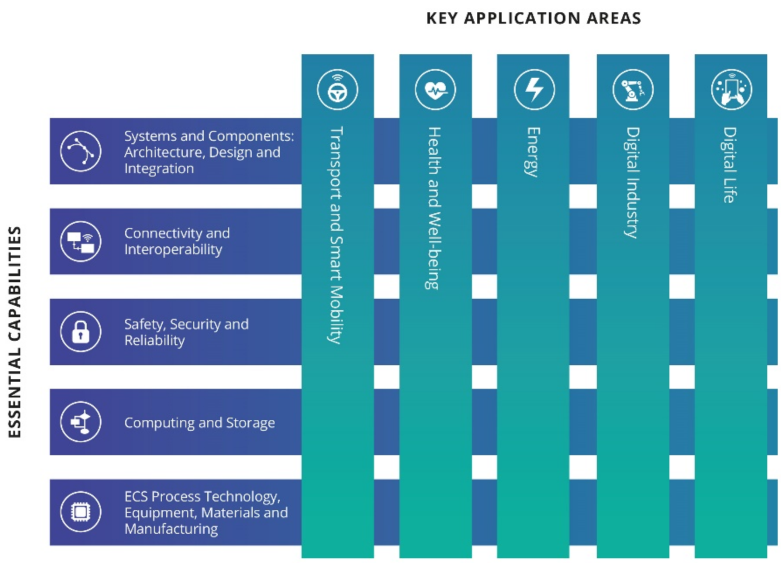
E C S Strategic Research Agenda 2018

# EXECUTIVE SUMMARY

**Chapter 0: Introduction and overview**

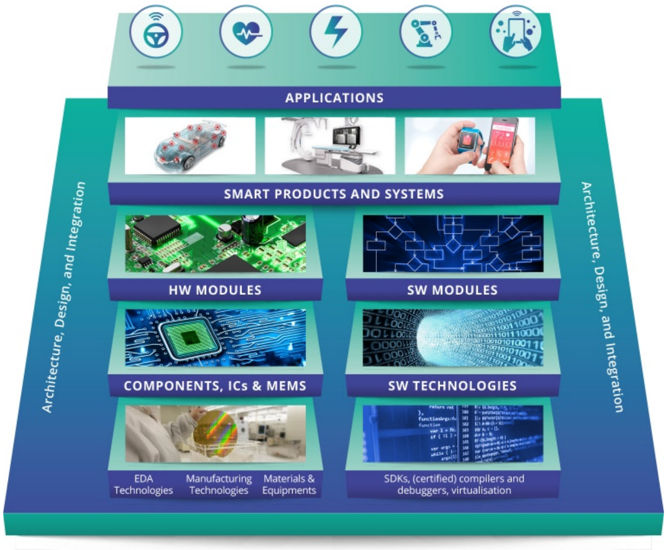
The Electronic Systems & Components (ECS) Strategic Research Agenda (SRA) 2018 breaks new ground. It is the first combined research agenda from the three Industry Associations AENEAS, ARTEMIS-IA and EPoSS that represent large companies, SMEs, universities and research institutes from across the entire ECS value chain. This common framework for Research, Development and Innovation (R&D&I) identifies key application areas, technology challenges and research priorities to foster Europe's transformation into a digital society, and to deliver societal and economic value.




*ECS SRA focus areas*

The ECS SRA incorporates the work of over 250 experts, with each chapter detailing how innovation can bring solutions to European challenges. It is a tool to coordinate R&D&I and funding for technologies that support multiple application areas as well as specific area needs. The SRA also stresses the importance of a harmonized regulatory environment in which Europe's digital transformation can flourish while protecting its citizens, its security and vital natural resources.

Digitalisation is a game-changer. Until recently, the capacity and performance of ECS were largely driven by ever more computing power on ever smaller chips ('Moore's Law'). Now, advances in individual components or systems alone are not enough. In the connected digital world, software and the integration of components and systems into smart systems are key. To do this successfully takes collaboration from all the stakeholders involved. Cooperation between academia, research and technology organisations (RTOs), and industrial partners in hardware, software, components, systems and applications is essential to understand the requirements of the digital world and to develop technologies, products and services that fulfil its needs. Europe is strong in such collaboration, and as digitalisation advances this can be a key competitive asset.




