ARTEMIS
STRATEGIC RESEARCH AGENDA
2011

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Preface

It was in 2006 that the ARTEMIS European Technology Platform issued its first Strategic Research Agenda to set the scene on R&D and innovation on Embedded Systems in Europe. One of the recommendations in that document was that a Joint Undertaking should be constructed to create an extra initiative in Europe to help to achieve the goals that were set out in the SRA 2006.

In 2007 the ARTEMIS Industry Association was founded as a legal body to continue the activities of the ARTEMIS ETP and to become the legal private partner in the ARTEMIS Joint Undertaking. The ARTEMIS Joint Undertaking became reality in 2008, and organised its first call for projects in the same year.

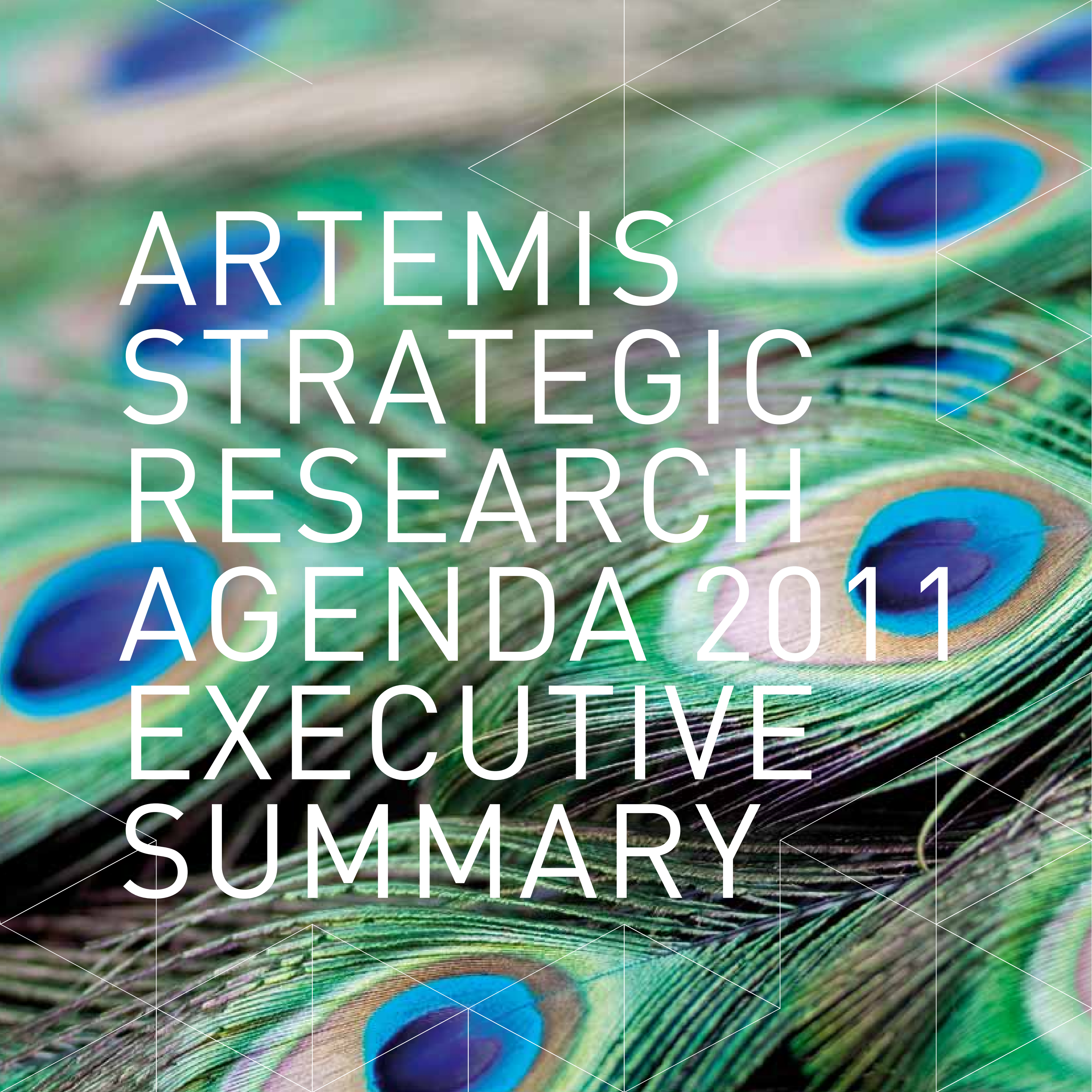
Now in 2011, the ARTEMIS Joint Undertaking is well up and running and organising its fourth call, and the results of first projects of the first call are becoming visible.

Since 2006 new technical options and challenges have occurred. It has become clear that Embedded Systems increasingly form the neural system of society and, therefore, are essential in helping to solve our major societal challenges. Hence, it was time to update the SRA 2006.

You now have before you the updated SRA 2011, which seeks to give a solid perspective of what is needed in Europe in the next decade from all R&D and innovation actors to make Europe the leader in Embedded Systems.

I thank everyone that has significantly contributed to this document (see page 99), specifically Laila Gide and Tatu Koljonen, the co-chairs of the Working Group SRA, who spent innumerable hours to achieve the result in front of you.

Klaus Grimm,
President of the ARTEMIS Industry Association



ARTEMIS STRATEGIC RESEARCH AGENDA 2011 EXECUTIVE SUMMARY

This document represents an update of the first ARTEMIS Strategic Research Agenda (SRA) that formulates a coherent and integrated European research and development strategy for Embedded Systems. It takes account of changes since the publication of the first SRA in 2006, particularly the impact of significantly increased networking and greater emphasis on the role of technology in addressing societal challenges. It also takes account of the First Interim Evaluation of the ARTEMIS and ENIAC Joint Technology Initiatives report[1] recommendation for reviewing and refreshing the Strategic Research Agendas and enhancing the innovation ecosystem.

In this SRA document[2] ARTEMIS stands for the ARTEMIS community i.e., the ARTEMIS Technology Platform, the ARTEMIS Industry Association (ARTEMIS-IA), the ARTEMIS Joint Undertaking (ARTEMIS JU) as the legal embodiment of the ARTEMIS Joint Technology Initiative, and other national or regional clusters and centres of innovation excellence affiliated to the ARTEMIS initiative and active in the field of Embedded Systems.

EMBEDDED SYSTEMS

Embedded Systems are electronic products, equipment or more complex systems containing computing devices that are not externally visible and are generally inaccessible by the user. They are in the electronic key for your car and in the control systems for a nuclear power plant. **Embedded Systems enable an every-day-object to become a smart object able to communicate with other smart objects either directly or via a network, such as the Internet. Embedded Systems form the edges of the 'Internet of Things' – they bridge the gap between cyber space and the physical world of real 'things'.**

[1] *First Interim Evaluation of the ARTEMIS and ENIAC Joint Technology Initiatives July 30, 2010*

[2] *This document is issued by and on behalf of the ARTEMIS Industry Association (the organisation that continues the ARTEMIS ETP) as endorsed by its members in the General Assembly on 2 March 2011.*

THE ARTEMIS JOINT TECHNOLOGY INITIATIVE

ARTEMIS (***Advanced Research & Technology for Embedded Intelligence in Systems***) was established in 2004 as the European Technology Platform for Embedded Systems. The technology platforms were conceived to ***"… bring together public and private stakeholders to set up and implement common research agendas in fields of industrial relevance …"***

The industry-led ARTEMIS initiative aims to consolidate the position of Europe as a leading worldwide player in the design, integration and supply of Embedded Systems. The ARTEMIS Joint Technology Initiative (JTI) was established to take forward the work of the Technology Platform and build on it. It is implemented by means of a 'Joint Undertaking' (JU)[3], which is a public-private partnership between the European Commission, Member States and ARTEMIS-IA, a not-for-profit Industrial Association formed by private stakeholders that participated in setting up the ARTEMIS ETP.

The Joint Undertaking was established in 2008 to manage and coordinate research activities through open calls for proposals in a ten-year, €2.5 billion research programme on Embedded Computing Systems. The programme is open to organisations in European Union Member States and Associated Countries.

An interim evaluation[4] of the ARTEMIS Joint Technology Initiatives performed by an Evaluation Panel confirmed that the original purpose for establishing them remains valid.

[3] *COUNCIL REGULATION (EC) No 74/2008 of 20 December 2007 on the establishment of the 'ARTEMIS Joint Undertaking' to implement a Joint Technology Initiative in Embedded Computing Systems*

[4] *First Interim Evaluation of the ARTEMIS and ENIAC Joint Technology Initiatives 30 July 2010*

The evaluation report highlights the fact that Strategic Research Agendas (2006) for the "first time established a coherent view across industry, Member States and the European Commission of Europe's priorities in these areas. Having a joint strategy with shared implementation is good for industry, good for Member States, and good for Europe."

The panel also concludes that the "establishment of these industry-led tripartite industry-national-EU PPPs is a major achievement and they validate the general concept of the JTI. The panel therefore recommends **that research and technology initiatives in the fields of embedded computing systems and nanoelectronics should continue to be coordinated on the European level."**

The SRA 2011 is also building on the success and work achieved so far through the JTI and ARTEMIS JU. **The JTI concept is unique and has no equivalent counterpart (FP7 or Eureka), allowing ambitious projects of a European dimension to emerge and benefit from EC, national and regional funding, and engaging key actors, being private industrial or academic partners, to invest together in strategic areas thereby creating a large-scale portfolio.** By grasping the embedded revolution pragmatically and drawing on shared resources, products can get to market quickly in a way that a single player cannot do alone.

THE ARTEMIS STRATEGIC RESEARCH AGENDA

The pan-European ARTEMIS Strategic Research Agenda is a tool to realise the industry-driven, long-term vision of the ARTEMIS technology platform. It helps to align and coordinate research policies in Europe such as those of the EU Framework Programme, national and regional research programmes, the programme of the multi-national Eureka clusters ITEA2 and CATRENE and, since the establishment of the Joint Undertaking, the research and development supported by the JTI itself. The SRA helps to match the allocation of programmes and resources to different technology and policy challenges.

