development of Artificial intelligence

Scope: In this topic, solid scientific developments will be complemented by tools and processes for design, deployment, testing and validation, certification (where appropriate), software engineering methodologies, as well as approaches to modularity and interoperability.

Each proposal will focus on one of the following topics

- **Advanced "intelligence" and autonomy:** scientific projects focusing on advancing the state of the art in AI, improving the level of "intelligence" and autonomy performances of AI algorithms and AI-based solutions essential to scale-up deployment, in solving wider set and more complex problems, adapting to new situations (making them "smarter", more accurate, robust, dependable, versatile, reliable, secured, un-biased, safer, etc.), and addressing real-time performance requirements. This will include a.o. integration of both learning and reasoning, causality, contextualization and knowledge discovery. Novel learning approaches (such as unsupervised, self-supervised, representational learning capable of contextualization) as well as symbolic approaches will also be supported.
- **Greener AI**: addressing data and energy efficiency. More research is necessary in topics such as research towards lighter, less data-intensive and energy-consuming models, optimized learning process to require less input (frugal AI), or optimized models, data augmentation, synthetic data, transfer learning, one-shot learning, continuous / lifelong learning, and optimized architectures or energy-efficient hardware.
- The call will also support projects working on transparency improvements: explainability, expected levels of performance which are guaranteed/verifiable and corresponding confidence levels.
- Development of tools and processes for design, deployment, testing and validation, certification (where appropriate), software engineering methodologies, as well as approaches to modularity and interoperability.
- Investigation of ethics by design approaches for the development and deployment of AI, making sure that developed AI solutions meet the ethical requirements, including respect of the ethical principles and the fundamental rights. 'Ethics-by-design' approach needs to be adopted from early stages of AI development.

In all these topics involvement of multidiciplinarity teams will be essential.

All proposals are expected to embed mechanisms to asses and demonstrate progress (with qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring processes), and share results with the European R&D community, through the AI-on-demand platform, to maximise re-use of results and efficiency of funding.

HUMAN-02-2021: AI for human empowerment (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Truly mixed human-AI initiatives for human empowerment
- Trustworthy decision-support systems
- Using AI to induce responsible human behaviours

Scope: Each proposal will focus on one of the three following topics

- To reach truly mixed human-AI initiatives for human empowerment, the approaches should combine the best of human and machine knowledge and capabilities including shared and sliding autonomy in interaction, addressing reactivity, and fluidity of interaction and making systems transparent and intuitive to use, which will play a key role in acceptance. The systems should adapt to the user rather than the opposite.
- Trustworthy decision-support will include approaches for mixed and sliding decision-making, and include context interpretation, dealing with uncertainty, transparent anticipation, reliability, human-centric planning and decision-making, and augmented decision-making. Transparency, non-bias, technical accuracy and robustness will be key.
- Using AI to induce responsible human behaviours

All proposals should adopt a human-centred development of trustworthy AI and investigate and optimise ways of human-AI interaction, key for acceptance, to allow users to take full advantage of the huge benefits such technology can offer. This include development of methods to improve transparency, in particular for human users, in terms of: explainability, expected levels of performance which are guaranteed/verifiable and corresponding confidence levels, accountability and responsibility, as well as perceived trust and fairness.

Innovative scientific approach towards human-centric approaches will require multidisciplinary approaches including SSH, and any other disciplines, as relevant to stimulate novel research avenues, and eventually improve user-acceptance.

All proposals should contribute to build the next level of **perception, interaction and collaboration, and empathy** between humans and AI systems working together as partners to achieve common goals, sharing mutual understanding of each other's abilities and respective roles.

All proposals are expected to embed mechanisms to asses and demonstrate progress (with qualitative and quantitative KPIs, benchmarking and progress monitoring processes, as well as illustrative application use-cases demonstrating concrete potential added value), and share results with the European R&D community, through the AI-on-demand platform, to maximise re-use of results and efficiency of funding.

HUMAN-03-2021: European coordination, awareness, standardisation & adoption of benevolent European AI, benefiting our economy, society and environment (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Support to the Public-Private Partnership
- Support the scientific community with the AI-on-demand-platform
- Widespread educations and outreach programmes
- Promote the adoption of trustworthy AI in procurement both public and B2B
- Propose standardisation methods to foster AI industry, helping to create, and guarantee trustworthy and ethical AI, and in support of the EC regulatory framework.
    - Online observatory of published standards and ongoing standardisation activities in AI worldwide.
    - Identification of gaps and recommendations for key topics for future standardization
    - Support to a mechanism for information exchange between international and European Standardization Organizations (ESOs) to increase the transparency of ongoing work at international and European levels.
    - Support participation of European stakeholders in the international standardization initiatives
    - Networking of all key players, collection of essential requirements for AI standardization and dissemination of information
    - Recommendations on links between standardization, certification and regulation
    - Recommendations for research activities supporting standardization
- Support and encourage the adoption of AI technologies in all Member States, with particular emphasis on geographical aspect and elimination of gaps between Member States.

Scope:

- CSA supporting the PPP: will support the development of a strong and inclusive network bringing, academia, industry, and public and industry users, including the major industrial European sectors and all relevant stakeholders, to guarantee strong coordinated efforts toward benevolent AI, for the economy, society and environment. The network will also include national representatives, to link to national programmes and to foster synergies and coordination between the various European, national, public and private initiatives. Such coordination of efforts in research, innovation and expertise will be important for Europe's leadership in AI. The objective is to support the community in defining and implementing the AI, data and robotics strategy, and support the PPP in its coordination and support of the community in non-R&D tasks.

Proposals are expected to develop synergies with relevant activities in AI, Data and robotics, in destination 3, 4 and 5 and share or exploit results where appropriate.

Such proposals should also include mechanisms to support exchanges, axchanges of knowledge among the AI-funded activities in AI, either in Cluster 4, but also in other clusters, missions, and other parts of Horizon Europe and DEP. Common portal gathering relevant information, success stories, organisation of joint event gathering projects etc. are encouraged.

- CSA for widespread educations and outreach programmes will increase the awareness of the potentialities of AI but also ensure expectations are realistic to avoid backlash in the adoption. Such project should target in particular the business community, with a particular focus on SMEs, as well as public administrators, and citizens at large.
- CSA on procurement of AI solutions for both public and B2B: this is crucial to foster the development of European AI industries and applications built on European data and compliant with the European regulatory framework, and to foster vast deployment of AI-based solutions.
- CSA Supporting standardisation in AI
    - Standards should guarantee that AI technology in industry brings a high level of trust and safety of operations, and that it respects fundamental values and human rights. Standards should also ensure appropriate governance of AI throughout the system lifecycle and make sure that decision systems are trustworthy by being robust, safe and secure.
    - Developing a coherent and broadly accepted set of AI standards requires a minimum level of support to ensure that all essential players are involved and that their voices are heard and in order to disseminate information and collect requirements essential requirements. Support is also needed to coordinate and encourage contributions to standardization activities around the world.
    - An important dimension will be to explore needs for standardisation and qualification of equipment and processes, notably the application of Artificial Intelligence to business processes.

HUMAN-04-2022: Excellence in the next level of "intelligence" and autonomy (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- towards a leading unified European AI, data and robotics community

Scope: This initiative will pursue the initiative started in H2020 to develop a vibrant European network of AI excellence centres, and a vibrant AI scientific community.

To ensure European strategic autonomy in such critical technology as AI, data and robotics, with huge potential socio-economic impact, it is essential to reinforce and build on Europe's assets in such technologies, including its world-class researcher community, in order to stay at the forefront of technological developments.

As stated in the communication from the European Commission on Artificial Intelligence for Europe and the coordinated action plan between the European Commission and the Member States, while Europe has undeniable strengths with its many leading research centres, efforts are scattered. Therefore joining forces will be crucial to be competitive at international level. Europe has to scale up existing research capacities and reach a critical mass through tighter networks of European AI excellence centres. The proposals should develop mechanisms to reinforce and network excellence centres in AI, bringing the best scientists from academia and industry to join forces in addressing the major robotics challenges hampering its deployment, and to reinforce excellence in robotics throughout Europe via a tight network of collaboration.

Such networks are expected to mobilise researchers to collaborate on key AI topics, to reach critical mass and increase the impact of the funding in progressing faster in joined efforts rather than working in isolation, with fragmented and duplicated efforts.

Proposals will mobilise the best European teams in AI, data and robotics community to join forces to address major technical as well as sector- or societal-driven challenges: strengthening excellence, networking, multidisciplinarity, academia-industry synergies.

Proposals will develop Networks of excellence centres including mechanisms to joining forces towards technical challenges such as (but not limited to)

- Increased intelligence and autonomy, adapting to new situations, addressing real-time performance requirements (both for robotics and non-embodied AI systems). Integration of advanced and adaptive sensors and sensing and perception (including multi-modal sensing and active perception, distributed sensing, etc.). Integrating learning and reasoning, combining data-driven and knowledge-based models, causality, contextualization and knowledge discovery. Building on simulation and digital twins. Including data augmentation, knowledge modelling, federation of AI systems – including the use of distributed data, and new learning methods ensuring scalability and re-usability. AI systems that are socially aware: able to anticipate and cope with the consequences of complex network effects in large scale mixed communities of humans and AI systems interacting over various temporal and spatial scales. This includes the ability to balance requirements related to individual users and the common good and societal concerns, including sustainability, equity, diversity etc..

- Greener AI: Data-agile and energy efficient AI, for frugal and greener AI, exploiting small data, transfer learning, exploiting latest development in optimised hardware (e.g.: neuromorphic computing).

- Joined AI, data and robotics scientific and technical challenges

These networks will also address a number of sector- or societally-driven challenges, mobilising the community towards achieving common goals in addressing such challenge that AI, data and robotics can help solving, demonstrating the potential positive impact on the society, economy and environment.

The proposals should

- include mechanisms to spread the latest and most advanced knowledge to all the robotics-labs in Europe
- develop synergies and cross-fertilization between industry and academia
- the network will become a common resource and shared facility, as a virtual laboratory offering access to knowledge and expertise and attracting the talents. It should become a reference, creating an easy entry point to AI excellence in Europe and should also be instrumental for its visibility.

Composition of the Network:

- it should be driven by leading figures in AI from major excellent research centres, bringing the best scientists distributed all over Europe. They will bring on board the necessary level of expertise and variety of disciplines and profiles to achieve their objectives.
- Industrial participation will be ensured through industrial research teams and also in bringing expertise to identify important technological limitations hampering deployment in industry.
- It will demonstrate access to the required resources and infrastructure to support R&D, such as robotics equipment, support staff and engineers to develop experiments, etc. Al

Activities of the Networks:

- In order to structure the activities, the proposals will focus on important scientific or technological challenges with industrial relevance and where Europe will make a difference, either in building on strengths, or strengthening knowledge to fill gaps critical for Europe.
- Based on these challenges, the proposals will develop and implement common research agendas. The main vision and roadmap with targets within the projects, as well as methodology to implement and monitor progress will have to be specified in the proposal and can be further developed during the project.
- Progress will be demonstrated in the context of use-cases, also helping to foster industry-academia collaboration.

- Strong links will be developed among the members of the network, notably through collaborative projects, exchange programmes, or other mechanisms to be defined by the consortia

- The proposals should define mechanisms to foster excellence throughout Europe, to increase efficiency of collaboration, and to develop a vibrant AI network in Europe.

- Each network will disseminate the latest and most advanced knowledge to all the academic and industrial AI laboratories in Europe, and involving them in collaborative projects/exchange programmes. (This could involve projects defined initially or via financial support to third parties[1][2], for maximum 20% of the requested EU contribution).

- Each network will develop interactions with the industry (inside the consortium and beyond), in view of triggering new scientific questions and fostering take-up of scientific advances

- Each network will develop collaboration with the relevant Digital innovation Hubs, to disseminate knowledge and tools, and understand their needs.