*The electronics value chain*

Besides strengthening its existing world-leading industries, Europe can take the lead in advanced materials, processes, software and disruptive technologies such as Artificial Intelligence (AI), new computing paradigms, photonics and robotics where the competitive landscape is still open. In addition, Digital Industry and technologies such as 3D Printing can bring wider manufacturing back to Europe. Overall, this will ensure the migration of our workforce towards higher value-added activities and retain vital educational resources within Europe.

Given increasing protectionism in global trade and rising cybersecurity threats, autonomy in ECS is crucial for Europe’s sovereignty and its ability to meet growing demand for electronic components, embedded-/cyber-physical systems (CPS) and smart integrated systems. Indeed, as digital technologies expand into every aspect of industry and daily life, ECS hardware and software – in products or as enablers for new services – are the foundations for Europe’s digital future, its prosperity and quality of life.

# PART 1: APPLICATIONS AREAS

**Chapter 1: Transport and Smart Mobility**

Transport and mobility in Europe have much to gain from digitalisation. Enabled by R&I in ECS, Europe can develop multi-modal (road, rail, aviation and maritime) transport systems based on forms of propulsion that are clean, affordable and sustainable (electricity and hydrogen fuel cells). The contributions to European goals, e.g. EC's Strategic Transport and Research Innovation Agenda[1], could be significant: 70% of infrastructure and vehicle technology could be emission and $CO_2$ free. Embedded intelligence in vehicles and infrastructure could prevent deaths and severe injuries in accidents and drastically reduce congestion.

Twelve million people are employed directly or indirectly in European transport and car manufacture. The sector contributes 16% to GDP. Europe is a world leader in the automotive industry. ECS innovation is key to maintaining this position at a time of profound change. Besides competition in conventional car-making, US technology companies (e.g. Google) are entering the automotive market because the challenges are no longer mechanical. Software, AI and machine learning running on embedded electronic systems will be the enablers for affordable, automated mobility that gives freedom to all, from the growing population of older citizens to those with specific needs.

Combined with technologies such as sensors, power electronics and connectivity (in and between vehicles, and with surrounding infrastructure), automation enables: advanced driver assistance systems (ADAS) and self-driving vehicles; smart traffic management; digital car sharing platforms; energy efficiency; greater comfort inside vehicles; and improved logistics. These will free up space in our cities, simplify journeys of every kind, and reduce environmental impact.

A transformation of such interconnected complexity cannot happen without collaboration among stakeholders[2] – the ECS and automotive, train, aviation and transport sectors; but also regulators, insurers, public transport, digital platform operators, and the public. Testing and integrating automation and electrification alongside today's vehicles and infrastructure will themselves be huge challenges, but social acceptance will be built on safety, security and reliability as well as convenience (Chapter 8).

**Chapter 2: Health and wellbeing**

As Europe's population continues to age, pressure on healthcare grows. For many Europeans, simply getting to see a doctor is becoming difficult. Spending on electronic systems and components for healthcare represents a small percentage of Europe's of health budgets. Yet, the technologies they enable could transform healthcare to meet the demographic challenge *and* stabilize costs for European economies at 10% of GDP.

Innovations in areas such as imaged guided interventions, biomedical science, AI and low-power electronics – available within the next decade –provide opportunities for a fundamental shift in healthcare. Care can move from hospitals to homes and be more focused on individual patient needs. Diagnosis will be faster; treatments more effective. Rapid analysis of massive data sets will support personalized medicine. Wearables and automated implanted medical devices powered by long-life batteries or energy harvested from their

[1] EC STRIA (http://ec.europa.eu/programmes/horizon2020/en/news/towards-strategic-transport-research-innovation-agenda-stria); Mobility4EU Action Plan for Future mobility (https://trimis.ec.europa.eu/project/action-plan-future-mobility-europe)

[2] As facilitated by Mobility.E, the ECSEL JU Lighthouse Initiative (https://www.ecsel.eu/lighthouse-initiatives) on safe, electrically powered, intelligent vehicles

surroundings will bring care into the home. Prevention can become the driving force, with people empowered to be actively engaged in their health and wellbeing, and to manage chronic conditions.

