Electronic Components and Systems

Multifunctional integration

Overview and initial priority settings

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Integration in short

Electronic Components and Systems

Multifunctional Electronic Smart Systems solving the needs of different application domains require the **physical and functional integration (with monolithic and hybrid trade-offs) into a given realization or platform (e.g. chip, board, package) of a set diverse HW (and SW) components, which in turn may require the recursive integration of materials, processes and subcomponents)**

Integration is the way to harness complexity and heterogeneity not only at system level but even at component level:

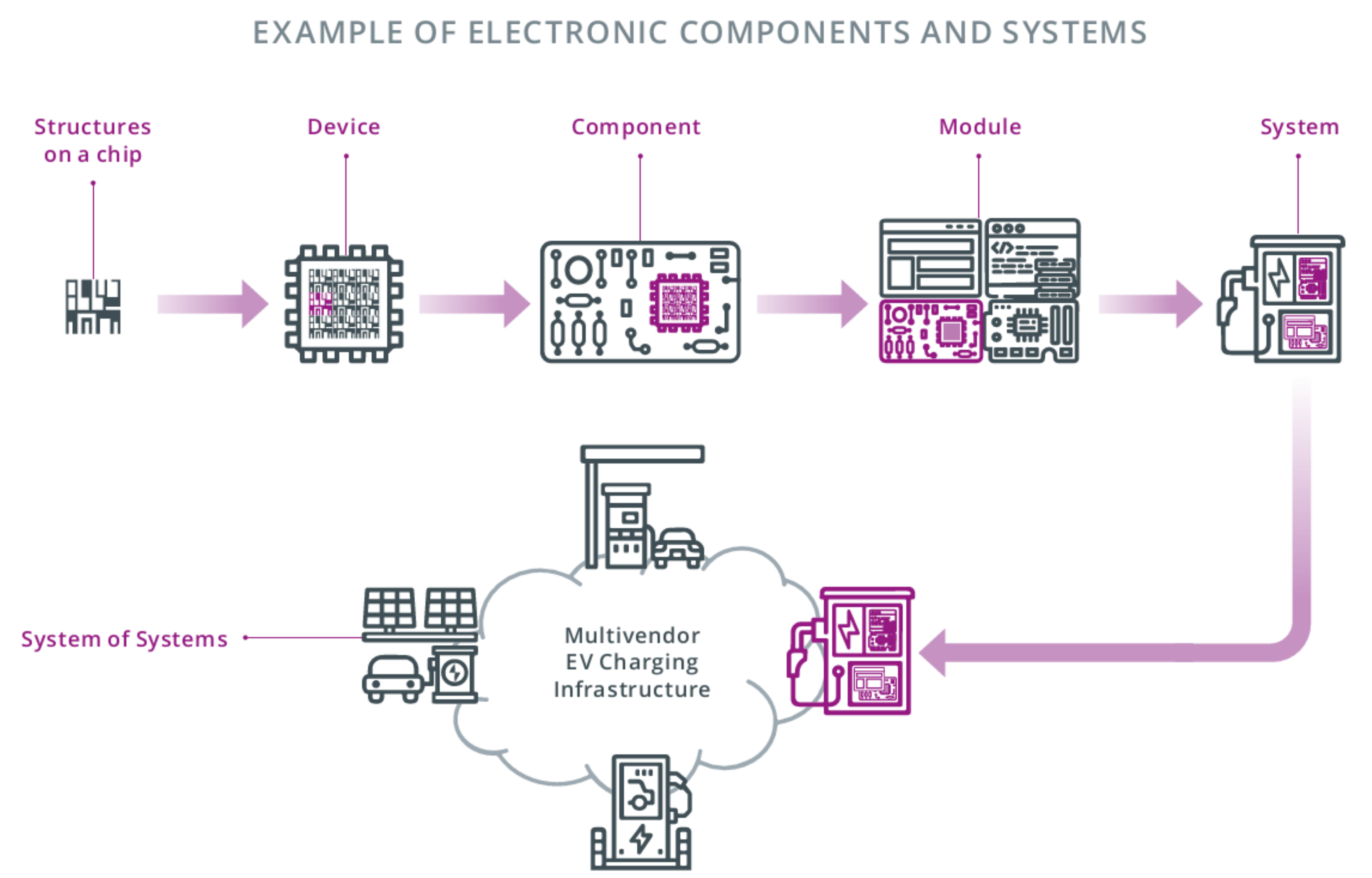
- **Component level:** advanced components are currently a natural integration testbed of novel materials and concepts.
- **Module/ System level:** Heterogeneous integration of diverse elements (electronic or photonic in nature) providing physical-to-digital transduction, communication, power, local information processing in SIP/hybrid platforms (including flexible) with appropriate internal and external interconnection schemes allowing robust, reliable, cost-effective, resources and power efficient operation, and deployment in accordance to environmental application constraints