- These networks should also foster innovation and include mechanisms to exploit new ideas coming out of the network's work (for instance via incubators).

- Overall, each proposal will define mechanisms to become a virtual centre of excellence, offering access to knowledge and serve as a reference in their chosen specific field, including activities to ensure visibility.

The proposals should include a number of major scientific and application challenges which will mobilise the community to join forces in addressing them. Continuous evaluation and demonstration of scientific and technological progress (with qualitative and quantitative KPIs, benchmarking and progress monitoring processes) towards solving the targeted challenges will motivate the entire network and support publications and scientific career developments (providing references to publish comparative results, using the reference data, scenarios, etc.), and also showcase the technology in application contexts, to attract more user industries and eventually foster take up and adoption of the technology.

The proposals are expected to include mechanisms to share resources, knowledge, tools, modules, software, results, expertise, and make equipment/infrastructure available to scientists to optimise the scientific and technological progress. To that end, proposals should exploit tools such as the AI-on-demand platform and further develop and expand the platform, to support the network and sharing of resource, results, tools among the scientific community maximising re-use of results, and supporting faster progress. Mechanisms to test results and continuously measure and demonstrate progress should be integrated in the platform, which is also important to support the scientific community, allowing also for comparative analysis.

The proposals are also expected to include collaboration mechanisms among the best AI teams, but also mechanisms to bring all European AI teams to the highest level of excellence. This is also in view of supporting and encouraging the adoption of AI technologies in all member states, with particular emphasis on geographical aspect and elimination of gaps between Member States.

Proposals will also exploit and develop technology enablers, such as methodologies, tools and systems and exploit latest hardware development and data spaces, cloud and HPC resources.

Projects are expected to develop synergies with relevant activities in AI, Data and robotics, in destination 3, 4 and 5 and share or exploit results where appropriate.

Section: An Internet of Trust

[Expected impacts addressed: #15 (Green), #21 (Data), #18 (Digital and emerging enabling technology sovereignty), #20 (Human-centred)

Objective: develop a trustworthy digital environment, built on a more resilient, sustainable, and decentralised internet architecture, to empower end-users with more control over their data and their digital identity, and to enable new social and business models respecting European values.

Current status: The issue of trust in the internet has become central, following revelations about the exploitation of personal data, large-scale cybersecurity and data breaches, and growing awareness of online disinformation. A 2019 survey[48] shows that half of global internet users are more concerned about their online privacy compared to a year previously. Distrust in the Internet is causing people to change the way they behave online, for example by disclosing less personal information. Users also express an increasing level of distrust of social media platforms.

Achievements sought / targets:

Internet technologies and services developed under this section are addressed to internet end-users, they will complement the general methods, technologies and infrastructures for data pooling, sharing and re-use developed under the Data destination:

- Review and upgrade the Internet infrastructure to make it more resilient to security threats, energy efficient, and increasingly supportive of open and decentralised technologies and services. Solve current blockchain limitations such as scalability, interoperability, energy efficiency or security, with the aim of deploying highly complex and sophisticated blockchain applications.
- Make GDPR a reality for Internet end-users by developing tools and services to ensure that they are fully in control of their personal data while companies and public administrations have full certainty on what they can do with the data. Develop secure digital identity that is platform-independent and standardised with global acceptance.
- Develop new platforms that address the dynamic nature of human communications for reliable production and diffusion of trustworthy information and quality content, to support the digital media transformation; develop tools and technologies for identifying and tackling disinformation and harmful/illegal content. Foster the connection of people, smart objects and AI agents in order to address key sustainability challenges through collective intelligence.

This section complements the other three orientations for topics under Next Generation Internet in order to build a competitive European Internet value chain that can meet the needs of emerging user-centric and industrial applications.

[48] 2019 CIGI-Ipsos Global Survey on Internet Security and Trust

Means/links:

The R&I actions under this section may provide direct support (e.g. in the form of cascading grants) to researchers, developers, high-tech SMEs and start-ups to develop the key building blocks of the internet of the future.]

Proposals are invited against the following topic(s):

HUMAN-05-2021: Trust & data sovereignty (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Increase trust, privacy and user control when exchanging and accessing personal data on the Internet, supporting the transition to a human-centric data economy.
- Contribute to social good by allowing citizens to securely share their data in areas as diverse as healthcare and well-being, democracy, or the environment.
- Build a trusted electronic identity ecosystem, fostering a universal, accessible, and user-centric digital identity as a passport to the digital society.
- Support a European ecosystem of top internet innovators, with the capacity to set the course of the Internet evolution according to a human-centric approach.
- Generate new business opportunities and enable the emergence of new business and sustainability models based on data sovereignty and Open Source.

Scope: The EU has an advanced legal framework in the areas of data protection, cybersecurity and electronic identity. The objective of this topic is to deliver tools and services to ensure that Internet end-users can exert their rights (e.g. under the GDPR) and benefit from technological solutions that ensure that they are fully in control of their personal data, while companies and public administrations have certainty on what they can do with the data and use them to develop new services.

Projects proposed under this topic should develop new technologies and data governance models for increased trust, privacy and user control of personal data and identity on the internet, empowering the end-users and enabling user-centric business and sustainability models, eventually supporting the transition to a human-centric data economy. Solutions should enable the portability of personal data set and allow the users to transfer or share such data with organisations of their choice for purposes and under conditions they decide and control. Proposals should contribute to a trusted digital identity ecosystem that is in line with eIDAS, platform-independent and standardised and gives individuals the possibility to effectively own, manage and control their digital identity and make it their passport to the digital society.

Projects awarded under this topic are expected to provide support to third parties, from open source developers, to academic researchers, hi-tech startups, SMEs and other multidisciplinary actors, so that multiple actors are funded and collectively contribute to increasing online trust and data sovereignty.

The projects should support open source software and open hardware design, open access to data, standardisation activities, access to testing and operational infrastructures, as well as an IPR regime ensuring lasting impact and reusability of results.

HUMAN-06-2021: Open search and discovery (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Empower citizens and companies to search and discover more information, data and resources online, providing increased accuracy, diversity and transparency in search results while preserving the privacy of end-users.
- Foster European competitiveness and sovereignty in future search and discovery systems with a strong focus on serving end-users' needs (including privacy) and increasing public trust in search results.
- Support a European ecosystem of top internet innovators, with the capacity to set the course of the Internet evolution and the search ecosystem according to a human-centric approach.
- Generate new business opportunities and enable the emergence of new business and sustainability models based on improved access to online data and resources and on Open Source.

Scope: The objective of this topic is to develop technologies enabling new ways of searching and discovering the internet across a variety of resources such as personal, scientific, industrial and environmental data, connected devices and objects, services, multimedia content, intranets and other IT resources, empowering end-users to share and discover more data and reliable information sources, while preserving their privacy and increasing public trust in search results.

Projects under this topic may notably explore advanced methods of search such as cognitive search combining technologies for natural language processing, semantic analysis and data visualisation, enabling new ways of discovering and accessing information.

Proposals may also explore how to improve search infrastructures, with a view to increasing European sovereignty in future search and discovery systems. Projects could notably design and pilot essential facilities such as web indexes and other distributed search infrastructures, with a strong focus on reliability, interoperability and trust.

Projects awarded under this topic are expected to provide support to third parties, from open source developers, to academic researchers, hi-tech startups, SMEs and other multidisciplinary actors, so that multiple actors are funded and collectively contribute to building a more open, trustworthy and user-centric search and discovery ecosystem.

The projects should support open source software and open hardware design, open access to data, standardisation activities, access to testing and operational infrastructures as well as an IPR regime ensuring lasting impact and reusability of results.

HUMAN-07-2021: Collective Intelligence for Sustainability (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- New collaborative and distributed Internet technologies at the service of people through well-tailored Collective Intelligence solutions help make citizens and the society collectively aware of sustainability problems and of the possible collective solutions.
- Innovative bottom-up and Collective Intelligence -based solutions in fields such as environmental sustainability, health and wellbeing, democratic participation, citizens' engagement, open policy making, circular economy and new economic models beyond GDP.
- Better (scientific and social) understanding of collective phenomena for designing the next generation of networking technologies, with a view to contributing to the management of the current grand challenges of environmental, economic and social sustainability.

Scope: Digital technologies, especially a proper and human-centric use of Artificial Intelligence (AI), can facilitate Collective Intelligence (CI) by effectively federating human intelligence. CI can provide collective solutions to social, economic, scientific and environmental challenges by enabling large-scale collective participation, by helping people to get a common understanding, and by identifying solutions for global problems, built on collective complementary knowledge, expertise and data. Networking technologies allow for collecting data, federating dispersed knowledge at all scales (communities, cities, nations, pan-European, worldwide) and enabling well-informed decision-making.

Examples of collective intelligence solutions are manifold and range from knowledge sharing architectures or crowd –sourcing –sharing and –mapping of data, to the use of social media to raise awareness and engage collective actions, and to science focused collaborations to gather specific data or solve problems requiring expertise globally dispersed.

To make CI a reality, scientific understanding of collective approaches and impact assessment methodologies will be necessary to allow delineating this new approach with respect to traditional methods in decision-making and appropriate governance of social networking. This will allow for designing better and more adapted technologies for CI which will furthermore facilitate the integration with AI technologies bringing mutual beneficial effects. It will be equally important to root these efforts in the strong cultural, humanistic traditions and values of Europe. Particular attention should be devoted to the treatment of data generated by citizens, to maintain them under the control of the citizens, which requires a high degree of decentralisation in data management and governance.

HUMAN-08-2021: Data Lakes for Media innovation (IA)

- Expected Outcomes: Advanced infrastructure following the principles of a Data Lake for sharing media products, audience data and relevant meta-data between audio-visual media creators and service providers including news media outlets.
- Prototypic new media format and user experience pilots and production processes, connected to Data Lakes.
- Reinforced European media ecosystem through the concept of Data Lakes for building new and emerging technologies, for an immersive and interactive prosumer experience.

Scope: Media has a central role in sharing European values and a free media is a pillar of European democracy. The complex media ecosystem of users and producers, audiences and performers with interchangeable, interactive roles and driven by state-of-the art technology, requires a faster pace of innovation. Therefore, within the new Commission's Media Action Plan, support to media innovation is prominently present.

In line with the European data strategy and interoperable data spaces in strategic sectors, the implementation of Data Lakes for sharing media development and product data, audience data and relevant meta-data between media producers, distributors and consumers is considered being a necessary game changer. Moreover, synergies with data spaces from non-media sectors might provide additional value to media data lakes.

This topic supports the implementation of Data Lakes, addressing technical, organisational, commercial and legal aspects and, in particular, user friendliness of data management interfaces, data interoperability and scalability, trans-national implementation and application, financial micro-transactions functionalities for content and data usage, and an appropriate consideration of copyright and GDPR issues.

The functionality of the Data Lake shall be used to prototype new media format pilots and production processes. A preference should be given to application areas such as entertainment (e.g. cinema, self-driving cars) and information/news media, using technology-based formats (MR, VR and AI).

HUMAN-09-2021: Next Generation Internet community-building and outreach (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Engage a broad community of stakeholders, with the capacity to set the course of the Internet evolution according to a human-centric approach.

Scope: The aim of the topic is to co-design and execute the Next Generation Internet community-building and communication strategy.

The project will support the European Commission in engaging a diverse community of stakeholders, including internet innovators, researchers, start-ups and SMEs, but also policy makers, internet end-users, local communities and citizens at large, in order to develop and implement the NGI vision of a human-centric internet. It will help grow the community by promoting broad stakeholder engagement in NGI activities and projects, in particular by engaging internet innovators who are new to EU programmes. The project will seek to ensure diverse participation in terms of profiles, gender and nationality. It will have dedicated activities to promote the involvement of women innovators and innovators from all EU Member States and from neighbouring regions.