The SRA is based on maintaining a strong technological capability in both the supply and application of Embedded Systems by overcoming fragmentation in the European supply base for the components and tools of embedded systems. By removing barriers between application sectors ARTEMIS aims to yield multi-domain, reusable components and systems.

The ARTEMIS SRA has established for the first time a coherent view of Europe's Embedded Systems priorities across Member States, the Commission and industry. It has been used as a reference by the European Commission and by a number of national bodies when establishing their own research priorities and programmes.

THE ARTEMIS VISION

Despite the convergence occurring in various markets and supply sectors, the Embedded Systems markets tend to be fragmented, which has led to fragmentation of supply and in RTD investment. ARTEMIS wants to overcome this fragmentation through a new Embedded Systems industry that cuts the barriers between application sectors so as to 'de-verticalise' the industry and facilitate cross-sectoral sharing of tools and technology that are today quite separate.

The vision driving ARTEMIS is of mankind benefiting from a major evolution in our society whereby our world is widely supported by intelligent Embedded Systems, a world in which all systems, machines and objects become smart, have a presence in cyber space, exploit the digital information and services around them, communicate with each other, with the environment and with people, and manage their resources autonomously. The ubiquitous presence of the Internet provides the communication infrastructure for smart objects to be connected. Life in our society, along with security and safety, will increasingly depend on Embedded Systems technologies.

ARTEMIS aims to establish a new, holistic approach to research, technology development, innovation and skill creation by means of innovation ecosystems that are sustained by 'eco-alliances' and 'co-petition', thereby benefiting from the advantages created both by cooperation and by market competition, breaking the barriers that may exist in various other models, and redefining the value chain. This will increase the efficiency of technological development and, at the same time, enhance the competitiveness of the market in the supply of Embedded Systems technologies.

Therefore, the ARTEMIS vision nurtures the ambition to strengthen the European position in Embedded Intelligence and Systems and to ensure its achievement of world-class leadership in this area by establishing an environment that supports innovation, stimulating the emergence of a new supply industry and avoiding fragmentation of investments in R&D.

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THE ARTEMIS STRATEGIC RESEARCH AGENDA - 2011 UPDATE

The validity of the SRA 2006 is evident in results from the early projects launched by the ARTEMIS JTI and intended to bring together important RTD players from different industrial domains to develop solutions that span multiple application sectors on a scale that had not been possible with the pre-existing mechanisms. These projects enable the engagement of not just researchers but also users to explain their needs, and those involved in the economic and legal conditions, such as standards and intellectual property management, that make the technical solutions viable. This present update does not make the SRA 2006 any less valid but such *an update allows the SRA to take into account new trends and the evolution of technology, industry and society* since the SRA 2006 was published.

There have been two significant developments, one technical and one societal.

> Technical: the impact of networking goes far beyond that anticipated in the original SRA. Many emerging embedded applications now share networks and components in configurations whose conceptual structure no longer readily maps to their physical structure. In parallel, open networks of Embedded Systems applications from multiple domains are coupled: everything can, in principle, be connected to everything else. Networked Embedded Systems will, in effect, become the neural system of society.

> Societal: one of the main reasons for the formation of ARTEMIS was the quest for greater economic growth in Europe. However, today Europe faces a number of other societal challenges arising from inverted demographic curves, constantly increased demands for non-renewable natural resources, constant expectations for improved quality of life, and climate change. As the neural system of society, networked Embedded Systems should no longer be considered only in isolated application contexts but in relation to what they can offer in addressing today's and tomorrow's societal challenges.

This SRA 2011 therefore introduces societal challenges as an overarching concept that will drive European competitiveness, with several application and research domains contributing to each societal challenge.

These societal challenges introduced in the first Multi-Annual Strategic Plan[5] of the ARTEMIS JU have now become a core element of the SRA 2011.

THE ARTEMIS RESEARCH AND INDUSTRIAL PRIORITIES - 2011 UPDATE

Many of the research priorities of the SRA 2006 still stand: they were and remain long-term, strategic, research challenges. However, this SRA 2011 updates them in the light of the technical demands of the vastly more extensive networking envisaged above, and in the context of the societal challenges.

The original ARTEMIS industrial priorities aim to achieve multi-domain compatibility, interoperability, and even commonality was already moving in this direction. In this update to the ARTEMIS Strategic Research Agenda, this strategy is now taken further: the societal challenges will be used to structure the inherent technological issues into a concrete research and innovation strategy spanning multiple application contexts, with results that will benefit both society and the economy.

Scenarios have been developed to break down the complexity of these challenges to manageable and comprehensible pieces and map them to application contexts and technological domains.

The ARTEMIS matrix approach presented in the SRA 2006 has now been extended to a three-dimensional representation, which puts applications contexts, research priorities and societal challenges into perspective.

5 *ARTEMIS JU MASP 2008*

Closer investigation of the societal challenges has highlighted the importance of interoperability, system autonomy, networking - including use of the Internet - and consideration of mixed criticality for more dependable systems.

This 'bigger picture' for Embedded Systems implies change from local networks to open networks of embedded systems. This leads in turn to a change from single-system ownership to multiple-design processes and responsibilities involving many parties, multi-views, with conflicting objectives.

There is a change from static networked Embedded Systems to systems-of-systems which are highly dynamic and evolving and are never down. The convergence of applications on open networks introduces requirements for component and network safety, availability and real-time behaviour in areas where such requirements have not been an issue so far, such as in home networks and car-to-infrastructure communication.

Embedded Systems will by far outnumber people using the Internet - leading European suppliers of Embedded Systems

> "The ARTEMIS Strategic Research Agenda 2011 introduces societal challenges as an overarching concept that will drive European competiteveness."

cores have on their own already shipped over 18 Billion embedded processors. The Internet will become part of the seamless integration challenge already found in the SRA 2006, and must be enabled to safely and reliably handle many different embedded applications. Embedded Systems must be made more autonomous and robust to compensate for the reduced real-time and reliability guarantees, and must operate dependably even in the presence of network degradation and temporary failure.

The *reference designs and architectures* objective is to create an energy-efficient generic platform and a suite of abstract components with which new developments in different application domains can be engineered with minimal effort.

The *seamless connectivity and interoperability* is vital for future Embedded Systems. Its requirements pervade the middleware, operating systems and other functions required to link the physical world, as seen by the networked nodes, and also the higher layer applications, as well as hardware features needed to support an efficient and effective interoperability implementation.

The *design methods and tools* for Embedded Systems have to support the introduction of disruptive hardware and software implementation technologies and, together with appropriate architectural principles, enable the corresponding innovation promises from these technologies to be turned into real products.

The *scientific research* that will be undertaken in ARTEMIS will provide a scientifically rigorous basis for the ARTEMIS reference designs, architectures, middleware and communication techniques.

MAKING IT HAPPEN – 2011 UPDATE

To achieve the economic and societal ambitions of ARTEMIS, it is not enough to perform research, and it is not enough to develop technology. The concepts emerging from research and the technologies emerging from development must be embodied in industrial and business practice and must both support and be supported by innovation ecosystems. The SRA update contributes to the Innovation Union[6] approach and to the Digital Agenda for Europe[7] and elaborates on key items that are important for Embedded Systems innovation.

By expanding on what is needed apart from the research and technology development to really make a more productive innovation environment for Embedded Systems in Europe happen, this SRA seeks to take the Multi-Annual Strategic Plans a stage further by outlining the actions required to 'make it happen'.

6 *Europe 2020 Flagship Initiative Innovation Union COM(2010) 546 final*

7 *A Digital Agenda for Europe COM(2010) 245*

The ARTEMIS JU has established a governance and integration framework where industry, research organisations and public authorities across the EU join forces. The rules and procedures of the Joint Undertaking are designed to ensure openness, fairness and transparency to all the stakeholders in the field under FRAND (fair, reasonable and non-discriminatory) conditions.

This Strategic Research Agenda is an important tool in coordinating our joint efforts and optimising the implementation of the JTI. It is instrumental for both ENIAC and ARTEMIS to pulling their technical efforts together in order to strengthen the European position in Nanoelectronics and Embedded Systems. It further seeks to set the scene for the other trans-national and national programmes in Europe since the ARTEMIS JTI programme lacks the mass (in terms of scope and depth) to reach all goals alone.

European forces must continue to combine their strengths in order to maintain leadership in one of the most dynamic, pervasive, fascinating and promising areas of information technology, using different instruments to achieve one goal.

The phenomenon of Public Private Partnerships (PPPs), driven by industry around specific themes of societal importance, such as the Factory of the Future, Energy Efficient Buildings, the Green Car and the Future Internet, are both evidence and confirmation of the growing need felt by industry to more than ever embrace collaborations over a broader spectrum of value-chain actors.

The current JTI organisation will expire in 2017 and the last call for projects provided for under the present ARTEMIS JU will be in 2013. Given the ambition of the SRA, continuity of the ARTEMIS JTI is recommended to ensure that the implementation of the ARTEMIS strategy and objectives is maintained. ARTEMIS aims to ensure that the results of the R&D efforts engaged by all stakeholders translate into new products and market opportunities quickly and effectively. To this end this SRA sets out the ARTEMIS strategy across a wide range of topics that are not themselves part of research or technology development but sustain R&D and enable its exploitation to the benefit of all stakeholders, economy and society.

Commitment from the respective stakeholders for long-term funding of an agreed common agenda is necessary to achieve the ambitious goals. This will allow enduring strategic alliances to be established among R&D actors necessary for developing and maintaining links between national/regional clusters and fostering collaboration opportunities among these actors.

ARTEMIS recommends setting up follow-up activities of projects throughout their implementation to enable sharing and mutualisation of results between R&D projects in order to boost the production of "prototype results" as an ARTEMIS repository[8].