Integration in many hierarchical levels

Integration is the art of combining physical devices, components and systems together to form a new entity with increased functionality.

Elements are integrated (sensors, actuators, fluidics, power sources, information devices, SW, communications, etc.) by means of **appropriate technologies** so that **new functionalities are enabled** (energy autonomy, smartness, self-monitoring & calibration, human-system interfaces, security, etc.)

The ECS SRIA covers all **ECS integration aspects** including **MNE, MEMS**, **flexible electronics and integrated photonics** (both as enabling technologies for device / component / system fabrication and assembly, and as potential integration platforms themselves).



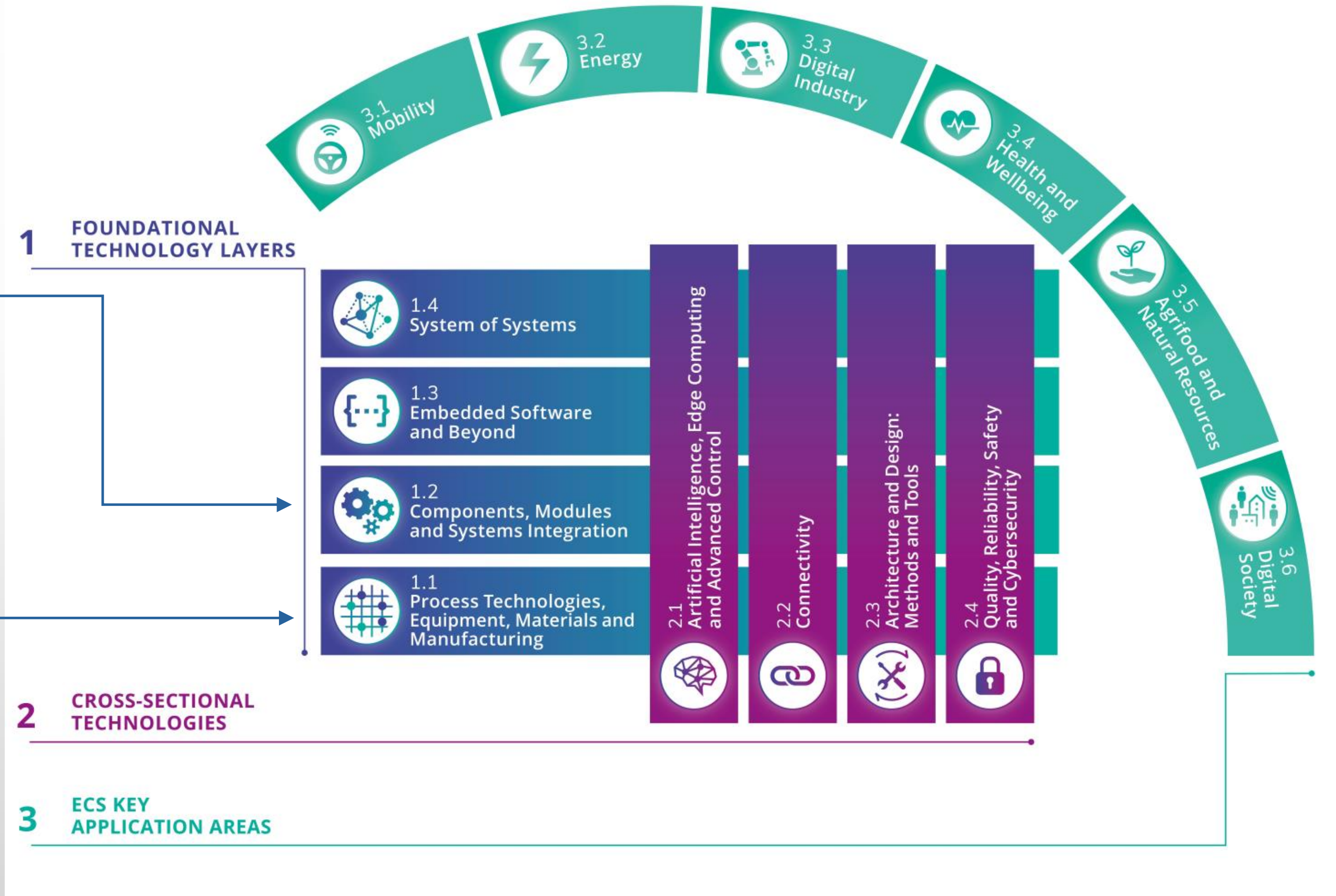
Multifunctional Integration in ECS-SRIA 2021