The project will support the European Commission in NGI branding and marketing activities, including extensive online and social media presence, press coverage and participation in key events, establishing a positive brand image in the Internet community and the public at large. Based on advanced digital and non-digital communication techniques, the project will lead NGI communication activities and coach other NGI projects in effective communication and marketing.

HUMAN-10-2021: NGI International Collaboration - USA (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Enhance EU-US cooperation in the development of Next Generation Internet technologies, services and standards.
- Support the EU internet policy objectives by sharing the EU vision and values with US counterparts and forging bonds through concrete collaborations.
- Support an EU-US ecosystem of top researchers, hi-tech startups / SMEs and Internet-related communities collaborating on the evolution of the Internet according to a human-centric approach.
- Generate new business opportunities and enable the emergence of new business and sustainability models based on Open Source.

Scope: The aim of the topic is to reinforce EU-US cooperation in the area of Next Generation Internet, and to establish a continuous dialogue among US and EU innovators. The focus will be on trust and data sovereignty and on internet architecture renovation and decentralised technologies.

A CSA will organise a fellowship programme providing support to European Internet innovators to travel to the US to work and collaborate with US counterparts, with a view to promoting knowledge-sharing and establishing long-term collaborations on NGI technologies, services and standards.

The project is expected to provide support to third parties, from open source developers, to academic researchers, hi-tech startups, SMEs and other multidisciplinary actors, so that multiple actors are funded and collectively contribute to enhancing EU-US cooperation in the development of Next Generation Internet technologies and services.

HUMAN-11-2022: Internet architecture and decentralised technologies (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Increase the security and resilience of the global Internet; reduce its energy consumption; and support a decentralised Internet that gives the control back to the end-users.
- Foster European competitiveness and strategic autonomy in core internet technologies, distributed ledgers and Blockchain. Reinforce the European Blockchain ecosystem and excellence in research and innovation.
- Promote interoperability and strengthen the role of Europe in Internet standard-setting.
- Support a European ecosystem of top internet innovators, with the capacity to set the course of the Internet evolution according to a human-centric approach.
- Generate new business opportunities and enable the emergence of new business and sustainability models based on decentralised technologies and Open Source.

Scope: The Internet architecture has developed as a mix of centralised, networked and device-based technologies with design choices largely coming from the past. In particular, the questions of security and energy consumption were relatively secondary in the initial architecture design of the Internet. At the same time, ever-larger fractions of the internet as we know it today are operated by a relatively small number of platforms controlling end-users' data and online transactions, effectively leading to a centralisation of the Internet.

The objective of this topic is to review and upgrade the Internet architecture (hardware, software, protocols) to increase the performance of the network, adapt it to new application requirements, make it more resilient to security threats, more energy efficient and respectful of the environment (e.g. recyclability), and increasingly supportive of open and decentralised technologies and services, such as Blockchain and distributed ledger technologies. Projects addressing Blockchain should aim to solve its current technology limitations, such as scalability, interoperability, energy efficiency or security, in order to make it a fundamental building block of the future Internet and the key user-centric applications running on it.

Projects funded under this topic should include a strong standardisation angle to promote the technologies developed in international standard setting organisations.

Projects awarded under this topic are expected to provide support to third parties, from open source developers, to academic researchers, hi-tech startups, SMEs and other multidisciplinary actors, so that multiple actors are funded and collectively contribute to building a greener, more secure and decentralised Internet.

The projects should support open source software and open hardware design, including how to maintain key open source building blocks of the internet, access to testing and operational infrastructures as well as an IPR regime ensuring lasting impact and reusability of results.

HUMAN-12-2022: Pilots for the Next Generation Internet (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Demonstrate next generation internet technologies in a variety of industrial and societal use cases, enabling the emergence of internet ecosystems supporting the needs of key vertical sectors.
- Support a European ecosystem of top internet innovators, with the capacity to set the course of the Internet evolution according to a human-centric approach.
- Generate new business opportunities and enable the emergence of new business and sustainability models based on Open Source.

Scope: The aim of this topic is to foster the take up of Next Generation Internet technologies and solutions in Europe by integrating them in a variety of industrial and societal use cases, enabling the emergence of internet ecosystems supporting the needs of specific sectors, such as (but not limited to) public services, healthcare and well-being, supply chain management, transport, energy and ICT sector.

NGI Pilots will make use of the rich portfolio of technologies and tools developed in the NGI programme and will apply them to real-life use cases with the goal of validating NGI human-centric solutions across value chains, as close as possible to operational conditions, engaging large user groups and proving their socio-economic potential. Pilots will also support the validation of the related business models to address the sustainability of the approach beyond the lifecycle of the project.

Pilots will involve user organisations from vertical sectors, NGI innovators and other digital technology providers, for example systems integrators. Projects will need to carefully consider the needs and expectations of the end-users as main drivers of the technological developments. For societal use cases, local communities and citizens' associations should take an active part in the projects.

Pilots will include development, integration, testing, deployment and operation activities. They will maximise the spectrum of use cases with high social or economic impact. Focus will be on open source solutions (both software and hardware) and their integration in vertical use cases, to ensure replicability of the results and portability in different areas.

HUMAN-13-2022: Next level social networks trustworthy user generated content (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- New social media applications developed in Europe, including decentralised approaches, and improvement of social network communication, addressing the dynamic nature of human communications.
- Better social behaviour and cohesion, including seamless online/offline existence.
- Avoidance of social, physical and mental problems, also by setting new standards for user interface design.

Scope: The scope of the topic is to design and prototype new social network concepts based on existing and upcoming technologies, including decentralised models, connected objects and online communication tools. Such technologies allow creating and stimulating new online multisensory interaction, which opens for novel social network experiences (e.g. virtually shared entertainment and education/information experiences). In the current social media climate, such experiences have a powerful impact on users' perception. Therefore, it will be necessary to promote a more diverse ecosystem of social media networks, and ensure content trustworthiness and limit the spread of disinformation on these networks.

Higher trust in social media networks through innovation will potentially reflect in higher engagement, involvement and support in new technologies. New social network solutions must allow users, through innovative technology (e.g. immersive technologies), to commute between the real and virtual worlds, and in particular to understand how their behaviour in the virtual space can affect their real life and have a strong societal impact. At the same time, users must be free to choose the network (or the elements of it) which they prefer and to change network and port their data between networks.

This entails collaboration between technology and creative sector/industries thinking to conceive innovative and imaginative online solutions – social networks, platforms, completely novel communication approaches – for reliable production and diffusion of trustworthy information and quality content, richer online interactions and for identifying and tackling disinformation and harmful content.

HUMAN-14-2022: A safer Internet (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Research on and development of AI tools and technologies (including classifiers) to identify digital Child Sexual Abuse Material (CSAM). Such AI classifier tools will help law enforcement agencies (LEAs), INHOPE Hotlines, and industry to analyse the vast amounts of digital CSAM more efficiently through automated identification and prioritization, thus leading to swifter takedown of illegal material by Hotlines and industry, and more effective investigations by LEAs.

Scope: One of the main challenges in the fight against online CSAM is the vast amount of potential new CSAM that Hotlines and LEAs have to assess and classify as illegal prior to takedown. In 2018, for example, national LEAs in the EU received more than 500,000 referrals stemming from US internet providers, while INHOPE Hotlines are seeing increasing numbers of reports of CSAM hosted in the EU resulting from proactive search for CSAM. Relying on human analysts alone to assess such vast quantities of material slows up both law enforcement investigations and notice and takedown actions. There is therefore an urgent need to further develop and test AI tools which support the classification of CSAM.

The projects shall aim to develop mature tools that support the analytical work of LEAs and Hotlines, based on relevant classifiers that correspond to typical elements/characteristics of CSAM. The tools shall allow identification, categorisation and prioritisation of digital CSAM from large data sets. The solutions should be robust enough and provide sufficient information to help Hotline analysts and law enforcement officers in their assessments.

To ensure that the proposed solutions are fit for purpose and effective, INHOPE Hotlines and LEAs shall be involved in each project. Working in close cooperation with them, the projects shall build on existing infrastructures and processes already available to LEAs and INHOPE Hotlines. The projects shall ensure European added value through cross-border interoperability.

The projects shall define the characteristics and granularity of classifiers required, develop the classifiers, compose and annotate representative CSAM data sets, train and test the tools in cooperation with LEAs and INHOPE Hotlines. As CSAM is illegal, these data sets need to be provided by or composed mainly in cooperation with LEAs. To reduce the development and training time on this sensitive data, the proposed tools should be able to incorporate dynamically user feedback, preferably without the need of retraining the model. The proposed tools should also allow pre-training on data available for other general tasks, like image classification, object detection, instance segmentation, etc., in order to increase the accuracy and to reduce the exposure to sensitive data during training. The tools to be developed can also include other relevant features such as text-based data analysis, audio analysis from videos and/or automated key word extraction from audio or age detection.

All tools developed throughout the projects shall be made freely available as Open Source Software, also for industry to use on a voluntary basis to detect and remove illegal material.

The topic also contributes to the objectives of Horizon Europe Cluster 3 Civil Security for Society.

HUMAN-15-2022: Blockchain/DLT for trusted decentralised data value chains in the NGI (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Shape the evolution of the Internet towards trusted decentralised data value chains enabling cooperation between different types of stakeholders.
- Create a European ecosystem of top researchers, hi-tech startups, SMEs, industry players and Open Source contributors with the capacity to set the course of Internet evolution, through new data chain models.
- Leverage trust technologies like blockchain, to generate new business opportunities and enable the emergence of new companies.
- Reinforce European leadership, foster its competitiveness and strategic autonomy in the data economy.
- Promoting interoperability and strengthening the role of Europe in international standardisation.

Scope: Towards a trustworthy internet enabling the exploitation of data coming from a high number and various types of sources, eliminating data silos through decentralised approaches, while helping individuals, groups and organisations to better govern their data when they participate in joint actions or value chains where cooperating partners can also be competitors.

Proposed projects should in particular explore methods for exploiting data samples for machine learning processes in areas like health, mobility, energy and environment related activities, in contexts characterized by always more connections between individuals, groups, companies and virtual entities (including automated processes, involving AI, machine to machine communication and IoT).

Trust is required for what concerns data provenance with real-time traceability, data integrity, data exploitation with notifications and secure exchange between stakeholders or autonomous systemswith possible incentive and compensation models to data owners that participate in joint activities. Trust means also to ensure security as well as data protection and privacy when it relates to individuals.

HUMAN-16-2022: NGI International Collaboration - USA (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Enhance EU-US cooperation in the development of Next Generation Internet technologies, services and standards.
- Support the EU internet policy objectives by sharing the EU vision and values with US counterparts and forging bonds through concrete collaborations.

- Support an EU-US ecosystem of top researchers, hi-tech startups / SMEs and Internet-related communities collaborating on the evolution of the Internet according to a human-centric approach.
- Generate new business opportunities and enable the emergence of new business and sustainability models based on Open Source.

Scope: The aim of the topic is to reinforce EU-US cooperation and strategic partnerships in the area of Next Generation Internet, and to establish a continuous dialogue among the actors involved in the US and EU programmes, in particular as far as internet standardisation is concerned. The focus will be on trust and data sovereignty and on internet architecture renovation and decentralised technologies.

A RIA will organise joint projects by EU and US teams on emerging topics for the EU Next Generation Internet and the US Tomorrow's Internet programmes, including technology development, joint demonstrators and joint contributions to standards. Proposals shall foresee twinning with entities participating in projects funded by the US. The project should support open source software and open hardware design, open access to data, standardisation activities, access to testing and operational infrastructures as well as an IPR regime ensuring lasting impact and reusability of results.