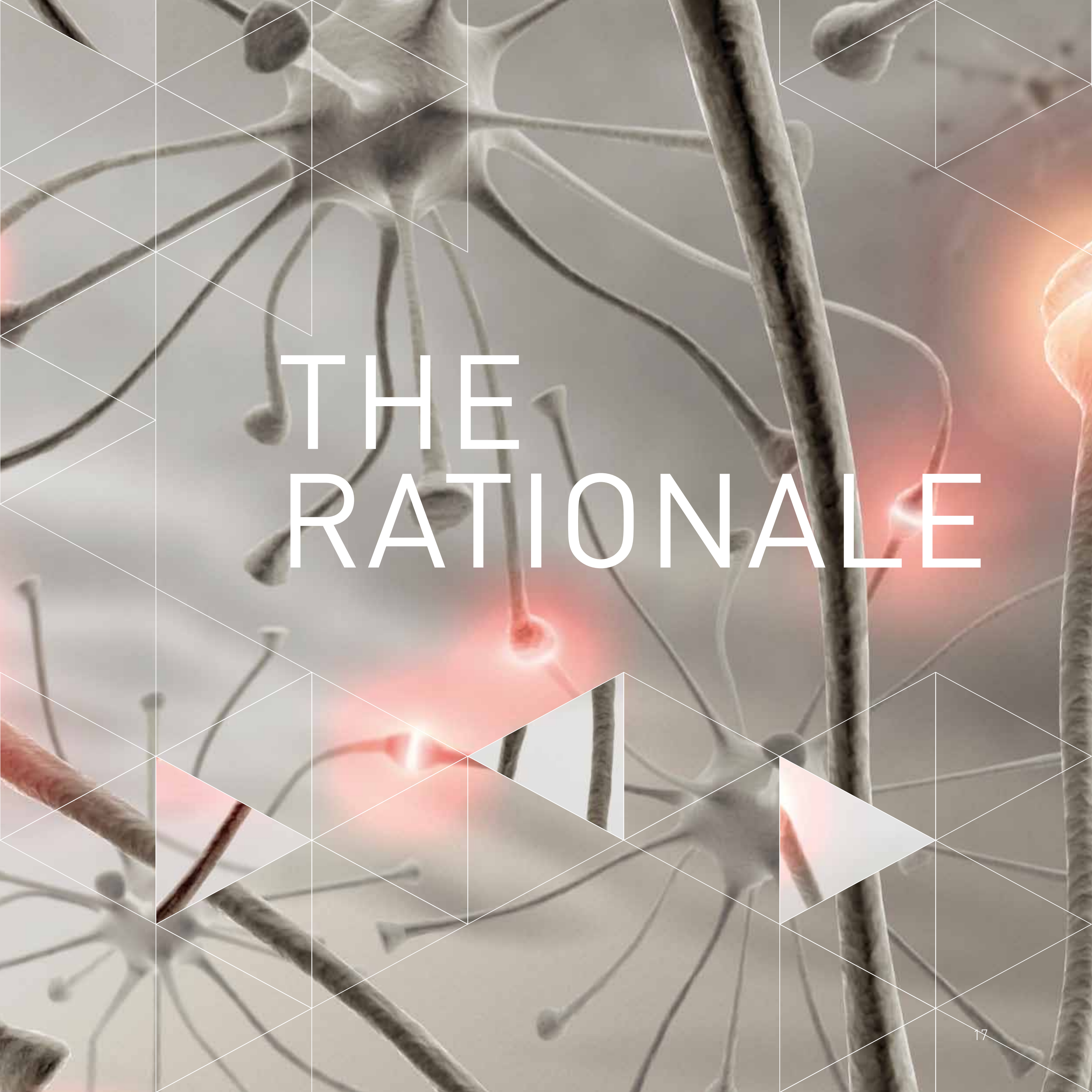
Creating new innovation eco-systems to overcome the barriers to innovation is needed. The holistic approach taken by ARTEMIS encourages collaboration throughout the whole value chain, from research institutes, high-tech SMEs, large industrial companies to constitute this eco-systems of interconnected activities and interests. The existing ARTEMIS Centres of Innovation Excellence (CoIE), such as EICOSE and ProcessIT.eu as well as future ones, will generate mutual benefit between these clusters and for ARTEMIS in breeding regional and national innovation initiatives. Such eco-systems will favour open innovation that will share not only RTD costs and risks but also know-how and expertise in order to sustain economically viable product and software development, and preserve industrial activity in Europe.

ARTEMIS proposes to establish referenced "Tool Platforms" as presently large-scale development environments come almost exclusively from a small number of non-European sources, while Europe has a large number of excellent suppliers - mostly SMEs - of tools for specific purposes. An ARTEMIS "Tool Platform" is not intended as a commercial entity but as a virtual platform that embodies a common set of interfaces, working methods and protocols that will allow tool vendors to integrate their products into tool chains adapted to the specific needs of sections of the embedded intelligence applications market.

Reducing the gap between the theory of academic education and the practice in industrial application is still a challenge that Europe should face. ARTEMIS must take actions to facilitate the development of new combinations of skills for better integration of hardware and software curricula and break down the present distinctions between system architects, hardware and software engineers, and promote a more holistic approach to system design.

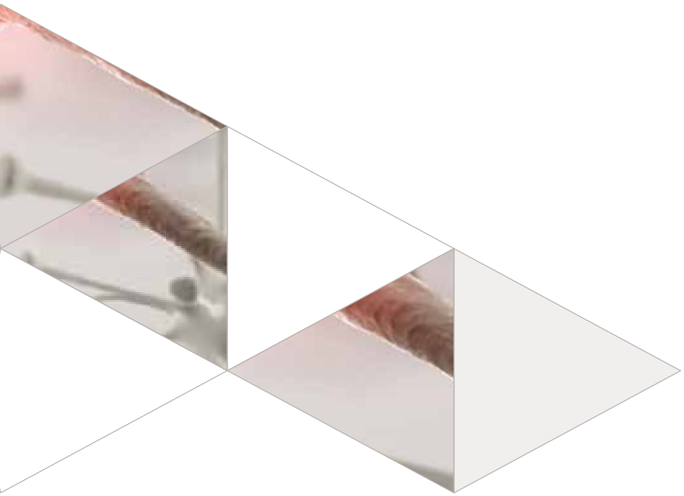
ARTEMIS will also foster synergies with other initiatives, targeting training and dissemination, and more particularly FP7 initiatives (such as Marie-Curie). As suggested above, ARTEMIS adopts a pre-competitive, all-inclusive approach that aims to bring about an environment in which a new openness allows standardisation and regulation for Embedded Systems to be driven and directed by the stakeholders. Within this environment, ARTEMIS has a major orchestrating or harmonising role and in acting internationally such that the industrial and research priorities of an Embedded Systems community that is beset by fragmentation can be galvanised to overcome the major challenges, both technical and societal, and become a well-aligned, highly-efficient and, therefore, even stronger European industry.

[8] *results can be technology components, complete systems, platforms, tools or methods.*



THE RATIONALE

Embedded Systems: Society's 'neural system'



Embedded Systems are everywhere, built into cars, roads, railways, bridges and tunnels, into medical systems and devices and surgical robots, into homes, offices and factories, into aeroplanes, airports and satellites, into mobile phones and communication and virtual reality glasses, and even into our clothes. They are interconnected in networks of many devices – the car to the fixed road infrastructure, the smart card to the banking and payment systems and usage of public services.

Embedded Systems technologies are deployed in all market sectors – automotive, aerospace, trains, healthcare, energy and environmental management, communications, entertainment, textiles, manufacturing, transport, logistics, printing and chemicals, agriculture, food & drink, timber and materials. Annual growth is more than 10% and over 40 billion devices are expected worldwide by 2020. Moreover, the value added to the final product by embedded software is often orders of magnitude higher than the cost of the embedded devices themselves.

As they pervade all artefacts of life, from children's toys to space probes, so more of the value of those artefacts will be derived from their embedded intelligence. In parallel, the dependable and safe operation of those artefacts will increasingly depend on the proper design and operation of Embedded Systems. Greater public awareness about their dependence on Embedded Systems will raise expectations as well as concerns about potential failures and safety, privacy and security so the quality and dependability of Embedded Systems are key issues.

The original SRA focused on individual application contexts: Industrial (including automotive and aerospace), Nomadic Environment, Private Space and Public Infrastructure. Embedded Systems have a major impact on the way these sectors work and collaborate, how they will develop, how they are perceived by both professionals and the public, and how successful their products will be on the world market.

Across these application contexts, three research domains were identified to form a second major research challenge dimension: these domains were Reference Designs and Architectures, Seamless Connectivity and Middleware, and System Design Methods and Tools. Furthermore, the networking of embedded systems was identified as a major future trend that would reshape the world of Embedded Systems from a collection of independent or locally connected computers to large interconnected systems.

While this prediction has proven correct, several important trends have seen the impact of networking go far beyond that anticipated in 2006. Many emerging embedded applications share networks and components. The networks form hierarchies, which often do not correspond to the respective application structures. Open networks of Embedded Systems couple interoperating applications from multiple domains, giving rise to another level of system complexity.

In future, the emerging use of the Internet for embedded system networking provides new opportunities. Embedded Systems will be able to exploit the emerging ubiquitous network topology not only for communication but also to gain access to the knowledge of Internet based information systems. In turn, information systems will utilise Embedded Systems as sources of information to enable the Internet of Things.

The availability of digital information from the physical environment is a unique opportunity for the Embedded Systems industry. The information base for systems will be larger than ever before resulting in more optimised, accurate and efficient realisations. Currently we are limited to strict syntactic interoperability, which means that communications across domains must use an identical protocol for communication. But this is increasingly inappropriate (and unachievable) in a widely networked world. Instead, semantic interoperability is needed, so that users (including physical artefacts and their embedded systems) may use the different languages of different domains but can nevertheless 'understand' each other. The emancipation of embedded information with semantics creates possibilities for completely new types of application that have not been possible before. All this together means that we will be able to create smart environments everywhere resulting in increased intelligence, better services and enhanced productivity for all aspects of living.

Networked Embedded Systems will, in effect, become the neural system of society. Embedded Systems technology should therefore no longer be considered in isolated application contexts but should be seen in relation to their contribution to the evolution of society and, in particular, to their contribution in addressing today's and tomorrow's societal challenges.