1.2 Component, module and system level integration technologies

1.1 Wafer level and SiP Integration technologies

2.1- 2.4 Technological links and boundary conditions

3.1 - 3.6 Application requirements



Multifunctional Integration Priorities

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- **Major challenges in technology development**
  - Advanced heterogeneous integration and packaging solutions
  - Physical and functional integration
  - Materials
  - Technologies, manufacturing and integration processes
- **Cross-sectional needs & contributions**
- **Application-specific integration needs**

1.1: Advanced heterogeneous integration and packaging solutions

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Scope

- Advanced heterogeneous integration to include new functionalities in SiP
- Advanced packaging and interconnection methods to bridge the scale gap between wafer dies of various technologies and printed circuit boards (PCBs)

Goal

Enable new solutions for the digital age and to ensure industrial competitiveness and European sovereignty

PRIORITY

Novel systems with advanced logic

(Heterogeneous / 3D) Integration with advance memory/logic circuits for Ultra-low power technology

PRIORITY

Advanced interconnect, encapsulation and packaging technologies

Vertical and horizontal integrations, TSVs;
Fan-out WLP;
Chip embedding;
Wafer-stacking;
Chiplet technology;
Thermal management in packaging;

PRIORITY

3D integration technologies.

3D integration density improvement;
Chip-package-board co-design.

PRIORITY

Specific power and RF application technologies

RF Miniaturization for millimetre wave and THz applications;
Functional integration for package, e.g. antennas, passive components;
Packaging of wide-bandgap materials, SiC and GaN;
Cryogenic packaging for quantum tech.

PRIORITY

Enhanced reliability, robustness and sustainability technologies

Testing of separate components before integration;
Built-in self-test

1.2 MC 1: Physical and functional integration

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Scope

- Development of new elements and methods that enable more functionalities to be integrated physically on components, modules and system levels, in the smallest feasible space

Goal

Build and boosts industrial competitiveness through interdisciplinary technology innovations

PRIORITY

Sensing, imaging and actuation

Integration for and of multifunctional sensors, such as MEMS/NEMS; MOEMS;
Photonic sensing; Imaging systems; Lidar/ Radar;
Selective gas-sensing; fluidics;
Disease monitoring and diagnostics platforms (in vitro, wearables);
Quantum technologies;

PRIORITY

Communications

Real-time, low-latency;
Photonics communications;
EMI;
Enabling 5G, 6G connectivity;

PRIORITY

Energy and thermal management

Energy harvesters
Energy storage devices
Low/zero power approaches
Thermal management at different integration levels incl. advanced and active cooling systems

PRIORITY

Information processing

Security and privacy;
Explainable AI, edge computing (SW and HW);
Hybrid modelling (physical and data-driven);
Integration for quantum computing;

1.2 MC 2: Materials

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Scope

- Development of new materials and new ways to use materials to support the needs of advancing integration
- Ensure best knowledge of materials is available for designers and reduce the use of hazardous or critical materials