Projects awarded under this topic are expected to provide support to third parties, from open source developers, to academic researchers, hi-tech startups, SMEs and other multidisciplinary actors, so that multiple actors are funded and collectively contribute to enhancing EU-US cooperation in the development of Next Generation Internet technologies and services.

HUMAN-17-2022: NGI International Collaboration - Canada (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Enhance EU-Canada cooperation in the development of Next Generation Internet technologies, services and standards.
- Support the EU internet policy objectives by sharing the EU vision and values with Canadian counterparts and forging bonds through concrete collaborations.
- Support an EU-Canada ecosystem of top researchers, hi-tech startups / SMEs and Internet-related communities collaborating on the evolution of the Internet according to a human-centric approach.
- Generate new business opportunities and enable the emergence of new business and sustainability models based on Open Source.

Scope: The aim of the topic is to reinforce EU-Canada cooperation and strategic partnerships in the area of Next Generation Internet, and to establish a continuous dialogue among the actors involved in the Canadian and EU programmes, in particular as far as internet standardisation is concerned. The focus will be on trust and data sovereignty, in particular digital identity, and on internet architecture renovation and decentralised technologies.

A RIA will organise joint projects by EU and Canadian teams on emerging topics in the area of Next Generation Internet, including technology development, joint demonstrators and joint contributions to standards. The project should support open source software and open hardware design, open access to data, standardisation activities, access to testing and operational infrastructures as well as an IPR regime ensuring lasting impact and reusability of results.

Projects awarded under this topic are expected to provide support to third parties, from open source developers, to academic researchers, hi-tech startups, SMEs and other multidisciplinary actors, so that multiple actors are funded and collectively contribute to enhancing EU-Canada cooperation in the development of Next Generation Internet technologies and services.

Section: New digital interactions, 3D, augmented and virtual reality

[Expected impacts addressed: #15 (Green), #18 (Digital and emerging enabling technology sovereignty), #20 (Human-centred)

Objective: gain industrial leadership in digital interaction, while ensuring the European values of privacy, ethics and inclusiveness.

Current status: Due to its low presence on the consumer electronics producing market, Europe is increasingly dependent on external providers for its digital services. This raises concerns about its digital sovereignty in crucial domains such as digital interaction services that are being adopted by a growing number of European users and industries.

Achievements sought / targets:

Europe becomes the world leader in interactive **applications in key sectors** such as healthcare, manufacturing and education, cultural and creative industries, with systems meeting European values in terms of use, ethics, privacy and security.

Innovative, secure and, where relevant language-transparent, **immersive and multimodal interactive applications** are available to European citizens for a wide range of societal and industrial applications (i.e. collaborative telepresence, visualisation, 3D and virtual reality experiences, human-machine interaction and cooperation, design, training and learning).

Europe establishes the social science and humanities concepts and methods for a pan-european human-centric development of digital interaction technologies and systems.

Based on user experiences, habits and knowledge, European **conversational systems** work irrespective of languages and make trusted autonomous decisions to solve everyday problems while ensuring meaningful human control and privacy.

Innovative systems and solutions **extend human perception**, understand user intention, and boost the interaction performance so that Europeans can interact equally, safely and seamlessly with each other based on ubiquitous technologies.

Means/links: Take-up of new digital interaction technologies will be supported by R&D actions, delivering scientific excellence and full testing in real-world scenarios. The academic and industrial ecosystem will be reinforced by cross-domains cross-technologies collaborations and coordination at EU level. SMEs in particular will be targeted. A special attention will be given to including social sciences experts, in order to deliver suitable, ethical and safe devices. Most sectors of the economy will benefit, from manufacturing to healthcare, tourism or education or consumer electronics. The development of Digital Interaction applications and services relies on effort in Data, AI & HPC as well as Key Digital Technologies and intrinsically trustworthy digital solutions.]

Proposals are invited against the following topic(s):

HUMAN-18-2021: Interactive Technologies in key industrial and societal applications (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Development of interactive and immersive technologies in key sectors for Europe (manufacturing, healthcare, education, climate, environment, cultural and creative industries), showcases and large scale pilots

Scope: This topic aims to increase the European competitiveness and innovation capacity to foster the adoption of digital interaction technologies in key industrial and societal domains.

The COVID-19 pandemic has caused major disruptions to global economic and societal activities. Companies are struggling to overcome restrictions imposed in the wake of the pandemic to ensure business continuity in production lines and other operations, while searching for innovative ways to be more competitive in a post-pandemic environment.

Social distancing and global lockdown, as well as climate and environmental pressing concerns, have accelerated the development and adoption of interactive and immersive technologies with the goal to boost the productivity of remote and online contactless activities. Examples of such technology adoption include manufacturers who enhance and augment their existing procedures for rapid and collaborative prototyping, reviewing and sign-off or for maintaining and repairing equipment, companies that use augmented and virtual reality to demonstrate their products or to train their staff more effectively and safely, hospitals that deploy devices to remotely treat patients in infectious wards, and universities that teach practical clinical procedures to medical students at home.

However, despite the increasing demand from European industries, businesses and consumers for interactive and immersive experiences, they cannot yet compete on an equal footing with American and Asian corporations in a globalised market.

Proposals should leverage on the maturity and convergence of enabling technologies such as Artificial Intelligence and Machine Learning, Computer Vision and Natural Language Processing for more sophisticated and user-responsive interactive and immersive experiences. They should target at least one of the listed topic of application (manufacturing, healthcare, learning, climate, environment, and cultural and creative industries) and include large-scale testing in real environments. Special attention will be given to including end-users and social sciences experts, in order to deliver suitable, ethical and safe solutions.

HUMAN-19-2021: Ethics, interoperability and impact of immersive technologies (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Coordination, exploration and study of topics of relevance for competitiveness (including SMEs), deployment and end-users acceptance.

Scope: New ethical risks and privacy concerns arise as virtual and augmented experiences become more realistic and immersive blurring the line that separates them from the real world.

Although the applications investigated and developed to date aim to provide benefits to individual and society, digital interaction technologies may also have harmful physical, emotional and cognitive after-effects.

The potential amount and type of information collected, processed and stored by applications based on digital interaction technologies may put individuals at high privacy and security risk.

Interoperability and safety is another major concern for the uptake of digital interaction technologies. The lack of widely accepted standards slows down the development process and increases design and testing costs. Several initiatives are trying to devise the industry standards at a global level; however, European players are underrepresented in such initiatives.

The selected project will help structuring and supporting the interactive and immersive community in Europe by

- devising responsible practices and guidance helping developers and producers of interactive and immersive experiences and applications to respect ethics and privacy values while ensuring the safety of the users;
- defining an European cross-industry code of conduct for digital interaction technologies while encouraging developers and producers to adhere to it;
- proposing new, or adapting existing, rating systems to support users in choosing the right interactive and immersive experiences and applications;
- gathering relevant evidence to help guarantee the respect of the European legal framework on personal data protection, taking into account the complexity and particularities of digital interaction technologies;
- fostering the contribution of European players to the definition of industry standards on digital interaction technologies ensuring interoperability and seamless integration with other relevant systems, technologies and data sources;
- helping to forge a competitive and sustainable ecosystem for the European interactive and immersive technologies industry by strengthening the links and promoting collaboration among the constituency.

HUMAN-20-2021: Next generation conversational systems (RIA with FSTP)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Research activities to drive multilingual and multimodal conversational systems to the next level of context awareness. Activities should contribute to the general understanding of system and user intent, abilities, belief, goals, and emotions, reaching explainable autonomous decisions, whilst ensuring human control, privacy and accessibility.

Scope: Recent advances in natural language processing, the field of Artificial Intelligence (AI) giving machines the ability to understand and derive meaning from human languages, have shown that automatic systems can exhibit **human-like performance** in e.g. machine translation or speech recognition.

Improvements in machine learning have made fundamental technologies such as natural language understanding or large-scale content analysis a reality; chatbots and personal assistants are now part of our daily lives.

Recent progress in AI has also enabled systems to **generalise** from one language to another, from one task to another, from one modality to another. Large pretrained multilingual language models can handle different languages, even with little or no training data. The same models can cover completely different -languagerelated- tasks, like text translation or summarisation, speech transcription, or sentiment analysis. Multimodal models can provide translation through image detection or lips synchronisation for speech dubbing.

Advances in user modelling and data analytics have now reached a level allowing systems to be increasingly **context-aware,** to efficiently support users in their decisions. Search engines for instance, do not only provide answers adapted to a user's recent queries, activities and localisations, but also predict future requests.

Drawing on the above-mentioned recent advances, the proposed projects will develop new conversational systems based on pre-trained interaction models and capable of adapting to a variety of forms of expression/interaction, languages, domains, styles and intent, in line with the context, preferences and abilities of the user, and capable of carrying **genuine human-like interaction.** Beyond supporting under-resourced languages, their work will focus on enabling new forms of interaction, avoiding bias, whilst ensuring accessibility, privacy, transparency and explainability.

Despite increased model complexity, the **efficacy, practicality and cost-efficiency** of the proposed new solutions will open up unprecedented opportunities in a wide range of industrial and societal application areas. Public availability of pre-trained models will foster innovation, jobs, growth and inclusion.

The underlying research will contribute to creating a **vibrant European research community**, i.a. through dissemination activities, standardisation efforts, sharing baselines, models and best practices, open source code, open data, shared tasks, etc.

To reach this level of performance, the new conversational systems are expected to address several of the following points:

- encompass different input and output modalities such as text, speech, touch or sign;
- cover multiple languages with different levels of resource availability;
- cover multiple tasks, such as speech recognition or synthesis, translation, question answering, summarisation or natural language understanding;
- easily generalise between tasks, languages and modality;
- be able to understand the context and derive meaning;
- be able to efficiently model and process content of any size without imposing limitation such as sentence per sentence analysis, document format and style or pronunciation speed and background noise;
- ensure a sufficient level of explainability so as to help understand why particular choices were made by the conversational system;
- allow easy and efficient integration of knowledgerich- resources such as knowledge graphs, dictionaries, structured domain knowledge;
- maximise the broadest accessibility such as by integrating minority speech accent or adapting to user capabilities;
- protect user privacy, for instance, by ensuring that privacy sensitive data are processed on the edge;
- be able to quickly adapt to new domains of applications such as health crises;
- be energy efficient by providing less computing intensive training and implementation protocols and algorithms with equivalent performance;
- actively counteract data bias such as gender or minority balance;
- ensure reproducibility and repeatability of the research;
- propose standards for data and programming interfaces for the new conversational systems and for their components; and
- demonstrate clear and efficient integration paths for the European language technology industry take up.

HUMAN-21-2021: Haptic interfaces (RIA)

<u>Expected Outcomes</u>: Projects are expected to contribute to the following outcomes:

- Research and develop next generation haptics hardware to deliver usable, affordable and sensory portable devices for instantly refreshable full-page interactive tactile displays which enable navigating, reading and editing digital content in both standard braille and tactile graphics format;

- Foster equal opportunities and digital/braille literacy among the blind and visually impaired[49], by enabling and encouraging greater access to haptic technologies as text to speech technologies become ubiquitous;

- Stimulate broader efforts for Europe to become a world leader in developing solutions for this increasing societal need.

Scope: Touch-screen technologies, smartphones and tablets have revolutionised the way in which we access and interact with digital information. Unfortunately current technology does not enable people with visual impairments to access digital information with the same ease and freedom as those without such impairments.

Haptic interfaces are the underlying technology of tactile tools such as refreshable braille displays. Braille displays enable the blind and visually impaired to fully interact and work with digital information in a fashion not available through text to speech technology.

Despite many advances, certain categories of information cannot be rendered using text to speech technologies in a way that is understandable and memorable by the blind and visually impaired. Such information includes technical text, scientific notations, mathematical formulae, computer code, tabular data and their associated graphical representation, as well as photos and images. This means that people with visual impairments can only fully access and interact with a wide range of information and tasks in education, in the workplace, in social contacts and in the digital environment by using braille readers.