This current SRA therefore introduces **societal challenges as an overarching concept, with several application and research domains contributing to each of the three key societal challenges selected** as examples: *Healthcare and wellbeing, Green, safe and supportive transportation and Smart buildings and cities of the future.*

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Networked embedded systems will, in effect, become the neural system of society. Embedded Systems technology should therefore no longer be considered in isolated application contexts but should be seen in relation to their contribution to the evolution of society and, in particular, to their contribution in addressing today's and tomorrow's societal challenges.

EMBEDDED SYSTEMS AND SOCIETAL CHALLENGES

> Get access to information systems and in turn the information systems get access to the embedded systems which now enables the internet of things.

INTRODUCTION

While seeking economic growth is one of the main reasons for investing in research, today Europe faces a number of new societal challenges that must be taken into account. These challenges arise from the last century's major evolutions in our social and political environments: inverted demographic curves and constantly increased demands for non-renewable natural resources, constant improvement in quality of life, and climate change ...

Science and technology may offer a key for answering these new societal challenges - 21st Century technology push has often provided unpredicted applications and services.

The technology of Embedded Systems is adding intelligence to all kind of objects. Due to the openness of the Internet, Embedded Systems will also be able to "get access to information systems and in turn the information systems get access to the Embedded Systems which now enables the internet of things"[9]. With communication, Embedded Systems have gained a strategic role and networked Embedded Systems are now considered the neural system of the digital society.

ARTEMIS is not striving to address all possible so-called Grand Challenges but rather **three specific societal challenges** in order to derive the research challenges and prioritise the Embedded Systems research topics addressed in this Strategic Research Agenda. These three societal challenges that take account of established European industrial expertise and infrastructure are:

> Affordable Healthcare and Wellbeing
> Green, safe, and supportive transportation[10]
> Smart buildings and communities of the future.

[9] *Extract from the Rolf Ernst article in ARTEMIS magazine August 2010 edition*
[10] *Contribution from EICOSE*

Affordable Healthcare and Wellbeing

READ POINTER

Three specific societal challenges in order to derive the research challenges and prioritise the Embedded Systems research topics addressed in this Strategic Research Agenda:

> ***Affordable Healthcare and Wellbeing***

> *Green, safe, and supportive transportation*

> *Smart buildings and communities of the future.*

HEALTHCARE: THE CHALLENGE

The global challenges in healthcare that are having a dramatic impact on the healthcare market are driven by the following global trends in society and healthcare:

> Global economic growth: increased spending on health related services, access to healthcare for a larger number of people and increased awareness of available healthcare options

> Dramatic changes in demographics with an ageing population - by 2045 more people will be over 60 than under 15, rising from 600 million to 2 billion.

> Increase in number of patients with age-specific, chronic and degenerative diseases (cardiac, cancer, diabetes, Alzheimer's, Parkinson's). The number of US patients with a chronic illness will have risen from 118 million in 1995 to 157 million in 2020. For Europe, a few key figures for the year 2006 are (source: Frost & Sullivan):

> Neurodegenerative diseases: 3,600,000 people affected with Alzheimer

> Cardiovascular disease: 460,000 deaths from strokes

> Oncology: 240,000 deaths from breast cancer

> Skyrocketing healthcare costs: global health care spending is expected to grow from 9% of worldwide gross domestic product (GDP) to 15% by 2015.

Healthcare professional staffing shortages are rising due to higher demand for patient attention.

> Efficiency and effectiveness of healthcare: need to further improve hospital work flow efficiency, integration of diagnosis and treatment. E.g. the average length of stay for acute care fell in nearly all OECD countries - from 9 days in 1990 to 6 days in 2005.

FROM CURE TO CARE

> As indicated above, healthcare is under intensive strain due to demographic and economic challenges - a globally increasing number of patients with chronic diseases – leading to skyrocketing healthcare costs and staffing shortages. This requires novel methods to handle more patients within acceptable healthcare costs while keeping a high quality of care. The healthcare cycle can be made more cost-effective by improving the quality of care and by shortening medical treatment and hospital residence through care at home, early diagnosis and prevention, image guided intervention and personalised treatment supported by validated decision support systems.

SCENARIOS

> Care at home and everywhere for patients, disabled and elderly people, using multi-parameter biosensors and tele-monitoring networks will improve the quality of the clinical and personal home environments. The same technologies will address new mass markets for the clinical care and wellbeing of the patient. A key economic goal is the reduced cost of hospitalisation and the monitoring of elderly people requiring prolonged medical care using point-of-care terminals. To aid these transitions, new packaging technologies will be needed to use polymers rather than glass for cartridges and platforms. Additionally, new IT networks in e-health hospitals will cut healthcare costs by enabling patients to get diagnosis and treatment anywhere at any time, such as recognising and managing a health problem while driving a car. The main challenges are to provide secure and reliable networks of low-cost, low-power devices that must operate with severe resource constraints. The network should be intelligent, and not transmit false alarms. In addition, an infrastructure has to be set

READ POINTER

Affordable healthcare and wellbeing:
> The challenge
> From Cure to Care

Scenarios
> Care at home and everywhere
> Early diagnosis and prevention
> Image guided intervention and therapy
> Clinical Decision Support (CDS) systems

READ POINTER

Affordable Healthcare and Wellbeing
> The challenge
> From Cure to Care

Scenarios
> Care at home and everywhere
> Early diagnosis and prevention
> Image guided intervention and therapy
> Clinical Decision Support (CDS) systems

up to pre-process the obtained data before presenting them in a concise way to medical professionals – this involves advance decision support, see below.

> Early diagnosis and prevention will be made possible through improved biosensors, enabling lab-on-a-chip and imaging systems allowing many diseases to be diagnosed – even before sufferers complain of symptoms – by 'in vitro' analysis or 'in-vivo' monitoring of biological samples (blood, saliva, sweat, etc.) and parameters (e.g. for cardiovascular & respiratory pathologies). Smarter, more accurate and cheaper solutions will help to spread these techniques to the physician and to the citizen ('the doctor in your pocket'). Seamless communication systems will serve as a hub in telemedicine between sensors and healthcare service providers. Highly reliable tests will identify those pre-disposed to certain diseases, allowing them to enter preventive programmes that will identify the early onset of the disease. Improved image detectors will lead to efficient, more precise and earlier detection of diseases. These improvements include increased resolution, higher data rates, and greater precision in the properties of the signals that are detected. In addition, the detection of other kinds of signals can lead to earlier detection of symptoms, and/or reduce harm to the patient. More precise and earlier detection also allows for significant dose reduction for a patient. For screening purposes, imaging systems without radiation will become cheaper, faster and more accurate. The main challenges are to provide secure and reliable networks of low-cost, low-power devices that have severe resource constraints. The system should be intelligent, and not generate false alarms. In addition, an infrastructure has to be established to rapidly pre-process the obtained data before presenting them in a concise way to medical professionals – this involves advance decision support, see below. Further image processing should be advanced to compare large amounts of images with each other and with 'standard' images

> Image Guided Intervention and Therapy (IGIT) will increase productivity and effectiveness in healthcare and reduce patient risk by supporting healthcare professionals in the transition from invasive, open surgery to minimally invasive IGIT[11]. The increase in productivity and effectiveness in healthcare enabled by image guided intervention is expected to significantly lower healthcare costs due to shorter hospital stay and higher throughput.
Image guided intervention and therapy involves medical diagnosis, planning and treatment of patients by minimally invasive placement of diagnostic and therapeutic devices such as catheters and stents inside the human body, enabled by medical image analysis and navigation methods. IGIT helps healthcare professionals to obtain better clinical outcome of treatment, predictable procedure

[11] *Minimal invasive image guided interventions are treatments via small punctures / holes in the skin or from outside the body without puncturing the skin, using pre- and/or intra-operative images (e.g. US, X-ray, MR, etc). These treatments range from intra-cardio vascular interventions, via ablations (such as RF, HiFu, laser) to radiotherapy treatments (such as Brachytherapy, external beam therapy, etc.)*

time, fewer complications, and lower morbidity and mortality rates. In addition, image guided intervention leads to a prolonged life, an improved quality of life and less discomfort for the patient.

Enabling this trend towards image guided intervention and therapy requires new medical image analysis and device specific navigation software and electronics to add interactive, interoperable and multiple modality characteristics to IGIT systems. Different medical systems need to be connected to operate in conjunction and be controlled by a user-specific, intuitive user interface. An example of such an interventional environment would be the combination of imaging, localisation and steering systems. Such a combination would allow for a fully automatic positioning of diagnostic and therapeutic devices, ready for an interventional procedure. The main challenges are the improvements in image processing to deal with low-dose images and be able to discriminate between different tissues, in real-time. Many images need to be compared quickly. This involves images of the same patient made from different positions, or with different modalities. Finally, advance decision support, supported by treatment planning, has to be available.

> Clinical Decision Support (CDS) systems are interactive computer programs that are designed to assist physicians and other health professionals with decision-making tasks. CDS systems support healthcare workers in the normal course of their duties, assisting with tasks that rely on the manipulation of data and knowledge. They are crucial for all other three scenarios above. Current examples of state-of-the-art systems are often integrated into Electronic Health Record (EHR) systems and provide alerts and reminders, for example when detecting a contraindication to a planned treatment or when detecting significant changes in a patient's condition.

CDS systems show clear potential for improving quality and efficiency in healthcare. The wide-scale deployment of CDS has been delayed mostly because of the unavailability of structured patient information. The deployment of EHRs and increasingly disciplined practices in patient data entry are key drivers for the rapid increase in CDS usage. According to market analysis (Frost & Sullivan), the CDS markets are expected to increase from € 159 m. in 2006 to € 289 m. in 2012. The potential benefits of using CDS systems in clinical practice fall into four broad categories:

- improved patient safety, through reduced medication errors and adverse events and improved medication and test ordering;
- improved quality of care, by increasing clinicians' available time for direct patient care;
- increased application of clinical pathways and guidelines, facilitating the use of up-to-date clinical evidence and improved clinical documentation and patient satisfaction; and
- improved efficiency in healthcare delivery, by reducing costs through faster order processing, reductions in test duplication, fewer adverse events, and changed patterns of drug prescribing favouring cheaper but equally effective generic brands.