Goal

Enhance the performance of systems for the Digital Age

Enable and ensure sustainable and green ECS industry

PRIORITY

Bulk materials

Functional materials (piezo, ceramics, polymers, glass, meta-materials);
Organic and biocompatible materials;
Compostable and biodegradable materials;
Materials enabling recycling and repair;
Replacement materials to comply with RoHS and minimize critical raw materials (CRM) dependence;
Photonic materials
Materials for flexible and stretchable electronics;

PRIORITY

Material properties

Enabling better material parameters information for design;
Database for simulation and reliability;

PRIORITY

Surface materials

Protective coatings;
Functional thin films;
Replacement materials to comply with RoHS and minimize critical raw materials (CRM) dependence;
Photonic materials;
2D materials, materials for quantum;

1.2 MC 3: Technologies, manufacturing and integration processes

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Scope

- Development of integration technologies, processes and manufacturing capabilities to enable more complex systems to be manufactured in a cost-efficient and agile manner
- Integration technologies for hybrid and heterogenous approaches critical, not only within a technology branch, but also spanning several domains, such as integration of fluidics and photonics for diagnostic sensors

Goal

Build and boost industrial competitiveness through interdisciplinary technology innovations

PRIORITY

Integration Technologies

Integration for complexity: Embedding of components into several types of substrate;
Integration for and of Fluidics;
Integration for and of Photonics;
Integration for and of Flexible electronics;
Integration for and of Structural substrate / 3D conformable electronics

PRIORITY

Integration processes

(Beyond wafer-level) Heterogeneous integration;
Rapid prototyping;
Integration for harsh environments;

PRIORITY

Manufacturing

Printing, lamination;
Additive manufacturing;
Scalable and agile manufacturing (lot one);
Zero-defect manufacturing;

1.2. MC 4: Decarbonisation and recyclability

Scope

- Reducing the CO_2 foot print of the ECS industry, taking into account the full life cycle
- Enabling recycling and re-use and repair

Goal

To make ECS industry more sustainable and resilient

PRIORITY

Decarbonisation

Decarbonization of ECS industry;
Electrification;
CO_2-neutral production;

PRIORITY

Recyclability

Materials for recycling;
Separation, Dismantling;
Lifecycle analysis;
Use of compostable and biodegradable materials;
Designs for re-use;

These topics will be adressed in more detail in the ECS-SRIA Workshop 3 on ”Green ECS and Decarbonisation on June, 1 2021.

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Cross-sectional needs & contributions

AI, Edge Computing & Advanced Control

Efficient data treatment, added value at minimum energy impact, improved multifunctional systems conception, integration and operations HW to SW.

Becoming one of the top players in the domain of efficient and trustworthy advanced edge computing solutions

PRIORITIES

- **Increasing the energy efficiency e.g.** by the development of neuromorphic chips; by in memory computing; pushing data analysis to the edge; development of efficient learning: only partial relearning required to adapt to a new application; federative and distributed learning; low and ultra-low power communications, materials and electronic.
- **Compatibility, interoperability and scalability;** AI will allow increased efficiency in multifunctional integration and in managing complexity.
- **Scalable and modularity**: Reusability and robustness are primordial to increase recyclability and expand lifetime; use of similar building blocks from deep edge to edge devices; quick implementation and optimization of HW for the new emerging algorithms; common interfaces and standards.
- **End to end trustworthiness**
- **Open Platforms (HW & SW)**

Connectivity

Connectivity is a key enabler in modern ECS systems.

Connectivity and integration for European sovereignty and solutions for the Digital age

PRIORITIES

- **"Plug and play integration"** of ECS into self-organised networks
- Multi-die System-in-a-Package **heterogeneous integration** including appropriate interoperable SW for IoT and SoS connectivity
- Solutions for **millimeter wave integration** with low loss, high reliability.
- **Innovative packaging** and PCB technology targeting connectivity application.