Despite the advantages brought by devices such as smart phones or tablets, people with visual impairments have relatively limited ways of accessing digital information. This is becoming a growing challenge as digital content becomes increasingly reliant on graphics, which are particularly challenging to translate. Text to speech technology, such as screen readers and audiobooks, has vastly improved in recent years. However, this technology in itself is not sufficient to enable the visually impaired to be independently literate in a digital world where information is increasingly only available on a screen. Several studies show that braille literacy is directly correlated with academic achievement and employment among the blind and visually impaired, in comparison to those who rely on text to speech technology[50]. Learning and using braille is generally in decline, partially due to the quality of screen readers and partially due to the lack of affordable braille technology enabling full interaction with digital information.

[49] The European Blind Union estimates that there are over 30 million blind and partially sighted persons in geographical Europe.
[50] https://www.indexbraille.com/getdoc/5c914b70-9698-4d82-947e-9f41d1b61aee/the-importance-of-braille

Existing tactile solutions are limited to refreshable braille displays which are bulky and/or prohibitively expensive. In addition to this, they offer a limited reading experience by providing only a single line of characters at a time, making long reads or the presentation of graphics, illustrations or scientific formulae difficult, if not impossible; and their output is considerably slower than an experienced user's ability to read braille. Thus there is a significant need for affordable, portable, usable full-page devices able to convey digital information in both braille and tactile graphics for people with visual impairments.

Key aspects which need significant improvement through research and development include:

- The solution is easy to read, understand, perceive and operate for users with visual impairments. Content is refreshed at an adequate speed and at low noise levels. The solution allows users to input content and interact with the displayed information. It enables users to meet their goals with effectiveness, efficiency and satisfaction.

- The size and weight of the solution are adequate; it can easily be carried around and used while traveling. It should work with Wifi and have a portable power source. The design is reliable, robust and safe and meets the needs and preferences of visually impaired people.

- The solution is interoperable with other ICT devices, including other assistive technologies. It provides open APIs for use by third parties to build on the existing technology/frameworks. It offers standards-based connectivity.

- The solution allows for back-translation of braille or tactile graphics into text or images. It is able to display and switch between text/graphics/braille to enable cooperation between visually impaired and sighted people.

People with visual impairments should be involved in all stages of the research and development; their involvement in validating the solution is a minimum requirement.

HUMAN-22-2022: Strategic scientific excellence in interactive technologies (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Research and innovation in strategic topics for immersive industrial and societal applications, such as collaborative telepresence, visualisation, 3D and virtual reality experiences, human-machine interaction and cooperation, design, training and learning, with a focus on well designed and fully tested scenarios in real-world environment.

Scope: The emergence of smart cities and factories, autonomous cars and homes, intelligent appliances in conjunction with virtual and augmented reality applications are transforming the way we live, work, care, learn, play and socialize. Whilst people, places and objects are being digitized and transferred into the virtual world and placed spatially and contextually, sensors are embedded into our environments and the objects around us. New digital interaction technologies are playing an essential role in this transformation by enabling us to interact naturally and intuitively with digital information in the physical world.

This topic asks for research and innovation proposals to develop and demonstrate novel digital interaction technologies aiming to augment the capabilities of users and machines and to provide seamless and persistent physical-digital experiences, while guaranteeing the privacy and rights of individuals and companies and ensuring safe, secure and trustworthy interactions. Proposals should focus either on:

- devising innovative digital interfaces that take advantage of spatial computing to allow users to interact with real-time contextual information activated by intuitive sensory triggers;
- developing novel multi-user virtual communication and collaboration solutions that provide coherent multisensory experiences and optimally convey relevant social cues;
- improving the robustness, accuracy and semantic understanding of the current mapping and positioning systems, while providing real-time bidirectional synchronisation between models and interactive applications;
- facilitating the exploitation of 3D data acquisition techniques, enhancing its performance while reducing technology costs and providing efficient and scalable encoding, processing, storage and rendering means;
- enabling the construction of compelling context-aware and embodied experiences by providing solutions for the creation of convincing digital avatars and agents, with natural looking and physically realistic behaviours, movements and expressions.

Projects will provide well designed and fully tested scenarios in real-world environment. They will cover at least one of the bullet points above, applied to at least one of the following topics: collaborative telepresence, visualisation, 3D and virtual reality experiences, human-machine interaction and cooperation, design, training and learning.

HUMAN-23-2022: Sectorial conversational systems (IA FSTP)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Development of multimodal and multilingual European human-to-human and human-to-machine communication technologies such as personalised virtual assistants and coaches, chatbots or conversational mediators supporting a wide range of sectors such as health, manufacturing, law enforcement or the cultural and creative industries.

Scope: Different sectors of activity can have different requirements for communication interactions. For some sectors, speech and text cover all their communication requirements, while for others communication can be intrinsically related to context, images, gestures or other modalities.

Conversational systems not only cover a wide array of software applications for **human-to-computer communication** such as virtual assistants and chatbots, they are also essential components of efficient search engines and tactile interfaces. They can also act as mediators for **human-to-human communication** by adapting the content to particular contexts and needs, like machine translation, speech to text or sign language recognition. Conversational systems that have become part of our daily lives already manage to derive human intention from simple utterances, and carry out mundane tasks like changing music or providing directions.

Current advances in natural language processing enable new conversational systems that can efficiently carry **genuine human-like communication,** by combining text and speech with gesture, touch, and gaze. Thanks to the latest progress in machine learning and continuous integration of human feedback, these systems demonstrate a growing ability to reason so as to either support **human decision processes** or provide limited **autonomous decision processes**.

However, to be efficient in **business applications**, conversational systems need to further address the specificities and requirements of the targeted vertical sector(s) reaching new levels of robustness, efficiency and explainability.

The new conversational systems should be developed in partnership with actors from the addressed vertical sectors. The projects should aim for solutions already proven by research and reaching technological readiness levels from 5-8, with focus on actions such as prototyping, testing, demonstration, piloting and integration.

The developed new conversational systems will:

- incorporate requirements specific to the addressed sector(s) such as explainability in the health sector or accessibility in the cultural industries;
- model sectorial knowledge acquired not only from a history of human decisions in a particular domain, but also from already existing structured knowledge supporting decision-making and task execution.
- adequately address a diverse range of modalities (text, speech, touch, images, videos, gaze ...);
- have multilingual and cross-lingual capabilities, with the potential to address the whole EU market;
- cover privacy and security concerns and build trust by providing adequate explanations/arguments, assuring the consistency of the decision mechanism and making the decision mechanism more transparent;
- quickly adapt to the context and incorporate human feedback; and

promote an open collaborative environment for data and programming interfaces standardisation covering a wide area of domains and avoiding narrow de-facto standards established through the usage of limited digital services.

Section: Digital learning technologies, including upskilling of the workforce

[Expected impacts addressed: #15 (Green#18 (Digital and emerging enabling technology sovereignty), #20 (Human-centred)

Objective: The overall objective is to support the digital transformation of education. This Horizon Europe initiative aims at creating a pan-European Digital Education Ecosystem (EDEE), encapsulating research and innovation activities with pedagogical, ethical and societal aspects of education, while also strengthening the SMEs and industry active in the sector

Current status: The COVID-19 crisis has shown how important distance and innovative learning is for society, our children, their parents and their teachers, maintaining social and educational links under challenging circumstances. However, most European schools are lagging behind the latest technology developments even though digital technology has huge, largely untapped potential for improving education and access to education. The crisis showed the numerous opportunities but also painfully highlighted the lack of readiness of some European schools, in terms of equipment, pedagogy and digital skills. The ongoing digital transformation of society also affects all sectors of our lives, and the upskilling of many industrial workers is a necessity to maintain Europe's competitiveness. Emerging technologies (such as Artificial Intelligence, data, blockchain, virtual reality, eXtended Reality or immersive environments) provide numerous opportunities for personalised, innovative, efficient and inclusive learning, for learners of all age and condition.

Achievements sought / targets:

R&D actions under this section will explore, develop and demonstrate the use of innovative technologies in the education sector, through R&I actions.

Europe becomes the scientific and industrial world leader in digital educational solutions, applications and tools based on emerging technologies such as Artificial Intelligence, Data Analytics, immersive and interactive applications, with systems meeting European values in terms of use, ethics, privacy and security.

The education community, including researchers, developers and innovators, technology providers, policy makers and end-users, is mobilised with the aim to share digital educational material and tools, coordinate and exchange best practices.

High value datasets are collected on the use of digital technologies in education, to support evidence-based policy-making and better informing the EdTech industry including start-ups and SMEs regarding the education sectors' needs for digital transformation.

Develop an On-Demand Education Platform for the European School of the Future, providing tools and applications, through FTSP projects.

Host a pan-European Network/Forum involving all relevant actors (educational and training organisations, parents, scientists, SMEs, policy makers and ministries), stimulating the exchange of best practices and developing guidelines for digital education methods and tools.

Means/links:

Links to other clusters: The topics proposed have strong links with other activities in Cluster 4 (e.g. Interactive Technologies) and Cluster 2 (Culture, creativity & inclusive Society).]

Proposals are invited against the following topic(s):

HUMAN-24-2021: Towards personalised and inclusive learning digital tools (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Make Europe the scientific and industrial world leader in digital educational solutions, applications and tools based on emerging technologies such as Artificial Intelligence or Data analytics.
- Provide personalised and inclusive learning, training and upskilling systems meeting European values in terms of use, ethics, privacy and security.
- Develop, apply and test the use emerging technologies, including Artificial Intelligence and Data/Learning Analytics, in education applications.

Scope: Artificial Intelligence and data analytics have the potential to allow for an individualisation and personalisation of learners' learning experiences as well as of their learning pace. They can efficiently support an autonomous training process, what proved to be necessary and useful during remote learning periods such as the COVID19 crisis one.

The goal is to:

- Develop, apply and test the use emerging technologies, including Artificial Intelligence, and Data/Learning Analytics in education applications.
- Take a human-centred and ethical approach, involving end-users, social sciences and humanities experts in the design process, to guarantee the developed solutions meet the needs and requirements of real-world applications.
- Demonstrate positive impacts of using emerging technologies in digital learning and upskilling processes by running large-scale pilots and deployment in digital educational settings (e.g schools, training organisations) and training environments (e.g. of industrial workers or health-care professionals);

Proposals should focus on the further development and demonstration of at least one emerging technology for:

- Personalised learning with a focus on supporting new pedagogical approaches for in-classroom education and encouraging life-long learning

- Inclusive education targeting specific vulnerable groups (e.g. socially disadvantaged persons, immigrants or minority groups, special educational needs students, etc.), address early school leavers
- Upskilling industrial workers or other professionals (e.g. in manufacturing; healthcare)

Projects will provide well-designed and fully tested scenarios in real-world environment.

HUMAN-26-2021: A human-centred digital education (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To address the growing ethical, economic and societal challenges and expectations related to the use of emerging technologies (including artificial intelligence, data/learning analytics, interactive and immersive technologies), for digital learning, training and upskilling;
- To guarantee the highest ethics and social standards at EU level and an improved take-up of responsible ICT research and innovation in the digital education area taking into account human and societal concerns and expectations and European values.

Scope: The selected coordination and support action will

- Follow a highly interdisciplinary approach, to foster networking and collaboration, between various disciplines, particularly between ICT and SSH communities and between a wide range of educational stakeholders (including a for example industry, policy-makers, teachers, parents, students, NGOs);
- Explore attitudes of the various stakeholders, including the research community, technology providers and educational stakeholders towards the use of emerging technologies in digital education and its ethical implications, and draft recommendations for future research and deployment of digital learning systems;
- Identify the necessary elements that could best support the R&I community in integrating European values and the ethics dimension into their research protocols for digital education, by producing guidelines to ensure ethics by design, to propose a code of responsible conduct for researchers in academia and industry in this area, and assess the possible need for dedicated legislation at EU level.