The main *challenges* are the making of decisions based on data aggregated from different large data-sets, such as images, large volumes of different sensor data, or combinations thereof. This information may be polluted with a large noise level. Many decisions by the medical professional have to be taken in real-time, or with short latency.

Green, Safe, and Supportive Transportation

The world is well aware that transportation, whether automotive, marine, air, heavy-duty road vehicles or rail, is a major contributor to climate change and, in some localities, to the ill health of the local communities. The global car fleet alone is predicted to grow from 800 million to 1.6 billion vehicles by 2030 while ACARE estimates 4-5% growth in air traffic per year, which will more than double air traffic density in two decades. In the ever more interconnected world, there is a global trend towards *more* mobility, which must be *sustainable* mobility. The European transportation industry can remain competitive only by leading in green technologies.

Green transportation is likely to contribute significantly to the Europe 2020 priorities of developing an economy based on knowledge and innovation (smart growth) and promoting a more resource efficient, greener and more competitive economy (sustainable growth).

The Europe 2020 flagship initiative 'Resource-efficient Europe' seeks to promote new technologies to modernise and decarbonise the transport sector. The strategy on clean and energy efficient vehicles[12] which supports the goal of reducing carbon emissions by 80-95% by 2050 is essential for Europe. In Avionics and Railway Systems, similar targets have been set, e.g. in ACARE's SRA-1 a 50% reduction of CO_2, 80% reduction of NO_x and 50% reduction of noise levels. ARTEMIS acknowledges this initiative and also the European 'green cars' initiative launched as a part of the European Economic Recovery Plan in November 2008.

At the same time, there are increasing expectations for safety. The European Commission has a target of a 50% reduction of road accidents by 2020 compared to 2010, ACARE aims for 80% accident rate reduction by 2020 compared to 2001 and ERRAC's safety target for rail is to reduce passenger fatalities by more than 50% by 2020 compared to 2000 levels.

Notwithstanding sustainability concerns, citizens expect more and more mobility at lower and lower cost and risk. Demand by end users (drivers, rail or air passengers) for comfortable, on-time, assisted mobility has risen considerably during recent decades. This trend is accelerated by the demographic changes (cf. challenge on affordable Healthcare and Wellbeing), with more and more elderly people participating in transportation as car drivers, airline and railway passengers.

Vehicles, trains and airplanes will be mobile nodes in extended communication networks, where safety related and service related data will be transported, making considerable demands of autonomy, interoperability, safety, security and quality of service.

12 *COM(2010) 186, A European strategy on clean and energy efficient vehicles, 28.04.2010, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0186:FIN:EN:PDF*

READ POINTER

Three specific societal challenges in order to derive the research challenges and prioritise the Embedded Systems research topics addressed in this Strategic Research Agenda. These three societal challenges that take account of established European industrial expertise and infrastructure are:

- *Affordable Healthcare and Wellbeing*
- ***Green, safe, and supportive transportation***
- *Smart buildings and communities of the future.*

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Green, safe, and supportive transportation

Scenarios:

- ***Green mobility***
- ***Accident free mobility***
- *Supportive individual transportation*
- *Efficient, clean, safe and seamless mobility*

SCENARIOS

> **Green mobility:** Improved energy management in vehicles is extremely important as nearly 20% of primary energy is consumed in the transportation domain. The improvement will be achieved by a combination of intelligent traffic management and in-vehicle efficiency and emission improvements, with a goal of zero-emission vehicles.

It is estimated that about one quarter of present energy consumption can be saved via innovative Embedded Systems to measure and control energy consumption and emission.

Alternative drive train concepts will be introduced, including hybrid solutions as well as fully electric drives or fuel-cell vehicles. These power train concepts are feasible only via the extensive use of embedded systems.

Another important lever is the reduction of weight in vehicles not only through lightweight physical materials and structures but also by the use of active electronic safety systems to replace heavyweight mechanical structures as in ***'all-electric aeroplane'*** concept.

Intelligent traffic management will contribute further. Intelligent traffic information and control systems could reduce road traffic jams by 50% by 2017 (making savings of €50 bn. per year just for Germany).

Integration of data from different traffic information systems and from the 'smart environment' (see next societal challenge) will allow convenient and optimised choice of transportation system ('seamless mobility').

The environmental situation and demand-based toll systems may be used for intelligent control of traffic with a consequent reduction of pollution.

Better optimised, less stressful journeys, in a cleaner environment will make a significant contribution to holistic healthcare management.

> **Accident free mobility:** Traffic accidents are expensive not just in terms of finance: they are also a huge load on our healthcare systems, they waste energy and material resources, and they harm our economies through the disruption they cause at all levels of society.

Embedded Systems plays an essential role in achieving accident-free mobility. Numerous assistance systems for drivers, masters and pilots, and integrated safety systems are realised via a combination of software, a set of networked electronic controls systems and sensors and actuators.

Integrated communications with traffic control and management systems and a smart environmental infrastructure to optimise a journey will reduce the inherent risks as well as improve energy efficiency and reduce pollution.

In vehicles, the combination of the roles of the human and automation will continue to evolve. Pedestrian detection systems, for example, combine information from different sensors and use intelligent electronics to warn the driver or even automatically brake and influence the steering of the vehicle. Communication in the other direction ('Car2Pedestrian-communication'), via mobile terminals, will enhance pedestrians' awareness so as to further increase road safety.

> Supportive individual transportation (including elderly people): An ageing society and societal demands for 'access and inclusion' impose increasing demands on the safety and comfort of transport systems. Older drivers are able to compensate partly for their limitations via their experience, dedicated planning and strategy. Nevertheless, the evaluation of accidents reveals that the risk of injury and mortality is still considerably higher for older people.

Better traffic management and situational awareness systems (using the smart environment) will help, but more sophisticated assistive systems will both support the driver and facilitate the easy flow of traffic. Embedded Systems play an essential role enabling, for example, a comprehensive sensor based detection of the environment and optimal filtering and presentation of the situation. Assistive systems will also compensate for limitations such as the degradation of visual and hearing capabilities or personal immobility.

On-person and on-board healthcare management systems, including biosensors, will monitor the state of the driver and provide reminders and warnings and even take automatic action if necessary for safety. Their performance will be enriched by communication, via the smart environment, with the individual's regular healthcare management system.

> Efficient, clean, safe and seamless mobility: More and more infrastructure cannot solve all the transport problems from congestion and safety to containment of CO_2 emissions. The use of ICT technologies in the rail infrastructure and rolling stock, control command and signalling has helped rail transport to become not only a cheap mode of transport today but also one of the greenest and safest. For medium-distance travel high-speed trains are acquiring market share as users increasingly shift from road or air to rail transport. Today combining road, rail, air and water transport presents challenging alternatives in the form of multi-modal transportation using Intelligent Transport Systems (ITS) that relies on intelligent devices from computers to sensors and satellites, integrating new applications and services. ITS can help to reduce travel time and increase capacity and safety by improving signalling as well as by offering a wide range of services that can be used by passengers for planning and organising complete journeys or on-board entertainment. In addition, more efficient freight transport will help to reduce CO_2 emissions as well as improve interoperability, something that is still a major obstacle in some regions to free and smooth travel through countries and continents.

In brief, innovation in this area will help to make transport more sustainable, which means efficient, clean, safe and seamless.

Smart Buildings and Communities of the Future

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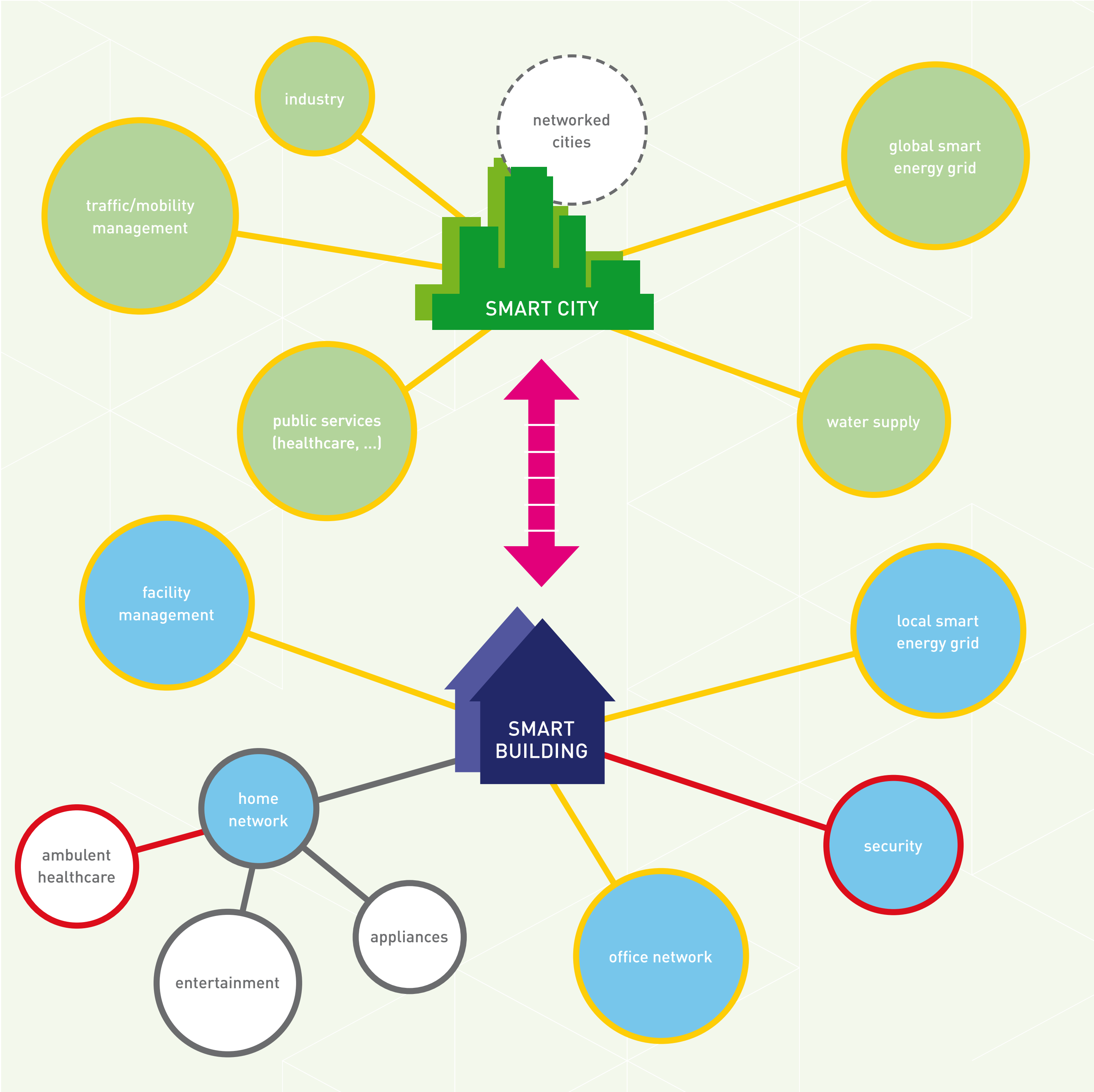
Three societal challenges that take account of established European industrial expertise and infrastructure are:

- *Affordable Healthcare and Wellbeing*
- *Green, safe, and supportive transportation*
- ***Smart buildings and communities of the future.***

Both urban and rural communities of the future will heavily rely on large, invisible networks of embedded systems. Distributed (and localised) energy generation, storage, distribution and management, water supply and waste management, mobility, healthcare, and security systems will all be efficiently controlled by seamlessly interacting large-scale service networks based on ubiquitous embedded systems. These Embedded Systems networks will combine the individual networks of future homes and offices with the networks of surrounding smart building facilities up to whole cities and regions. The Embedded Systems networks will further collaborate with the information infrastructure of the environment. At the same time, privacy will have to be preserved as far as possible. The city of the future will be spanned by a huge system-of-systems that will enable our society to respond to other societal challenges such as energy management, safe transport, and healthcare.

While city infrastructures and large buildings appear to be the first target of complex embedded system networks, in Europe more than 50% of the population lives in rural areas so that solutions for rural areas are of high importance also. Smaller communities and rural areas have their specific challenges that require similarly efficient Embedded Systems solutions. Communication networks span longer distances, have less bandwidth or are incompletely wired due to costs while public infrastructure including energy and water supply, healthcare, transportation and security is less dense, widely distributed and more at risk of disruption. This is even more the case in developing countries, where the access to power networks is difficult in remote areas, and alternative sources of energy are essential rather than additional.


industry
networked cities
traffic/mobility management
global smart energy grid
SMART CITY
public services (healthcare, ...)
water supply
facility management
local smart energy grid
SMART BUILDING
home network
ambulent healthcare
security
appliances
entertainment
office network

SCENARIOS

> **Mobility for everyone:** Many people today in both urban and rural environments suffer from limited mobility due to challenges in navigating, traffic stress, or extraordinary physical conditions of the individual. This group is very diverse, including seniors, children (that need careful surveillance), people with chronic diseases and people that are convalescing.

Future cities can be different. Embedded Systems can support the particular needs of individual citizens to drastically increase their mobility. Seniors will not only be able to stay much longer in their familiar environment - the main goal of developments today - but will even be able to safely participate in public life. When leaving home, they will take wireless medical monitoring with them. Within buildings, Embedded Systems will offer navigation adapted to the elderly, keeping track of their specific needs when opening doors, using elevators, and avoiding potentially difficult passages. When leaving the building, traffic surveillance will provide highly dependable real-time information of the surroundings, including approaching cars and other potential threats, and actively avoid accidents by feedback to the traffic, e.g. to cars, which might even include automatic emergency stops. ***(This scenario is closely linked to the 3rd transportation scenario, above.)*** In emergency situations, the systems will guide the assistance teams.
Moreover, these systems must able to adapt to an individual person's needs, abilities and health status, and to the amount expected and wanted by the individual. They will be informed by, and contribute information to, the healthcare management of the individual ***(see the 1st societal challenge, above)***. They will be self-learning and self optimising to maximise efficiency, safety, and comfort.

> **Energy control in the urban and rural environment:** Current cities and other urban or rural environments are inefficient energy sinks. More than 40% of their total energy consumption is spent on buildings, and a large amount is spent on city traffic. Much of this energy is wasted in a multitude of unconnected building control systems, private devices and transportation systems.

The urban environment of the future will be managed more optimally through monitoring and global control optimisation.

Devices that will be deployed in order to provide buildings and districts with more intelligence (i.e. sensors, actuators, control and communication systems) will consume less energy than the energy savings that can be achieved with them. Due to the huge number of devices needed, it will be ever more necessary for a significant proportion of them to be autonomous in terms of energy supply by the use of energy harvesting technologies, such as vibration, temperature gradients, photovoltaic cells, etc.

READ POINTER

Three societal challenges that take account of established European industrial expertise and infrastructure are:
> Affordable Healthcare and Wellbeing
> Green, safe, and supportive transportation
> Smart buildings and communities of the future

Scenarios
> Mobility for everyone
> Energy control in the urban and rural environment
> Security

Increasing numbers of sensors, actuators and control and communication systems will be progressively integrated to give new capacities to buildings. Information on their status will be available at any time so as to efficiently manage all the devices within the building: HVAC, intelligent lighting solutions, appliances, energy micro-generation and storage, etc. The same approach will be adopted outside the buildings, at district level, where all these technologies will be used to manage and maintain community energy-related services, such as outdoor smart lighting solutions, renewable energy systems at district level, micro-grid management, etc.

Smart metering services and Building Management Systems (BMS) as well as distributed energy generation and storage will gradually converge, enabling remote centralised management of buildings in order to achieve energy efficiencies at greater scale. Advanced optimisation methods will be adopted that will take into account information from various sources: climate, weather forecasts, time of year, time of day, user's profiles, etc.

In parallel, energy will be increasingly produced locally, using local thermal power stations, solar panels and micro-generation, and stored locally in, for example, car batteries or thermal buffers. Together these developments will lead to decentralised local smart power grids that will take all systems in the local area into account and take account of and exploit their interdependence. Supply will be better matched to demand and distribution losses will be minimised.

For instance, during working hours office buildings can benefit from the energy produced by residential buildings that are mostly empty, while during the rest of the day the energy exchange would go in the opposite direction thereby creating a balanced energy structure among the buildings within a city, adapting to grid load and injecting excess produced energy into the grid.

The transportation aspects of urban and rural energy management - which are at present addressed separately from energy management for the fixed infrastructure - will in future be considered part of the total urban energy management system. There are therefore close links with the 'Green mobility' scenario above, with more energy-conscious traffic management using - and being guided by - the monitoring and control systems of the urban environment and urban energy management including traffic management as part of the total urban system to be optimised.

It is important to consider the interrelation and balance between the energy management in urban environment with the energy production, transport and consumption of energy in rural areas where the smart grids are deployed. ….

> Security: The future urban environment will be more resilient to the wide range of security risks that we face. The risks range from breaches of personal security, terrorism and crime (requiring surveillance, prediction and counteraction) through health emergencies (needing fast detection and individual emergency care) to catastrophic situations such as earthquake, fire, floods, and environmental disasters (demanding coordinated actions for a large number of people).

Even though these security risks are very different in nature, their management will depend on real-time, robust functions with fast and seamless interaction between different sensors, information systems and embedded networks.

Security management in the future urban environment will benefit from the use of interacting embedded networks to rapidly gather, analyse and distribute huge amounts of sensor data, so as to observe the scene, recognise emergency situations, keep the public informed, and trigger and control management actions as well as, if necessary, emergency response and rescue actions. These include control of energy and water supplies, mobility support (including mobility for those with special needs), and control of the transport network, all of which can immediately and effectively support emergency, search and rescue actions.

Security management systems will do all of these things even when the energy and communication infrastructure is degraded or even partially or totally destroyed. They must also operate effectively in the presence of information security threats. With widely distributed embedded networks, a large amount of sensitive personal and public data are collected, communicated and locally and centrally stored. Controlling information access and guaranteeing privacy will be one of the key challenges, not only for the information system but also for the embedded system component and network hardware and software.

Information security is a challenge that is shared with the internet of things, but is much more accentuated in this scenario since information manipulation or obstruction may not only inhibit the effective management of other risks but also directly cause actions that could trigger emergencies and even catastrophes.

This security scenario is a good example of an important requirement for all future networked Embedded Systems on which the citizen and society depend: the core functionality must survive a communication system breakdown and continue autonomously in case the Internet is down, and establish alternative ***ad hoc*** communication.

Security risks threaten the envisaged worlds of all the scenarios described here. The designs of the systems that will enable each scenario must take into account the need not only to operate in 'normal' mode but also to interface to security management systems both to provide information so as to detect and manage risks, and to accept control to reduce risks or, in the worst case, to respond to emergencies.

SOCIETAL CHALLENGES DRIVE EUROPEAN COMPETITIVENESS

Whether by design or by evolution, society's responses to the various challenges that we face will create demands for new and enhanced services, systems, products, devices and technologies. They will also define new needs for infrastructures, public or private, new or existing.

Analysis of the role of Embedded Systems in addressing the societal challenges shows that responses to those challenges require systems interoperating across ***many*** and ***multiple*** application domains. The scenarios above have been developed with the purpose of breaking down the complexity of these challenges to manageable and comprehensible pieces and mapping them to application contexts and technological domains.

This Strategic Research Agenda therefore structures the inherent technological issues into a tangible research and innovation strategy spanning multiple application contexts to the benefit of both society and the economy.

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These demands create market opportunities for applications in a range of domains. ARTEMIS has grouped these application domains into a set of 'Application contexts' in which ARTEMIS believes that benefit will be derived from having common goals to focus and prioritise research, and also encourage coherence, compatibility and synergy of technological developments across specific application domains. **These Application contexts are:**

> **Industrial systems** - large, complex and safety critical systems that embrace Automotive, Aerospace, Healthcare, Smart Manufacturing and specific growth areas such as Biomedical;
> **Nomadic environments** - enabling devices such as smart phones and on-body systems to communicate in changing and mobile environments that offer users access to information and services while on the move;
> **Private spaces** - such as homes, cars and offices, that offer systems and solutions for improved enjoyment, comfort, wellbeing and safety, and lighting;

Industrial Systems

> **Public infrastructures** - major infrastructure such as airports, cities and highways that embrace large-scale deployment of systems and services that benefit the citizen at large (communications networks, improved mobility, energy distribution, intelligent buildings, …).