Europe has much to build on: strong industrial players, a wealth of smaller 'medtech' companies, component and integration technologies suited for medical applications, design capabilities, cooperation with RTOs, extensive telecommunications infrastructure. Here collaboration across the entire value chain is vital to deliver the necessary connectivity, data security and privacy; to understand the needs of patients, medical professionals and hospitals; and for large corporations and SMEs to combine forces to bring innovations to market quickly.

Competitors from the USA and the Far East frequently operate in large, harmonized markets that deliver high returns. Europe's smaller, fragmented healthcare markets, with disparate regulation and reimbursement schemes, can hamper commercial investment and innovation. This makes funded collaboration all the more important, if Europe is to maintain affordable, accessible healthcare at home and competitiveness in markets worldwide. In addition, the development of open technology platforms and standards for medical devices and systems must be stimulated[3], to move away from the inflexible and costly point solutions that presently dominate electronic medical device manufacturing.

**Chapter 3: Energy**

ECS in the energy domain can go a long way to meeting Europe's commitments to emissions reduction[4] and to the Paris COP21 Agreement: for instance, by increasing the share of renewables in the electricity sector from 21% today to at least 45% by 2030. Moreover, with increasing global protectionism, Europe also has a strategic interest in maintaining its ability to manufacture components and systems for energy generation and distribution.

ECS is already playing a key role in the transition to renewable energy (sun and wind) and higher energy efficiency. The challenge is to intensify progress, particularly in making renewables cost-competitive with non-renewable sources. Besides generation, smart, secure distribution grids are needed to manage the variability of renewable sources, the 'decentralisation' of production (everywhere from wind farms to roofs) and the two-way flows as consumers also become producers. In addition, continued innovation in technologies such as power semiconductors and modules, where Europe is a world leader, will support Europe's Ecodesign[5] objectives and reinforce the benefits of higher efficiency: reduced emissions, cost savings and increased industrial competitiveness.

The vision of a Digital Europe – with zero-emission cities, electric mobility, digital industry and vast demands for data processing – cannot come about without sustainable generation and power conversion, storage, smart grids and higher energy efficiency. Equally important is a regulatory environment that supports Europe-wide harmonization and markets, helping to deliver the affordability, reliability and security that will ensure consumer acceptance.

[3] The ECSEL lighthouse Health.E is addressing this challenge

[4] EU policy (https://ec.europa.eu/energy/en/topics/energy-efficiency) targets 30% energy savings by using innovative nano-electronics based solutions

[5] European Ecodesign Directive (http://ec.europa.eu/growth/industry/sustainability/ecodesign_en) and background

**Chapter 4: Digital Industry**

Industry itself is going digital, moving beyond automation to an era that holds out a crucial promise – economically and ecologically sustainable growth. Often referred to as Industry 4.0, this 'digital industry' is bringing the internet, 5G communications, simulators, AI and virtual technologies into factories.

The economic, industrial and social benefits are manifold. Manufacturers can respond to people's desire for products tailored to their unique preferences ('mass customized production'). Flexibility, productivity, quality, and competiveness go up. Innovations can reach market more quickly. And all this can happen while moving towards zero-defect, zero-emission production.

Many European companies are leaders in digital industry – both in using and supplying equipment and services. With investment, innovation and new business models, European industrial ecosystems can become leading contributors to global high-end manufacturing and keep pace with the strides being made in major industrial nations such as the USA and China.

The technological path to these goals includes innovations such as 'digital twins', complete virtual software-based doubles of factories that allow hugely complex combinations of diverse equipment and processes to be simulated in every detail. Their potential to increase efficiency, quality, prevention of downtime, and optimum use of materials, energy and water is huge. Longer-term, AI and virtual reality may enable speech-based interaction with industrial systems. New kinds of factory employment will emerge, offering intellectually stimulating work in comfortable environments.

Digital industry will be built on connecting and sharing equipment and data from multiple suppliers, in ways that are safe, cyber-secure and trusted. Developing such digital platforms means bringing together ecosystems of multiple providers of equipment and services, research and technology organisations, and industrial users, and developing business models that share the value created[6]. Targeted innovation now can put Europe on the road to leadership in high-end manufacturing by 2025.