Architecture & Design

Design and test methods, supported by novel architectures and efficient tools for safe, secure, reliable and dependable ECS

Managing new functionalities in evolving, safe, secure, and trustable systems and systems of systems

PRIORITIES

- **Virtual Engineering Support** for future ECS, also supporting multi-functional integration
- Consistent methods and new approaches for (multi-level, multi-paradigm) **modelling, analysis, verification and formalisation** of ECS's operational reliability and dependability
- **Holistic design flows**, including V&V and Test
- **Modelling, analysis, design and test methods for heterogeneous systems** considering properties, physical effects and constraints
- **Functional integration of different models from different sources** that are needed simultaneously in the simulation of an heterogeneous system
- **Connecting the virtual and physical world** of mixed domains in real and simulated environments.

Quality, Reliability, Safety & Cybersecurity

Modern technologies & new digitised services are key to the sustainable growth of the EU and the well-being of its society

Contributing to Europe's sovereignty in terms of reliable, safe and secure electronic devices, and systems

PRIORITIES

- "**HW quality and reliability**" paradigm shift in fabrication and qualification, model-based design across supply chain incl digital twin, availability through continuous monitoring, and unclonable physical functions.
- "**Ensuring dependability in connected software**" The employed connected software components, architectures and technologies will be enriched with dependability for their operation, and resilience to detect in advance if network conditions change.
- Challenge "**Cybersecurity and privacy**" aims to contribute to the European sovereignty plan in terms of cybersecurity, digital trustworthiness and the protection of personal data.
- Challenge "**Safety and resilience**" aims to the development of safe and resilient autonomous smart systems in dynamic environments, including AI.

Application-specific integration needs

ECS
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Mobility

Connected, automated and electrical cars will need more and better sensing.

Multifunctional Integration of sensors for connected, automated, clean and safe electrical mobility.

Precise, robust, highly integrated (photonics-based) sensors & measurement devices to optimize lifetime, safety & performance of automotive components & systems (e.g. battery, fuel cell, inverter, in-vehicle sensors, control units etc.)

PRIORITIES

- **Higher functional (micro/nano) integration** of different sensor components (optical, electrical, magnetic, etc.) including analog and digital signal processing & novel physical measuring effects
- Sensor systems based on **highly robust materials** for applications in harsh environments (e.g. high temperatures)
- **Miniaturized highly dynamic, spatially resolved (2D/3D) measurements** of various variables
- **Hybrid sensors** (combination of real integrated physical sensors and sensor models)
- **Sensor self-monitoring, self-reconfiguration or self-adaptation** (e.g. optimal measuring range)
- **Sensor fusion** to reduce the amount of uncertainty

Energy

Our lives, our daily activities and the way we do business depend on a sustainable energy supply and its efficient management.

Bring intelligence to the grid, for asset management, security, generation and demand management, from the grid edge.

PRIORITIES

- Smart systems for **smart & efficient management** of energy generation, conversion, storage systems and grid integration.
- Smart sensors with improved data processing, stream processing for **real time application**
- Smart, secure edge devices for **secure data management and control**
- Improvements in **robustness** of ECS devices to withstand strong magnetic field changes and temperature fluctuations
- Advanced **packaging solutions for power electronics**

Digital industry

Digitalization keeps being a key factor for the future success of European industry and an enabler of synergies and transformations in different domains.

Improve industrial processes automation, smartness, sustainability, efficiency, safety, interoperability, human centric production, remote operations, training, …

PRIORITIES

- **Exploitation of advancements on sensing and actuation** in robotics and mechatronics for improved system autonomy and system-human interactions
- **Computational Capacity and data security i**n micro/ nano electronics for next generation of manufacturing
- **System solutions for responsive, smart and sustainable production,** to quickly react to changes, efficient work allocation, improve use & reuse of the resources, real life cycle assessment, human in the loop, digital twins, VR, AR …
- **Artificial Intelligence** for production, operations, maintenance, dynamic and autonomous management, asset monitoring, decision-making, edge AI.
- **Exploiting communications for industrial remote and collaborative operations,** with fleet management, edge to cloud solutions as services, telepresence, lifecycle engineering, training and simulation environment**.**

Application-specific integration needs

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Health & wellbeing

P4 approach (predict, prevent, participate, personalize) is reshaping healthcare

Integration of electronic, optical, fluidic and mechanical functionality for Point-of-Care (PoC) and new gently invasive healthcare systems