HUMAN-27-2021: Workforce skills for industry 4.0 (RIA)

Targeted Outcomes: projects are expected to contribute to the following outcomes:

- A quantitative and qualitative assessment of the nature of job transformations in the context of the 4^{th} industrial revolution, estimating and mapping the emerging occupations. Establishment of an “Industry 4.0 platform” for future skill requirements improving the critical understanding of the ‘black box’ of new jobs creation;

- guidance and recommendations, including avenues for new learning and training systems, for policy-makers, businesses, individuals, to reduce the skills’ gaps, to cope with possible unemployment effects, to foster industrial competitiveness while enhancing inclusiveness.

Scope: The 4th industrial revolution, has been associated with production efficiencies, cost reductions, streamlined labour requirements and business model adaptations. However, this is accompanied with social, economic and organizational challenges such income inequalities, public perception for job quality and scarcity, legal issues and data security. The RIA will investigate the social and economic impacts generated by emerging disruptive technologies (artificial intelligence & machine learning, block chain, big data, internet of things, 5g, etc..), robotisation and digitalization on labour markets and business models by means of a multidisciplinary approach in social sciences and humanities (SSH). They will explore innovative methodologies in redefining work activities and automatable tasks also through an historical comparison with previous eras.

Furthermore distinctive learning trajectories and training paths will be identified for both STEM and soft skills, including combined public-private learning ecosystems, skills taxonomies will be developed in order to monitor track changes in the demand that are continually challenged by technological progress, thus contributing to close unintended skill gaps and unemployment spill-overs.

HUMAN-28-2022: Climate change teaching in the digital age (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To contribute to the EU Green Deal objective by helping students building up fact-based and scientific knowledge on sustainability topics including climate change and biodiversity through deeply immersive learning experiences.

Scope: Projects will make use of immersive technologies (virtual and augmented reality) to develop and test virtual tools supporting the teaching of issues related to climate change and biodiversity. Immersive technologies (e.g. virtual reality or augmented reality) can simplify complex instructions through visual instructions and provide individuals embodied experiences remotely.

Projects will for example:

- Provide visualisation and simulation tools, complemented by educational modules, based on scientific climate and environmental data

- Develop serious immersive games about climate change and biodiversity

- Offer collaborative platforms for knowledge and ideas exchange, for leaners and teachers

Projects are expected to be highly multi-disciplinary involving IT specialists, climatologists, pedagogical experts. The developed systems will be fully tested, involving a large set of end-users (students, teachers, youngsters).

HUMAN-29-2022: European platform for digital education and learning (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- To mobilise the whole education and learning communities across the entire European Union to ensure a scientific and technological leading position for Europe in educational technology solutions
- To support the development, testing and take-up of digital tools for learning in Europe

Scope: The selected project will create an on-demand European digital education platform for the European school of the future with the aim to:

- Provide access to teachers, students, parents and school administration to multi-lingual reference platform where they can find educational solutions appropriate for their educational needs.
- Build a focal point where the EdTech community (including SMEs, start-ups, companies, academia/research community) can share/market their existing digital educational solutions, including those developed in the context of EU funded projects;
- Further support digital start-ups, SMEs and industry active in the sector through "'Financial Support for Third Parties" actions allowing them to further advance early prototypes of an educational solution to a market-ready product, with the overall aim to populate the on-demand education platform;
- Build upon and link to existing relevant initiatives, including for instance existing platforms, catalogues or repositories;
- Gather user requirements where the needs of the various types of potential users of the platform are represented;
- Reach out to potential user groups through awareness-raising and communication activities to boost the use of the platforms.

The project will be populated with FSTPs and smaller projects such as:

- FSTPs or projects for fully tested and ready-to-deploy digital learning solutions/apps

FSTPs or projects including Mini-Piloting projects/schools to be used for user-tests/examples/communication

HUMAN-30-2022: European digital education and learning: status, challenges and opportunities (CSA)

Expected outcomes

- To better inform EU and national policy makers regarding the use of digital technologies in primary and secondary education in time of rapid technological developments, the need for distance learning due to the Covid-19 crisis and a shift in Member States education policies putting more and more emphasis on digital education

- To better inform the EdTech industry including start-ups, SMEs and larger companies regarding the education sectors' needs for digital transformation.

Scope:

- To collect comprehensive and high-value up-to-date data on the use of digital technologies in primary and secondary education at EU level in a coordinated way, following up on the results of two precedent iterations of the European Surveys of Schools: ICT in Education ESSIE1 and ESSIE2;

- To harness a wide range of new data related to: connectivity, use of ICT in educational settings, uptake of key skills in schools (media literacy, critical thinking, digital skills, online risks); educators' and parents' awareness and behaviour in relation to ICT, key policies such as awareness in relation to disinformation online, integration of AI in educational curricula, etc.

HUMAN-31-2022: Green skills and training needs for a just transition

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Identify, along with relevant stakeholders, "green skills", defined as those needed to underpin the ongoing and upcoming green transition of the economy to climate neutrality by 2050, with a particular focus on those that are in shortage;

- Devise and test scalable (through ESF+) trainings to endow the labour force with the green skills that are identified as in shortage;

- Where possible, such trainings should be designed with a particular focus on the needs of workers that are at risk of becoming redundant due to structural transformations related to the green transition or whose task profiles are expected to change significantly, or currently unemployed people.

Scope:

- Projects may focus on the overall labour market, or on the needs of specific sectors. In the latter case, they should build on the existing sectoral blueprints for skills where available (introduced in the 2016 New Skills Agenda for Europe, and gradually rolled out for an increasing number of sectors);

- Projects should have a clear strategy for identifying the effectiveness and efficiency of the proposed training, for instance by using experimental designs with a treatment and a control group or quasi-experimental approaches. Creative uses of case studies or observational data may also be accepted, if common pitfalls to the interpretation of results from such analyses, such as self-selection of training participants, are adequately addressed;

Projects should anticipate questions related to the scalability and dissemination of the resulting output, for instance by involving suitable stakeholders.

HUMAN-32-2022: Reskilling for the unemployed

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Devise and test trainings to allow unemployed people to reenter the labour market, considering both the effectiveness and the cost-efficiency of training offers, with a view to providing evidence of how to best achieve upward convergence in the training participation of the unemployed in the EU Member States;
- Research suggests that the heterogeneity of starting points and corresponding learning needs, as well as preferred learning styles, is even greater among adult learners (compared to initial education). Projects should focus on the question of how training offers for the unemployed should best address this heterogeneity, for instance through guidance offers or by using the potential of modular online or blended learning offers that allow for a more individualized/targeted training provision. The benefits of improved targeting may for instance materialize in the form of (i) greater effectiveness in bringing unemployed participants into employment, (ii) greater efficiency/cost-effectiveness by achieving the same result with less resource input, and/or (iii) higher satisfaction & uptake of training among potential participants due to increased respect for individual needs and expectations.

Scope:

- Projects should have a clear strategy for identifying the effectiveness and efficiency of the proposed training, for instance by using experimental designs with a treatment and a control group or quasi-experimental approaches. Creative uses of case studies or observational data may also be accepted, if common pitfalls to the interpretation of results from such analyses, such as self-selection of training participants, are adequately addressed;

- Projects should anticipate questions related to the scalability and dissemination of the resulting output, for instance by involving suitable stakeholders.

Section: Cross-cutting topics

[This section is intended for activities that cut across the areas of intervention of the Cluster, and which place a particular emphasis on human-centred developments. It will include, for example, business intelligence and valorisation (especially in the context of resilience); societal engagement; contributions to the development of skills; and general coordination and support actions.

Valorisation of European R&I and data to address industrial and societal challenges: Contribute to prosperity and well-being in Europe through increased valorisation of excellent research results and innovation, i.e. transforming R&I into sustainable solutions with economic and social value. Contribute to engaging citizens and bringing together the supply and demand side (joining technology push and societal pull) to ensure the uptake of results. This further ensures that the solutions developed, including through technological and non-technological innovations, are socially acceptable. The orientation for topics also contributes to promoting a new agenda for industry-relevant skills and standardisation (see Specific Programme HE).

Innovation driven by European strengths in cutting-edge technologies and creativity: Strengthen and accelerate technology design and deployment across all sectors that emphasise sustainability and centre on human needs and values. Europe must take advantage of its unique assets in culture and the arts to drive an alternative European model to digital innovation.

Precautionary socio- and human centric simulation approaches for testing new and emerging technologies: The narrow objective to improve our simulation capabilities at scale of complex techno-socio-economic systems. The broader objective is to facilitate research at system level where several cutting-edge technologies will interact with each other within wider complex systems. This is different from, but complementary to, more focused secure-by-design or ethical-by-design approaches in individual areas such as Artificial Intelligence. Systems require holistic analysis as interactions of buildings blocks, digital and physical components, human and machine, etc., regularly lead to impacts that cannot be foreseen from the analysis of individual system components (emergent properties of a system). Cluster 4 gathers research topics in many of the relevant components of advanced technology systems, including many enabling technologies (at system level in addition to component level). More specifically, the objective is therefore to research possible ways of making the precautionary principle a regular design principle in the development of new and emerging technologies. In particular, complex interactions and emergent properties of complex systems combining cutting edge technology components shall be investigated and made fit for future use. Research under this objective will increase trust in complex systems and reduce the likelihood of unintended impacts, accidents and failure, and thereby loss of human life, as well as destruction of economic value.

Constant reskilling of workforce: to increase productivity and inclusiveness through skills endowment, while maintaining high employability in Europe, by facilitating transitions to quality jobs (in the twin green and digital transition) and reducing the number of people at risk of becoming redundant in the labour market.]

Proposals are invited against the following topic(s):

HUMAN-33-2021: Awareness raising on Intellectual property (IP) management for European R&I (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Increased awareness among knowledge generators of the importance of the generation, protection, management and use of IP for the development of key technologies and achieving sovereignty in strategic value chains.
- Stronger open innovation ecosystems by providing guidance and best practice examples on how to use the intellectual property.
- Increased and optimised use of intellectual assets to promote innovation with high value to the economy and society.

Scope: The EU's new Industrial Strategy aims for Europe to lead the next wave of technology based innovations, transforming scientific breakthroughs into world leading companies. To achieve technological sovereignty in critical technology areas, the management of intellectual property, from the early stages of the knowledge creation process to the final deployment of solutions, is key.

IP management is considered one of the main challenges facing valorisation of knowledge and research. Better awareness of appropriate IP management enables transforming R&I results into ground-breaking technological solutions, and enhances open innovation ecosystems.

The action will address the need to increase awareness and knowledge on intellectual property management. It will build the bridge between technology generation and technology upscaling via IP management awareness. It will address the knowledge generators, early career researchers, researchers, entrepreneurs in the making etc.

The action will include an awareness campaign as well as specific activities to support research institutions and SMEs on the management and valorisation of IP to demonstrate public value. The action will not overlap or duplicate existing initiatives but should build on them and maximize the impacts well as seek synergies with major European level intellectual property actors.

HUMAN-34-2021: Fostering standardisation to boost European industry's competitiveness (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Reinforcing the links between research, innovation and standardisation ensuring that standardisation is an integral part of the European research and innovation landscape.
- Facilitating the entry to market of innovative solutions, which could address major societal challenges such as climate change and digitalisation.
- Promoting standardisation as an important enabler towards the enhancement of the competitive edge of the European industry.

Scope: As emphasised in the European Green Deal and in the New Industrial Strategy for Europe, developing new standards, coupled with increased EU participation in international standardisation bodies, will be essential to boost industry's competitiveness and build a sustainable future.