**Chapter 5: Digital Life**

Digital services are already part of almost every aspect of our lives, in every space – public, professional, private (home & family) and personal (ourselves alone). On an individual level, further development of 'digital life' can provide for our fundamental needs for safety, comfort and fulfilment. At a societal level, digital life is the foundation for a resilient society where European digital technology is used for the involvement of citizens, and for their safety, security and privacy.

This vision is diverse: from preventing major incidents in public environments to supporting older people to lead independent lives, to reducing human impact on the planet's resources. By 2025, it foresees digital services that will anticipate our needs – imagine a living space that adjusts the lighting and ventilation before you even touch a switch, or a robot that helps out based on your daily routine. Privacy, health, entertainment, sustainability: all fall within the scope of digital life.

The building blocks appear throughout the ECS SRA: IoT (Internet of Things), 5G, AI, Virtual Reality and Augmented Reality, Brain Computer Interfaces, wearables, robotics, energy harvesting and more. However, digital life applications are currently dominated by US companies and other countries are following. China

[6] Industry4.E (https://www.ecsel.eu/industry4e) is the ECSEL Lighthouse Initiative which pulls together the necessary work that is core to the "digitalisation of industry"

has enormous investments in renewables, IoT, and smart cities, and Japan is investing heavily in smart cities and robotics.

Bringing digital life to all Europe's citizens requires infrastructure deployment, and open access to public data, knowledge and cloud-based "wisdom", for which the Digital Single Market is an important enabler. In technology, Europe can leapfrog competitors in emerging areas such as Edge Computing (Chapter 9). And Europe's culture concerning safety, security and privacy (as embodied in the GDPR) presents a unique opportunity. Through collaborative innovation, European companies can create trusted applications that ensure consumer acceptance in Europe and offer distinctive solutions for world markets (Chapter 8).

## PART 2: ESSENTIAL CAPABILITIES

### Chapter 6: Systems and Components: Architecture, Design & Integration

Beyond visions, the question arises: how to design, integrate, analyse and test all the components, systems and applications that enable the digital future? The degree of complexity is unprecedented: integration of electronic, physical and biological components and systems (e.g. a smart wearable medical implant); systems that are extremely small or embedded in environments where there is no access to them (e.g. in an avionics system or ADAS), yet which are very harsh (e.g. extremes of heat, cold, vibration). Thousands of disparate elements with different characteristics will have to be combined and work together. To enable this, hardware and software must be jointly designed and integrated at each level from components to modules and systems.

Smart systems will be everywhere from factories to homes. Many will interact with humans. Often they will evolve over their lifetime due to updates-in-the-field or based on AI and machine learning. Nonetheless, such systems and applications must be verifiably safe, secure, dependable and reliable – the essential for consumer acceptance (Chapters 7 & 8).

The answer is to strengthen Europe's world-leading design expertise and tools, methodologies for ECS-based products that enable the digital world: Cyber Physical Systems, IoT, smart devices and smart systems. The ECS industry and the industries that use ECS – among them transport, health, and energy – need these tools and methodologies to remain competitive. Speed is essential. Inaction will result in Europe's industry losing vital knowledge, as well as industrial efficiency and the ability to design and build products for its own and global markets.

From now to 2030, R&I needs to be directed towards developing standardized tools and methodologies with multiple stakeholder participation (including SMEs). Collaboration at the pre-competitive stage facilitates understanding of application needs (pull) and technology potential (push). It can create a set of first principles available to all industries for 'safety, security and dependability by design'. These will lead to faster time to market, and certifiable applications and products. Success depends on creating an open, seamless, sustainable design and integration ecosystem for cost-efficient, standards-based procedures, methods and tools aligned with a coordinated research agenda.

**Chapter 7: Connectivity and interoperability**

Connectivity and interoperability are inherent in the digital world – for IoT, 5G communications, smart mobility, smart energy, smart cities, smart health… Machines, people and organisations need to be able to exchange information in a secure, seamless and timely manner. The goal of ECS innovation in this domain is to make this possible at low cost, so European companies can create applications profitably and Europe can benefit fully from digitalisation.

Connectivity for healthcare (Chapter 2), energy (Chapter 3), education and public services that expand citizenship, inclusion and equality can underpin a flourishing society. Connectivity and interoperability also lie at the heart of Industry 4.0 (Chapter 4), in which Europe leads the world and that is the backbone of other world-leading sectors including the automotive and the process industries.