PRIORITIES

- **Highly miniaturized** electrical and optical systems will enable smart minimally invasive catheters and laparoscopic instruments
- CMOS-integrated low-cost, silicon-based MEMS **ultrasound transducer** technologies is bringing ultrasound diagnostics within the reach of the ECS industry
- **Lab-on-a-chip (LoC) solutions**, embedding multiple sensor platforms, microfluidics and simple processing/ storage elements are the basis for accurate, versatile and friendly portable and wearable PoC devices.
- Merger of highly miniaturised electronic, optical and communications technologies with conventional wound dressing materials will allow the **treatment of chronic wounds** of patients in their home
- Small and **smart implantable neuromodulator devices** wirelessly powered by radio frequency (RF), microwave, ultrasound or energy harvesting will enhance treatment of chronic diseases

Agrifood and natural resources

IoT systems are key for sustainable agriculture practices, natural resources management, preserve biodiversity and restore the planet's ecosystems.

Highly integrated, low power and robust devices including multi-sensors, data analysis and connectivity are a must.

PRIORITIES

- **Food security & safety**: sensing for high-quality monitoring to reduce the amount of water and chemicals used in food production, and to prevent contamination. Diagnostics and monitoring platforms to rapid alert local and regional disease incidence.
- **Environmental protection and sustainable production**: in-situ, real-time monitoring of soil nutrients and herbicides through intelligent and miniaturized sensors with appropriate packaging
- **Water resources**: Connected and high-integrated multiparameter diagnostic sensors for real-time chemical analysis to ensure freshwater and its distribution.
- **Biodiversity restoration, ecosystems resilience, conservation and preservation:** Sensors for environment monitoring of forests and fields as well as CO_2 footprint monitoring and remotely monitor wildlife behaviour and habitat changes.

Digital society

We already live in a digital society, but digitalization is accelerating, and we need to be sure that it is for the benefit of all, sustainable, inclusive and safe.

Individual inclusion, development and protection, towards the collective wellbeing of a resilient and sustainable society.

PRIORITIES

- **Maximize individual development** and protection of citizens: tools, training and connectivity for digital inclusion; online education; HMI & VR; embedded cobots, chatbots.
- **Safeguard the collective wellbeing and resilience** of a society: crowd management; responsible, explainable and trustworthy AI; SW platforms for surveillance, emergency & crisis response; homeland security and cybersecurity.
- **Contribute to environmental sustainability**: IoT and AI-based management of physical infrastructure, industrial areas, traffic and logistics; SW platforms for distributed digital Infrastructure management; mobile e-government and citizen support; resource monitoring.

Key contributions of Multifunctional integration to ECS main objectives

E C S

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Boost industrial competitiveness	Ensure European digital autonomy	Green Deal	European Digital Age
Interdisciplinary technology innovations (incl. Photonics and Flexible Electronics integration)	Secure, safe and reliable ECS	Sustainable ECS value chains	Intelligent and autonomous ECS-based systems
Turn smart into intelligent through AI integration/ application at the Edge	Supporting key European application domains with key components and systems	Decarbonization of ECS industry; Electrification	Novel multi-functionalities of components & systems
Apply and manufacture secure, safe and reliable ECS in EU	Resilient ECS value chains	Mastering the reduction of energy consumption for future ECS	Solutions that work for people (safe & secure)

Summary

Electronic Components and Systems

- **Multifunctional integration** builds and boosts industrial competitiveness through **interdisciplinary technology innovations**, including MNE, MEMS, integrated Photonics and Flexible Electronics etc.
- Create new **multi-functional components & systems** for the Digital age with improved functionalities based on **physical and functional integration** as well as **intelligence at the Edge**
- Support developments of **new sustainable materials, technologies, manufacturing and integration processes** critical for European industrial competitiveness and green manufacturing of ECS
- Master the **reduction of energy consumption** for future ECS through proper design & integration

Enable **European ecosystems** and platforms in **heterogeneous integration** and support industrial access and utilization to these platforms and ecosystems, also for SMEs