This action will identify obstacles hampering standardisation efforts of research generators, develop remedies to the obstacles, and propose solutions to foster standardisation as a means of knowledge valorisation.

The action will create an interface to facilitate networking between the beneficiaries and their national, European, international standardisation bodies for the exploitation and valorisation of EU funded research results, organise trend analysis workshops, and promote the discussion between R&I and standardisation. This interface will be a one-stop-shop for all these related matters.

HUMAN-35-2021: Testing innovative solutions on communities-demand (IA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- **Increased uptake of new technologies and knowledge-based solutions**, achieved through better understanding of societal needs and higher societal acceptance;
- **Increased place-based innovation and experimentation**, through testing of new solutions with SMEs and users, drawing on local characteristics and strengths;
- **Increased innovation capacity across Europe**, through new models of co-creation and exchange of good practises and learning from experimentation, so that innovative solutions are adapted to the needs of local communities.

Scope: This action will promote uptake of research-based technological and non-technological solutions in cities and local communities by strengthening citizen engagement, in line with the European Green Deal's aim "to involve local communities in working towards a more sustainable future, in initiatives that seek to combine societal pull and technology push".

This action addresses the need to accelerate uptake of innovative solutions with citizen engagement in order to achieve the aims of our industrial strategy in a socially inclusive way. It will address needs of cities, regions and local communities to improve citizens' lives by supporting them to match their demand with existing knowledge and innovative responses derived from EU R&I. Synergies with other initiatives including the EIC communities will strengthen its success.

Within the scope of this action is to facilitate testing and experimentation, so that R&I developed in the EU Europe can be tested in the EU, taken up in the EU and, where effective and socially acceptable, scaled up with different programmes and initiatives (public and/or private). The core concept lies in collecting, and then matching, needs of cities and communities with supply of possible solutions from research results, testing the latter in real environments (cities/communities as testbeds) and ensuring benefits for all parts of society.

Cities and communities looking for solutions, which are founded in excellent European R&I and can be tested and adapted to their own needs, will be the beneficiaries of this action, together with the research and business partners involved in the testing and further uptake of the innovative solutions. Beneficiaries may provide financial support to third parties. The maximum amount to be granted to each third party is EUR 60 000. The respective options of the Model Grant Agreement will be applied.

HUMAN-36-2021: Talents-On-Demand: Piloting a new industry-academy knowledge exchange focussing on companies' needs (CSA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Stronger industrial ecosystems through reinforced industry-academy collaboration.
- Enhanced use of the EU pool of talents and skills supporting the EU industry to deliver innovative solutions.
- Upskilling university students for their entrepreneurial and transversal skills by offering early exposure to real business environment and problem solving.
- Increased competitiveness of the European SMEs by facilitating access to knowledge and talents.

Scope: This action will promote industry-academy knowledge exchange focussing on companies' research and innovation needs, complementing university-business collaboration in line with the European Skills Agenda for sustainable competitiveness, social fairness and resilience[51].

This activity will build on already existing instruments in the field of university-business cooperation such as EIT Knowledge Innovation Communities and Knowledge Alliance. Gap analysis of the existing EU instruments in the field of university-business cooperation shows that there is a need for enhancing the support for ad-hoc collaborations focussing on companies' specific needs. This activity will develop and pilot, in coordination with the European Institute of Innovation and Technology (EIT), a standard collaboration module that will support short-term co-creation teams of university students, researchers and companies own R&D personnel to work jointly to solve the company's identified R&I and business challenges.

The Talents-On-Demand co-creation process will be facilitated by a platform through which companies can find the most suitable, skilled and motivated international teams on ad-hoc basis to work together with the company staff to find a solution. The platform will be in charge of matching the company with individuals to form a bespoke and fit-for-purpose interdisciplinary team to tackle the particular challenge in question. Furthermore, the platform will be in charge of the project management for the co-creation teams and provide the teams with professional guidance and facilitation to solve the defined challenges within a limited period of time. Beneficiaries may provide financial support to third parties. The maximum amount to be granted to each third party is EUR 60 000. The respective options of the Model Grant Agreement will be applied.

HUMAN-37-2021: Research on Empathic AI including the arts (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Exploration of synergies between art and AI, where artists' critical reflection, out-of-the-box thinking and a human-centered approach can help inspire new ideas for AI development in the following fields: Health/Aging Society, Urbanism/Mobility, Social Media, Green production & logistics, Space.
- Pilot systems and applications based on empathy (system behaviour and development process oriented on human needs, explainable AI). This will help in accelerating uptake and use of technologies.
- Showcasing the link of AI with human creation, e.g. in music, through a dedicated annual event.

Scope: A key feature of Artificial Intelligence is autonomy and its capacity to learn independently. As this implies opportunities and risks, it must be ensured that AI is and remains centred on human needs. The topic addresses the collaboration of all relevant

[51] COM/2020/274 final

stakeholders in AI and artists though dedicated corporation schemes as part of the STARTS initiative. Beneficiaries may provide financial support to third parties. The respective options of the Model Grant Agreement will be applied.

HUMAN-38-2022: Industry-driven Lighthouse pilot on new cutting-edge technologies including the arts (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Support the next generation of digital technologies, advanced materials and computing, and bio- and nanotech. Stimulate thereby the uptake of digital technologies across selected industry fields: Manufacturing, Mobility/Transport, Urbanism/Urban agriculture and Space/Earth observation.

Scope: Technology development which ignores the needs of humans, societies and the world, remains a key problem. The topic will address how technologists, scientists, users, artists and other creative minds can cooperate for making technologies realistic, experienceable, and responsive to human needs. The topic addresses the collaboration of all relevant stakeholders in industry and artists though dedicated industrial projects as a continuation of the existing STARTS lighthouse pilots. Beneficiaries may provide financial support to third parties. The respective options of the Model Grant Agreement will be applied.

HUMAN-39-2022: Simulation approaches for complex socio-economic systems (RIA)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- Foster research and knowledge capacity in the modelling of technologies in evolving socio-economic systems and their complex interactions of technology, law and economics. This continuous effort will build simulation capacity at EU research institutions and bring down the traditionally elevated cost levels in areas such as large agent-based computational models. As a result the need for real life experiment to produce unintended consequences at the cost of loss of human life or health is reduced. This would also help policy makers to better anticipate the socio-economic second and third round effects from large macro shocks beyond the core sector where a shock originates or impacts (e.g., financial crisis of 2008, Covid19 crisis). In the discussion around new technologies, meso- and macro-scale granular simulation techniques with improve estimates of take up and acceptance by better anticipating interactions both with legacy systems as well as other cutting edge technologies.

Scope: The scope of this topic encompasses multi-agent models that concern strategic interactions of agents in market as well as non-market environments and combinations thereof (strategic market games, strategic social games), and well-specified interactions of those (heterogenous) groups of agents with their physical environment (social games, games against nature). The topic addresses a gap in the market for research where demand for such models is typically high, but competence centers are few in numbers, and modelling costs are typically too elevated for SMEs and most university departments. In terms of methods, this topic will not only allow but indeed require multi-disciplinary teams of researchers, typically covering the areas of computational social science, computer science, statistical physics (modelling of networks), economics and finance, law, behavioural psychology, but can also include researchers coming from ecology, epidemiology, architecture, or operations research.

Other Actions not subject to calls for proposals[52]

[52] The budget amounts are subject to the availability of the appropriations provided for in the general budget of the Union for years 2021 and 2022.

Direct action grants

1. Scientific and technical services by the Joint Research Centre

Administrative Agreement with JRC – GLORIA - Global Research and Innovation Analysis

Extended Industrial R&D&I Investment Monitoring and Assessment Facility

Provision of extended data and analysis for assessing industry's R&D&I investments to achieve 'Green Deal' and Commission's priorities goals, to check fitness of EU companies participating into strategic value chains and to assess technologic and economic competitiveness of EU industries in the areas of green and other technologies.

Expected Impact

This activity will continue the 15-year collaboration of the monitoring of top R&D players (Scoreboards) and build an extended facility around it, expanding the Commission's internal analytical capacities towards the priority goals. This will allow better understanding how the concept of "corporate R&I for sustainable competitiveness" can contribute to the Prosperity policy goal. For this, the EU Industrial R&D Investment Scoreboards will be developed towards a more meaningful tool regarding the directionality of corporate R&D&I.

Scope

The previous monitoring activities already provide a number of indicators on corporate R&D intensity, type of invested technologies and economic strength. The objective of this action is to continue adding indicators and dedicated analyses on investments in R&D&I, technologies and assets, targeting specifically the monitoring of industries that are critical to current policy priorities, such as green or advanced manufacturing technologies.

Indicative timetable: Q3 2021

Estimated budget: € 5 M

Duration: 48 months

Prizes

SPACE-64-2021: CASSINI New Space inducement prizes for disruptive innovations in space technology (Inducement prize)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- The development of technological breakthroughs that can strengthen the EU industrial leadership and keep it at the forefront in the space domain, either by performing in much more efficient/effective ways existing operations or by introducing complete new ones. In brief, theses prizes should award step-change innovations that have potential to transform and evolve the upstream space industry.
- The development of market-ready solutions enabled by one or more EU space technologies that can strengthen the EU industrial leadership and keep it at the forefront in the application of space services/data, either by performing in much more efficient/effective ways existing operations or by introducing complete new ones. In brief, theses prizes should award only major, step-change innovations that have potential to transform/disrupt the downstream segments thanks to the space-based solution.

Scope:

Any sort of satellites & satellite sub-sytems (e.g. new satellite concepts or new subsystems), any space upstream services (e.g. space mining, debris removal & control, space real estate, biomedicine, commercial suborbital space missions, human spaceflight, …).

Any sort of product, service, solution using one - or a combination of - EU space technologies (Galileo/EGNOS, Copernicus) as enabling input with game-changing potential in any downstream – transport or non transport, segment.

SPACE-66-2022: CASSINI New Space inducement prizes for disruptive innovations in space technology (Inducement Prize)

Expected Outcomes: Projects are expected to contribute to the following outcomes:

- The development of technological breakthroughs that can strengthen the EU industrial leadership and keep it at the forefront in the space domain, either by performing in much more efficient/effective ways existing operations or by introducing complete new ones. In brief, theses prizes should award step-change innovations that have potential to transform and evolve the upstream space industry.
- The development of market-ready solutions enabled by one or more EU space technologies that can strengthen the EU industrial leadership and keep it at the forefront in the application of space services/data, either by performing in much more efficient/effective ways existing operations or by introducing complete new ones. In

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Procurements

2. Public Procurement for Business intelligence study on the technological maturity, technologies' market prospects, conditions and market concentration for enabling and emerging technologies

Expected Outcomes:

Intended results of the action in a period of 1-2 years will be a number of data sets, connected indicators and related methodology on the amount and quality of R&D&I that the industry is investing in high potential emerging technologies and KETS for competitiveness and for reaching SDG goals.

Hence, analyses will provide data and conclusions based on comparisons with R&D&I investments by main competitors and based on comparisons with the minimum viable amounts of R&D&I in KETs and emerging high potential techs that are essential to tackle emissions and scarcity of resources.

Overall impact is that based on industry's strengths and weaknesses expressed in the analyses, the R&D&I industrial dimension of competitiveness and sustainability will start playing a much stronger role in all EU policy areas such as industrial policy, external relations, international cooperative research, trade negotiations, etc.

Scope: To collect and analyse data from IP, balance sheets, annual reports, cutting-edge industrial experts and other documentation and any other sources to assess each industry's economic and technologic fitness, fitness of industries' value chains, market share and other related data, and their individual potential (specific indicators) in terms of addressing SDGs and in keeping European technologic and economic competitiveness. Focus will be on particular technologies after consultation with colleagues in the R&I family and after analysis of what are the priority areas that are set in the 'Destinations' in HE and Green Deal Call.