In the coming 5-10 years, innovation needs to focus on IoT and 'Systems of Systems' (SoS) that connect diverse technologies (hardware and software), devices and applications; and 'semantic interoperability' – the ability to share data in ways that each part of a network can understand and make use of. And of course, data must be secure at all times (Chapter 8).

Ecosystems of industrial and academic partners will be key to creating tools for SoS and hardware integration (including connecting new technologies to legacy systems). By delivering 'engineering simplicity', such tools could cut connectivity development costs by 80%, enabling European companies to compete with the USA and China in developing high-end applications that capture higher value.

Global opportunities exist in ADAS, digital industry, connectivity for data centres and telecommunications infrastructure. But collaboration is important to offset the cost of developing for Europe's smaller, fragmented markets. Europe also needs to retain relevant academic strengths, so engineering talent is not lost, as well as its role in standardization to shape emerging technology. Finally, strengthening European capabilities technologies (including in chip packages, PCBs, etc…) would reinforce Europe's sovereignty to produce solutions, particularly for strategic but small volume applications in the space and defence sectors.

**Chapter 8: Safety, Security and Reliability**

Society will only benefit from the digital revolution if people trust the products and services on which it is based. Think of personal healthcare monitoring, autonomous cars or smart homes – users must be confident that they are safe (i.e. do not cause accidents or injury), secure (i.e. protect from danger and keep data private) and reliable (i.e. works when you need it, no breakdowns or failures).

On a societal level the challenge is huge. Connectivity is booming. By 2020, there may be as many as 20 billion connected IoT devices. Industries and infrastructure are facing new threats – from data theft to cyber-attacks from rogue states, through to incidents like the Wannacry worm of 2017 that held 400,000 computers to ransom, to name a few.

If Europe wants its citizens to continue living in a society with high levels of protection and privacy, innovation is essential. Governments, society and industry need to build resilience in the face of novel cyber-attacks. Security cannot be an 'add-on' to products to services. Safety, security and privacy by design must become the norm (Chapter 6). Over the next decade, industry needs to create new tools and methods, based on multi-disciplinary collaboration across the entire value chain from semiconductor manufacturers to application developers – because security is only as good as its weakest link. Equally, Europe must maintain its own semiconductor manufacturing to retain oversight of how chips are made and security is implemented within them.

Beyond this, Europe can start on a path towards creating certified and trusted products, which embody its culture of protection and privacy. The USA may dominate technology markets, but Europe has relevant strengths: its world-class academic research; its leadership in technologies and standards for e-passports and electronic payments, and in embedded systems and semiconductors for the transport sector. If European cyber security companies and digital platform industries can transform themselves, the way is open for safe, secure, reliable European products to become the quality label (such as 'Trusted IoT') for markets worldwide.

**Chapter 9: Computing and Storage**

Computing and storage are underlying enablers of the digital world. But the forecasted growth in demand for processing power cannot be met by existing technologies. The ambition of ECS research is to make the necessary computing and storage affordable in terms of energy, cost and reliability for the new applications. That means working towards a 50-fold increase in peak performance while keeping these costs at a viable level.

Demand for computing is everywhere. Climate science; healthcare; clean, secure energy and smart cities call for vastly powerful High Performance Computing[7]. Embedded systems (in vehicles and aircraft, for example) must handle new degrees of complexity e.g. self-driving cars must safely interact with the physical world, often instantaneously and with only the computing power on board. And the trend to 'Smart Everything' is enabled by, and driving development of, AI and intelligent machines.

Europe needs R&I into computing and storage technologies along More Moore[8] and More than Moore[9] paths (Chapter 10), both for the ECS industry and for the major industries it supports: automotive, aviation, health, energy, security and telecommunications. R&I in processors, accelerators, microcontrollers and hardware and software for intelligent embedded systems (Cyber Physical Systems - CPS) will help maintain Europe's leadership in the face of fierce competition, especially from China and the USA. And in an increasingly protectionist world, Europe will be strategically vulnerable without its own capabilities to produce high-end semiconductors for computing and Artificial Intelligence. Equally important is building on Europe's educational and industrial leadership in software – both for future applications and in the short-term to obtain greater performance from existing hardware.