Application development in these domains is driven by both society's responses to the societal challenges that we face and the availability of new application products based upon emerging technology that can either respond to existing societal demand or create new societal expectations.

AUTOMOTIVE:
"Clean, safe car"

To reduce fuel consumption and pollution, the vision is that of a 'near-zero emission' car. The automotive industry in western European has already reduced the average fleet fuel consumption drastically. **In the future, the development of fully electrical vehicles will require Embedded Systems for the complex control strategy of the various integrated components.** Similarly, to reduce road fatalities, the '100% safe' car is envisioned, where neither the driver nor the vehicle is the cause of any incident.

These very ambitious goals can only be reached by using more intelligent systems - so called 'active safety' systems, where sensors, actuators and smart software embedded throughout the vehicle are combined with context awareness in the Human Machine Interface, and ad-hoc networking for car-to-car and car-infrastructure communication. **Together, these developments will enable optimally energy-efficient, safe driving that takes maximum benefit from a combination of both human and technological situational awareness and control.**

AEROSPACE:
"Customisable, time-efficient safe air transport"

The vision is of extremely customisable, affordable and sustainable life-cycle products and services for environmentally friendly, safe, secure and time-efficient transfer of people and goods within Europe and across continents. Within the next decade, most aerospace embedded system product lines will be platform-based and have 100% operational availability and reliability. They will offer full situational awareness and human-centred intuitive paperless operation to ensure total safety in any circumstance. They will enable the high bandwidth, secured, seamless connectivity of the aircraft with its in-flight and on-ground environment for passenger convenience and overall fleet management. They will support advanced diagnosis and predictive maintenance, guaranteeing a 20-30 year life-cycle supportable product.

HEALTHCARE:
"From cure to care"

Embedded Systems will play a major role in bringing cost effective solutions to the market that can actively contribute to this challenge. With a targeted approach, focusing on the consumer/patient and his or her specific disease(s) and treatment data, embedded technologies will be involved inside and outside the hospital to prevent, screen, diagnose, treat and monitor diseases, with improved patient comfort and enhanced treatment effectiveness.

The key application areas for healthcare are medical imaging, healthcare informatics and home monitoring. Early detection of diseases is also a very promising new application area.

MANUFACTURING & PROCESS INDUSTRIES:
"100% available factory"

The ambition is to reduce the environmental impact of manufacturing industries while maximising manufacturing efficiency. This will not only augment manufacturing employment in Europe but also assure jobs in the design, manufacturing, integration and servicing of the manufacturing equipment itself.

Embedded Systems will precisely control process parameters, including the active reduction of pollutants, to reduce the total cost and environmental impact of manufacture. Further competitive

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Application contexts:

- ***Industrial Systems - such as Automotive, Aerospace, Healthcare, Smart Manufacturing and specific growth areas such as Biomedical;***
- *Nomadic Environments - such as smart phone and on-body systems*
- *Private Spaces - such as homes, cars and offices*
- *Public Infrastructures - such as airports, cities and highways and services*

advantages will be achieved by controllability, flexibility and condition monitoring made possible through Embedded Systems solutions that will also reduce the need for maintenance, lowering cost still further.

Automation will support flexibility, from real-time product grade changes and process tuning to raw material quality changes. Improvement in end-product quality will be achieved through active control of the manufacturing process, moving from 'off-line' to 'in-process' quality control through advanced automation. Improved man-machine interaction through advanced Embedded Systems and "human-in-the-loop" control systems will improve quality, flexibility and productivity by assuring zero operator errors, as well as reduce accidents.

Manufacturing flexibility will assure agile adaptation to market demands, particularly for individual customisation. This will be achieved through reduced commissioning and production ramp-up times, allowing fast changes in product type or grade to be made. Concrete targets are to reduce commissioning time from 3 - 6 months to less than 1 month, and assuring quick turnaround times, where model changeover time is reduced from 8 -12 weeks to 1 - 2 weeks.

NOMADIC ENVIRONMENTS: "*Walk, Talk, Hear, See*"

Nomadic devices that access Internet-based services are already extremely widespread. The Internet is widely available and will be available almost everywhere. The next step will be Smart Environments that can be created ad hoc with existing devices and technologies. They may either be connected via services on the Internet or act independently. Connected to the internet they will act as the means to gain personal access to local and global services in the ubiquitous digital environment, using private and public information to provide a seamless experience of the world around us. Infrastructure applications will use data from nomadic devices to provide advanced and intelligent services. Applications and services will span from private to public, professional to social applications, in diverse environments.

The data needed for the services and applications will, in most cases, be provided by embedded systems. Despite technical progress, there is still a need to overcome the technical limitations that prevent communication with people and the provision of access to information and services anywhere at any time. Issues to be resolved include the demand for ubiquitous, secure, reliable, and instant access to information and services. User interaction and interfaces call for natural and intuitive, commonly adopted solutions. Light, handy, high-functionality, low-power terminals are demanded in which sophisticated energy management techniques and connectivity solutions provide the always-on always-connected experience.

Many applications will be of an ad hoc nature through self-organising Embedded Systems to create larger entities, and new services will be enabled by the semantic based aggregation of information that takes into account both user preferences and the actual context.

PRIVATE SPACES:
"Efficiency, safety and wellbeing in the home"

The establishment of business cases around new digital media has already been launched, though the goal of ubiquitous yet secure, safe and easy to use access to information and entertainment with appropriate content anywhere has yet to be realised. In addition, in the near future almost every object and device will be connected to some network, and often to the Internet. Collections of such objects and devices will form systems, such as the audio/video system in one's home.

Worldwide, lifestyles are changing and becoming more knowledge and convenience driven. But despite these changes, our societal values still reflect the industrial age in which productiveness and effectiveness are key drivers. As a result people are less physically active, have more stress, unhealthy nutrition patterns, less sleep and are sometimes isolated. Our societies create ageing populations, and we expect and need to be both productive and independent for longer, and to be engaged in society for longer.

A balanced lifestyle with sufficient and pleasant relaxation, an adequate activity level, involvement in society and the consumption of safe and healthy food forms the basis for a healthy life and is a necessity for an uncompromised independent life for the whole population, rich and poor.

Embedded Systems will enable, for instance, further improvement in the comfort and economic efficiency of the home - through a smart grid that manages energy use in an intelligent and rational way. At the same time, responding to the demographic changes that are apparent in society, Embedded Systems offers a safe and secure home for families, singles, elderly and disabled people, and via the Internet they enjoy the value of social networks.

In addition, the significant cost reduction possible in portable medical care equipment through the use of Embedded Systems will facilitate the introduction of eHealth and telecare services, by means of intelligent, portable devices and systems that will enable improved health monitoring and treatment.

Networked Embedded Systems will enable the augmentation of education (eLearning). This will help to bridge the 'Digital Divide', as well as enable participation in socially beneficial eGovernment schemes.

To realise all this potential, there is a need for multidisciplinary, multi-objective, systems design methods that will yield appropriate price/performance for acceptable power, with manageable temporal behaviour, and user-centred reliability and security within a multi-vendor environment.

READ POINTER

Application contexts:

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- ***Nomadic environments - such as smart phone and on-body systems***
- ***Private spaces - such as homes, cars and offices***
- *Public infrastructures - such as airports, cities and highways and services*

The reuse and certification of Embedded Systems will allow consumer lifestyle appliances to better adapt to a very fast market with cycle times of as short as 3 months.

Key technological ingredients will be access to sensor information, smart sensor fusion, smart reasoning algorithms, persuasion technology and efficient and effective actuation. Managing the complexity of the desired and ensuing system behaviour in the context of a large number of connected heterogeneous devices will be a considerable challenge.

PUBLIC INFRASTRUCTURES:
"*Secure and dependable environment*"

Our public infrastructures face many challenges if Europe is to maintain a competitive economy. They must enable improved mobility, of both people and goods, through fast, efficient, safe and accessible public transport (trains, metro, roads, maritime transport, …). They must enable the supply and efficient management of utilities and energy (such as smart grids, energy distribution, waste management, residual flows, …). They must offer a better connected communication infrastructure.

The application of Embedded Systems opens up real opportunities for improved operation and security of public infrastructures, with increased simplicity of use, connectivity, interoperability, flexibility and security.

A safer, more secure, better controlled road infrastructure (active road safety support, traffic management systems with more cooperative vehicles, active bridges, secure tunnels, …) can be achieved through greater integration of Embedded Systems to provide integrated end-to-end capabilities and active sensing and decision-making surveillance in undergrounds, railways, public spaces and communication networks

Buildings - public and private, integrating a variety of sensors and actuators, equipment for safe water and air, embedded lighting solutions and intuitive interfaces to naturally respond to user's needs - will be more comfortable yet more economical as well as provide secure access and exploitation.

Embedded Systems will also support all aspects of the lifecycle of such infrastructures including ownership, long-term storage, logging of system data, maintenance, alarms, actions by the emergency services, authorisation of access and usage, and charging and billing under a range of different conditions of use.

This future of intelligent public infrastructure will require the global integrity of large numbers of interacting, independent and autonomous systems from different organisations. This will pose new challenges for the integration of these intelligent sub-systems so they can be used collectively. Embedded Systems will have to be "network enabled", and incorporate capabilities of self-management, self-supervision and the means for self-organisation as well as failure auto-recover mechanisms.

READ POINTER

Application contexts:

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> Public infrastructures - such as airports, cities and highways and services

ARTEMIS: VISION, TARGETS & STRATEGY

The ARTEMIS vision

Despite the convergence occurring in various markets and supply sectors, the Embedded Systems markets tend to be fragmented, which has led to fragmentation of supply and in RTD investment. ARTEMIS wants to overcome this fragmentation through a new Embedded Systems industry that cuts the barriers between application sectors so as to 'de-verticalise' the industry and facilitate cross-sectoral sharing of tools and technology that are today quite separate.