Timing: Q2, 2021

Estimated budget: € 1 M

Duration: 48 months

3. Public Procurement - Extended Industrial R&D&I and Technologies Investment Monitoring and Assessment Facility

Provision of extended data and analysis for assessing industry's R&D&I investments to achieve 'Green Deal' and Commission's priorities goals, to check fitness of EU companies participating into strategic value chains and to assess technologic and economic competitiveness of EU industries in the areas of green and other technologies.

Expected Outcomes:

Intended results of the action over a period of 4 years will be a number of data sets and connected indicators on the amount and quality of R&D&I that the industry is investing in green techs and other critical industries addressing environmental, competitiveness and inclusiveness capacity targets.

Overall impact is that industry's technology proficiency as shown in the analyses would start playing a much stronger role in all EU policy areas such as industrial policy, external relations, international cooperative research, trade negotiations, FDI, etc., providing impact on the EU general level of competitiveness, sustainability and inclusiveness.

<u>Scope:</u> Activities in the topic will build on a previous line of preliminary data and analyses provided for under the GLORIA II administrative agreement with the JRC. The activities will include a more in-depth analysis of the take up, use and provision of green technologies by industries involved in green and other technologies and of their systems as well as of in general more in depth analyis in other technologies. The activities will as well include, for example, building synthetic indicators to measure the importance of industries overtime impact respectively on SDGs and on economic and technologic competitiveness.

Possible data types for collection and analysis could furthermore include economic, technologic and SDG targets positioning in all sectors of partnerships in green tech areas and related assessment of their level of priority. Possible data types would also include collection of consistent time series in all green technology main areas and calculating a new indicator showing the level of contribution of each green technology industry over time in reaching SDG targets. A similar new indicator to the one for green tech will apply for the priority industries that are not in the green tech areas.

Indicative timetable: Q3 2021

Estimated budget: € 6 M

Duration: 48 months

4. Public Procurement - Monitoring and assessment of industrial R&D&I investment for SDG targets

Framework contract to support the setting up of a monitoring and assessment facility on industrial R&D&I investment data in the context of the Green Deal/Sustainable Development Goals and in the context of economic and technologic competitiveness of green-tech industries.

The current Industrial R&D Investment Scoreboard already provides a number of indicators and baseline analyses on top actors' corporate R&D intensity, type of invested technologies and economic strength.

The objective of this action is to build up a multiannual facility to extend the analysis to industries beyond the top actors and to add a number of specific indicators and analyses to the baseline ones [that are part of the current administrative agreement between the JRC and DG R&I]. The facility will bring focus on climate and environment relevant industries and technologies and their sustainable competitiveness. Overall, compared to one-off studies, the action will aim for a more systematic, methodology based and continuous monitoring of industrial R&I agendas and investments relevant to achieve the Green Deal goals. The extra indicators will address a more in depth analysis of green tech providers and user companies' economic and technologic competitiveness, innovation networks and value chains, as well as their fitness to address SDGs targets and in general the adoption of sustainable solutions by industry sectors and eco-systems. Based on the above, the action will as well provide dedicated statistical and qualitative analysis of Industrial R&D&I investment in view of addressing evolving policy needs with regard to deploying and measuring impact of R&D&I support actions. Apart from sustainable competiveness issues, analysis will also address strategic autonomy and industrial leadership in value chains and eco-systems relevant for achieving the Green Deal goals.

Furthermore, for a complete picture, the above indicators will supply more information in particular to measure performance of step-change innovation and emerging KETS, start-ups and smaller companies, and give insight into the market for technologies feeding into the R&D process. As we rely on new and key enabling technologies to address global challenges, also technological sovereignty deserves attention in the analysis of strategic green tech areas and value chains.

Type of Action: Public Procurement - Framework Contract

Indicative timetable: 1Q 2021

Budget: € 5 Meur

Duration: 48 months

5. Public Procurement - Simulation approaches for complex socio-economic systems

Expected Outcomes: Projects are expected to contribute to the following outcomes:

Provide the Commission with a granular social simulation tool to assess the impact of changes in consumer rights and fundamental rights. The agent-based computational model approach provides unique opportunities in an area where intangible assets are disproportionately relevant and as a result data from observable market prices will typically not allow the specification of testable research hypothesis. The artificially created environment of multi-agent simulation tools can step into this void and fill the gap. The Commission will benefit from this tool for the assessment and ex-post evaluation of changes in individual rights in strategic market and non-market settings. (This item is linked with HUMAN-39-2022 and shall receive 20% of the overall budget provided for this type of research activity.)

6. Public Procurement - EGNSS Evolution: Mission and Service related R&D activities

The objective is to study potential new services, as well as the enhancement of already defined services, answering to new user needs and determine whether and how the EGNSS mission of Galileo and EGNOS shall be enlarged or complemented to answer these new user needs. This includes the preparation of contributions and technical analysis supporting the EU position in multilateral and bilateral working groups and meetings.

Actions under this area will cover the assessment of services improvements and of new services or capacities to be introduced, justifying the need, developing the service concept including with international partners when relevant, assessing costs to the programme versus benefits to users and defining the roadmap of activities until an operational service could be provided.

Type of Action: Public procurement

Indicative budget: EUR X million from the 2021 budget and EUR Y million from the 2022 budget

7. Public Procurement - EGNSS Evolution: Operation and service provision related R&D activities

To design and validate the provision scheme of new services, the development of service demonstrators for EGNOS and for all services of Galileo (including PRS) will be required. Service demonstrators enable early simulation of new service concepts at early stages of maturity, supporting the definition of the mission requirements. These activities will contribute to the decision of whether to implement a new service, providing initial feedback from future potential users on the various options considered and on the service provision requirements. In addition, the improvement of the complex operations is essential to improve the performance of EGNSS services. Likewise, maintenance activities must be subject to a continuous improvement process to guarantee the service continuity.

Actions under this area will cover the development and use of service demonstrators to consolidate the future EGNSS services, the optimization of the operation schemes using advanced dynamic strategies (e.g. machine learning) for Galileo constellation / system management for the efficient and continuous provision of the full portfolio of Services in EGNOS and in Galileo, and others.

These activities will be implemented by GSA under the FFPA between the Commission and GSA.

Type of Action: Indirect management by GSA

Indicative budget: EUR X million from the 2021 budget and EUR Y million from the 2022 budget

8. Public Procurement - EGNSS Evolution : Technology and infrastructure-related R&D activities

Actions under this area will cover the maturing of the existing technologies and the development of new and emerging technologies, the engineering activities for the further evolution of Galileo and EGNOS existing systems, technical studies for the assessment of exploratory system concepts and/or responding to new mission needs and a changing environment, the development and maintenance of state-of-art system tools and technical test-beds, the implementation of actions agreed at Programme level to reduce the dependence of the supply chain on non-EU markets, the definition, design, development and implementation of experimental satellite demonstrator, and others.

These activities will be implemented by ESA under the FFPA between the Commission and ESA.

Type of Action: Indirect management by ESA

Indicative budget: EUR X million from the 2021 budget and EUR Y million from the 2022 budget (including ESA remuneration costs).

9. Public Procurement: organising CASSINI Prizes for Innovative Solutions

• Prizes awarded for initiating new market opportunities for innovative (EU space) data/service based applications

• Provide public and private end users with user-friendly solutions

• Create business and societal impacts and benefits

• Increase the overall value of the space programmes Copernicus and Galileo by developing innovative downstream applications.

- Encourage SMEs and innovative entrepreneurs/organizations to invest in Copernicus and EGNOS/Galileo based applications and foster pan-European space-based downstream entrepreneurship.
- Increase the use of Copernicus data and services and EGNOS/Galileo services, notably by raising awareness of Copernicus/EGNOS/Galileo in new geographical areas and user communities. Special efforts should be dedicated to building strong links with the ICT community (i.e. Information and Communication Technologies, such as big data, augmented reality, artificial intelligence or the Internet of Things).

10. Public Procurement - In Orbit Demonstration/Validation (IOD/IOV) service

To ensure EU non-dependence and competitiveness in technologies, there is a clear need for a regular, sustainable, cost-effective and responsive In Orbit Demonstration/Validation (IOD/IOV) service in EU. Space flight heritage in real conditions and environment is often required to de-risk new technologies, products, concepts, architectures, services and operations techniques be that it for unique or recurrent, institutional or commercial missions.

Intended results of the action is to provide a service service for regular aggregation and/or launch and operations in orbit for IOD/IOV experiments; the objective is to have at least one opportunity every year all through Horizon Europe implementation period. This will contribute to reduce the time to market or operational use of new technologies, products, concepts, architectures, and operations techniques.

The IOV/IOV activities intends to provide regular and cost-effective service and solution for common flight ticket actions (management, spacecraft design including reuse of existing solutions, assembly, integration and tests, launch and operations) based on EU solutions both for the spacecraft (i.e. platform, experiments aggregation, operations in orbit including preparation and associated Ground Segment) and for the launch services.

The actions will be selected through a call for expression of interest for IOD/IOV experiments, an analysis of the results in regards to a set of criteria (e.g. technical fit, policy relevance, programmatic fit, complementarity with other existing/planned actions) and if necessary by a preliminary feasibility. To be noted that the selected IOD/IOV experiments shall develop their own experiment up to and including the flight model, in another framework than this IOD/IOV service.

The scope of the activities includes mission design, integration and implementation, for all the necessary tasks to prepare, provide and operate spacecraft(s), together with the related ground segment, which accommodates the selected IOD/IOV experiments as well as the associated launch services.

For the aggregation and operations, the activities include:

- System studies, at ground and space level, including the compatibility with the available launchers;
- Input to the launch mission analysis performed by the launch service provider;
- Selection, assembly, integration and testing of the spacecraft(s) and related ground segment;
- Management of interfaces with and between the different IOD/IOV experiments, between the spacecraft and the launcher and between the spacecraft and the ground segment;
- Preparation of the spacecraft(s) for the flight;
- In-orbit testing and operations including data provision.

Concerning launch aspects, IOD/IOV activities shall support the European launcher exploitation policy, therefore relying on EU manufactured launcher solutions. The actions will include the provision of flight opportunities with EU manufactured launchers which encompass the mission analysis, the verification of interfaces between the spacecraft and the launcher, the preparation of launch campaign and the flight up to the injection of the spacecraft(s) on the required orbit(s).

<u>Indicative budget</u>: EUR X million from the 2021 budget and EUR Y million from the 2022 budget.

Other budget implementation instruments

11. Expert Contracts for New indicators for the Green Deal and EU industry sustainability and competiveness

Expected Impact

Intended results of the action over a period of 4 years will be a number of data sets and connected indicators on the amount and quality of R&D&I that the industry is investing in green techs and other critical industries addressing environmental, competitiveness and inclusiveness capacity targets.

Overall impact is that industry's technology proficiency as shown in the analyses would start playing a much stronger role in all EU policy areas such as industrial policy, external relations, international cooperative research, trade negotiations, FDI, etc., providing impact on the EU general level of competitiveness, sustainability and inclusiveness.

Scope

Striving for a climate-neutral economy/Europe 2050 requires a new set of data to plan, monitor and evaluate the effectiveness of policy measures and industrial investments in R&D and innovation.

While the Industrial R&D Investment Scoreboard provides data on 2500 R&D leaders worldwide and 1000 in Europe, it does not include data on investments into R&D and innovation for decarbonisation, climate mitigation or other sustainability aspects. It also lacks indicators for industrial R&D&I competitiveness, which however we will need on a systematic base to inform policy as well as industrial decisions.

Type of Action: Individual Contractual Experts and/or Group of Experts [Not concerned by Decision C(2016)3301]

Indicative timetable: 1Q 2021

Indicative Budget: € 1 M

Duration: 48 months