By the 2030s, novel technologies such as quantum computing[10], neuromorphic computing (inspired by the human brain), spintronics (ultra-low power), etc… will mix with 'classical computing'. The USA and China, and the extended GAFA[11], are investing heavily here. Although lagging, Europe can draw on its know-how in areas such as CPS and embedded systems to catch up. Now is the moment to seize the lead in key disruptive technologies including AI Accelerators and Edge Computing (enabling devices to process data without being connected to a network, for instance, in a self-driving car to be sure it can function at all times).

[7] Europe renewed its High Performance Computing (https://ec.europa.eu/digital-single-market/high-performance-computing-hpc) strategy in 2017

[8] Extending the trend of Moore's Law

[9] Integrating other technologies with conventional silicon-based CMOS semiconductors: analog, RF, passives, power, sensors & actuators, biochips, MEMS (micro electromechanical systems)

[10] Quantum Technologies are one of Europe's Future & Emerging Technologies (https://ec.europa.eu/digital-single-market/en/future-emerging-technologies-fet) programme

[11] Google, Apple, Facebook, Amazon plus Microsoft and Baidu

**Chapter 10: ECS Process Technology, Equipment, Materials & Manufacturing**

Semiconductor technologies form the base of the ECS value chain; the physical building blocks for digital applications. Nano- and micro-electronics have been identified as key enabling technologies[12] for Europe. If Europe is to build a digital future fitted to its citizens and its social, economic and industrial goals, it must continue to innovate here.

Globally, the market for electronic components is expected to exceed 1,000 billion USD by 2030. In Europe, the semiconductor ecosystem employs some 250,000 people, with 2.5 million in the overall value chain of equipment, materials, system integration, applications and services – mostly in jobs requiring a high level of education.

In the past, the semiconductor market has been extremely volatile, and R&D investments are high (up to 10 to 20% of total revenue). Nonetheless, private-public funding has enabled Europe to lead the world in semiconductor equipment, materials and manufacturing solutions, particularly in technologies such as Extreme Ultra Violet Lithography, System in Package (SiP)[13] and Fully Depleted Silicon on Insulator (FD SOI). Continued investment is vital not only for the ECS industry, but also for the downstream industries that depend upon it, among them: automotive, aviation, healthcare, energy, security and telecommunications.

Advances in ultra-low power data processing for IoT, AI, big data and cloud computing will call for improved IC and electronics performance, heterogeneous integration of functionality, and implementation of novel paradigms such as quantum and neuromorphic computing (Chapter 9). Likewise, Industry 4.0 and 'green' manufacturing of semiconductors will require new processes, manufacturing techniques, equipment and materials (Chapter 4).

In meeting these challenges, the creation of manufacturing pilot lines is key (as it has been in successful European projects to date). Pilot lines are a launching ground for new processes and equipment technologies, and materials, and allow for early validation of new concepts in support of industrial introduction. They help to maintain an understanding of application needs, cut products' time to market, and showcase European capabilities to potential customers worldwide.

Despite competition from East Asia and the USA, Europe can reinforce its lead in semiconductor processing, equipment and smart systems based on the priorities in the ECS SRA (covering the timeframe 2018-2030). There are also strong arguments for bringing back leading-edge semiconductor manufacturing to Europe – to maintain sovereignty and to be present in AI and other key technologies of the digital world.

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[12] European Key Enabling Technologies (http://ec.europa.eu/growth/industry/policy/key-enabling-technologies_en)

[13] ICs put together in a single miniaturised module, for instance for functions in mobile phones

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## ABOUT THE ASSOCIATIONS

**AENEAS** is an Association, established in 2006, providing unparalleled networking opportunities, policy influence & supported access to funding to all types of RD&I participants in the field of micro and nanoelectronics enabled components and systems, and its applications.

See https://aeneas-office.org

**ARTEMIS Industry Association** strives for a leading position of Europe in Embedded Intelligence. The multidisciplinary nature of the membership provides an excellent network for the exchange of technology ideas, cross-domain fertilisation, as well as for large innovation initiatives.

See https://artemis-ia.eu

**EPoSS**, the European Technology Platform on Smart Systems Integration, is an industry-driven policy initiative, defining R&D and innovation needs as well as policy requirements related to Smart Systems Integration and integrated Micro- and Nanosystems.

See https://www.smart-systems-integration.org/