The vision driving ARTEMIS is of mankind benefiting from a major evolution in our society whereby our world is widely supported by intelligent Embedded Systems, a world in which all systems, machines and objects become smart, have a presence in cyber space, exploit the digital information and services around them, communicate with each other, with the environment and with people, and manage their resources autonomously. The ubiquitous presence of the Internet provides the communication infrastructure for smart objects to be connected. Life in our society, along with security and safety, will increasingly depend on Embedded Systems technologies.

The ubiquitous presence of the Internet provides the communication infrastructure for smart objects to be connected. Life in our society, along with security and safety, will increasingly depend on Embedded Systems technologies.

ARTEMIS aims to establish a new, holistic approach to research, technology development, innovation and skill creation by means of innovation ecosystems that are sustained by 'eco-alliances' and 'co-opetition', thereby benefiting from the advantages created both by cooperation and by market competition, breaking the barriers that may exist in various other models, and redefining the value chain. This will increase the efficiency of technological development and, at the same time, enhance the competitiveness of the market in the supply of Embedded Systems technologies.

Therefore, the ARTEMIS vision nurtures the ambition to strengthen the European position in Embedded Intelligence and Systems and to ensure its achievement of world-class leadership.

> The ARTEMIS vision nurtures the ambition to strengthen the European position in Embedded Intelligence and Systems, to ensure its achievement of world-class leadership.

ARTEMIS envisages Embedded Systems playing a major role in responding to the Societal Challenges we face, while responding to the evolution of application markets and the emergence of new technologies.

This evolution will have a range of consequences for society and for the economy:

> the intelligent capabilities offered by networked and integrated Embedded Systems will determine the worldwide competitiveness of many conventional products, such as cars, machinery, medical devices;
> the smart environments that are envisaged will create completely new possibilities to develop application and services and to reduce costs and use of resources;
> the dramatically increasing importance of Embedded Systems to productivity growth and employment means that Embedded Systems technologies are critically important in redressing the present imbalance in productivity growth between Europe and the US and Asia.

The importance of Embedded Systems both to the economy and to quality of life makes it imperative for Europe to intensify its efforts in this area. European efforts must at least match, if not exceed, comparable investments being made in the US and Asia: the aim of ARTEMIS is for Europe to achieve leadership in intelligent, interconnected Embedded Systems.

This requires significant investment in research and development. ARTEMIS will facilitate and stimulate European success in Embedded Systems by:

> **establishing an environment supportive of innovation** in which both co-operation and competition in technological development are enhanced;
> proactively stimulating **the emergence of a new supply** industry for new components, tools and design methodologies supporting Embedded Systems;
> focussing research and development to make more effective use of resources, to **avoid fragmentation, and to facilitate deployment**.

ARTEMIS targets

To realise the full potential of this SRA, the stakeholders in the field of ARTEMIS should strive to realise the following, still valid targets contained in the SRA 2006:

> 50% of Embedded Systems deployed throughout the world will be based on ARTEMIS results and will have been developed within the engineering discipline established by ARTEMIS, encompassing hardware, software and systems design for Embedded Systems.

> Achieve the cross-domain connectivity and communication capabilities necessary to realise the seamless interoperability between the 'Ambient Intelligent Environments' envisaged for the European citizen (at home, travelling - in various modes, at work, in public spaces, …).

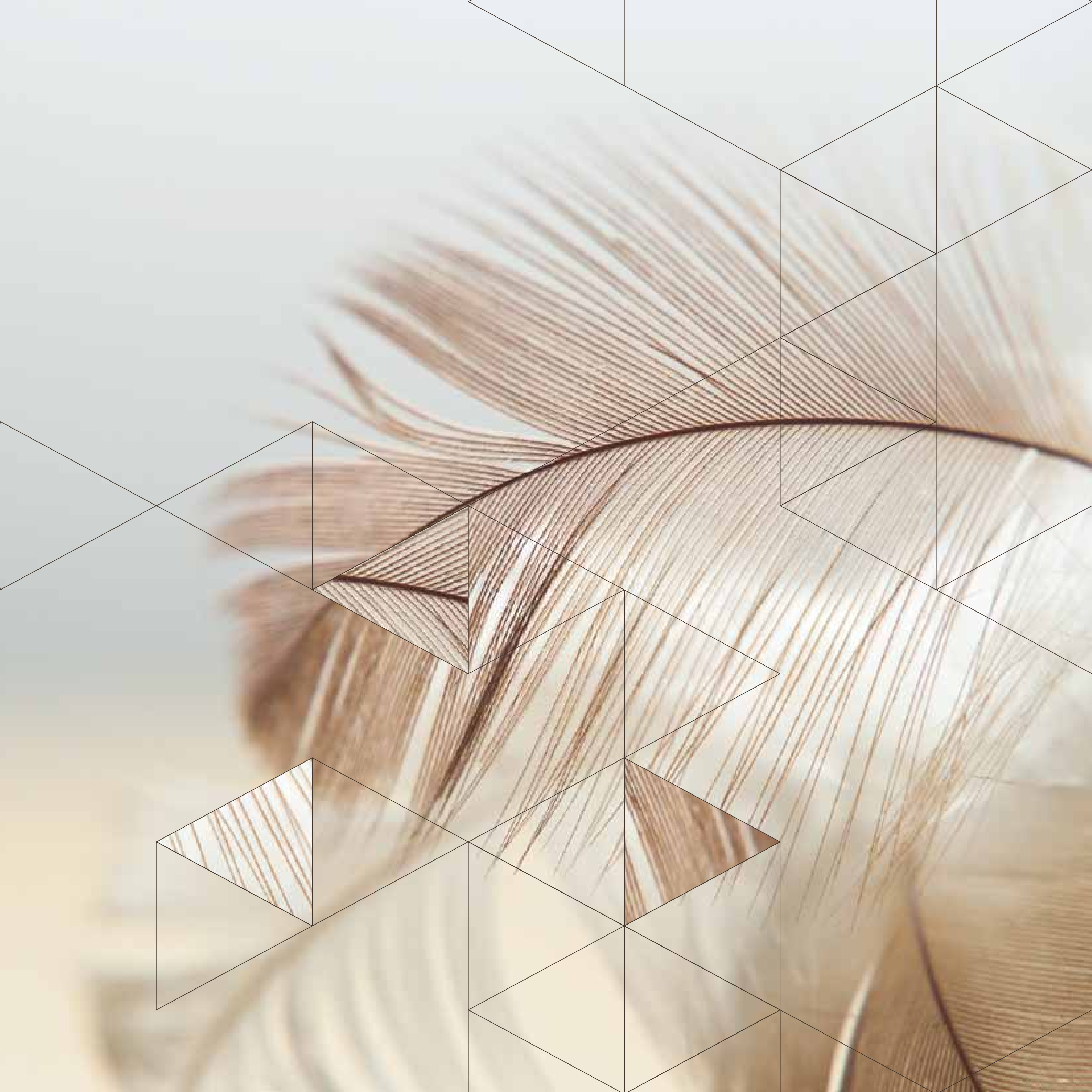
> There will be twice as many European SMEs within the aegis of ARTEMIS engaged in the Embedded Systems supply chain, from concept through design and manufacture, delivery and support, as there are today, through involvement in relevant "Centres of Innovation Excellence"

> There will be an integrated chain of European-sourced tools, based on ARTEMIS results, to support development of Embedded Systems from user requirements, through system design, to system-on-chip production.

> ARTEMIS will generate at least 5 'radical innovations' of a similar paradigm-breaking nature to the microprocessor, digital signal processing and software radio. As a general indicator of innovation, the number of relevant patents granted per annum to European companies engaged in ARTEMIS will have doubled.

> By 2016, the European research infrastructure and education system will have developed the capability to support the fast dynamic evolution of the Embedded Systems industry needs in terms of design skills, based on the ARTEMIS recommendations. Major educational programmes and technology acquisition programmes will be able to deliver new skills in less than 2 years.

> To close the design productivity gap between potential and capability, ARTEMIS will:
- reduce the cost of the system design by 50%. Matured product family technologies will enable a much higher degree of strategic reuse of all artefacts, while component technology will permit predictable assembly of Embedded Systems.
- achieve 50% reduction in development cycles. Design excellence will aim to reach a goal of 'right first time, every time' by 2016, including validation, verification and certification (to today's standards or higher)
- manage a complexity increase of 100% with 20% effort reduction. The capability to manage uncertainty in the design process and to maintain independent hardware and software upgradability all along the life cycle will be crucial.
- reduce by 50% the effort and time required for re-validation and re-certification after change, so that they are linearly related to the changes in functionality.
- achieve cross-sectoral reusability of Embedded Systems devices (for example, interoperable components (hardware and software) for automotive, aerospace, lighting, healthcare and manufacturing) that will be developed using the ARTEMIS results.



The ARTEMIS strategy

OVERCOME FRAGMENTATION

The bottom-up development and evolution of Embedded Systems in a wide range of different application sectors has led to a fragmented industry with a consequent fragmentation of RTD investment. This fragmentation hinders the interconnection of diverse systems that is needed to provide more efficient products and services to take advantage of the new technological capabilities (such as ubiquitous wireless connectivity, cloud computing, semantic information).

ARTEMIS aims to overcome this fragmentation. One aspect of the ARTEMIS strategy is to cut barriers between the applications contexts. This will stimulate creativity and increase the efficiency of technological development by yielding multi-domain reusable results. It will accelerate the horizontalisation of industries through common technologies, design principles and open information concepts. At the same time, it will open the market in the supply of Embedded Systems technologies to greater competition, benefiting both technological innovation and the end-user.

Recognising that the fragmentation of R&D effort will not be resolved if the scientific and technological needs are addressed piecemeal within the existing structures of markets and of scientific and technological communities, **the ARTEMIS strategy is to establish common technology to support the development of high value-added Embedded Systems solutions that are reusable across a wide range of application sectors and can be integrated so as to respond to the societal challenges.**

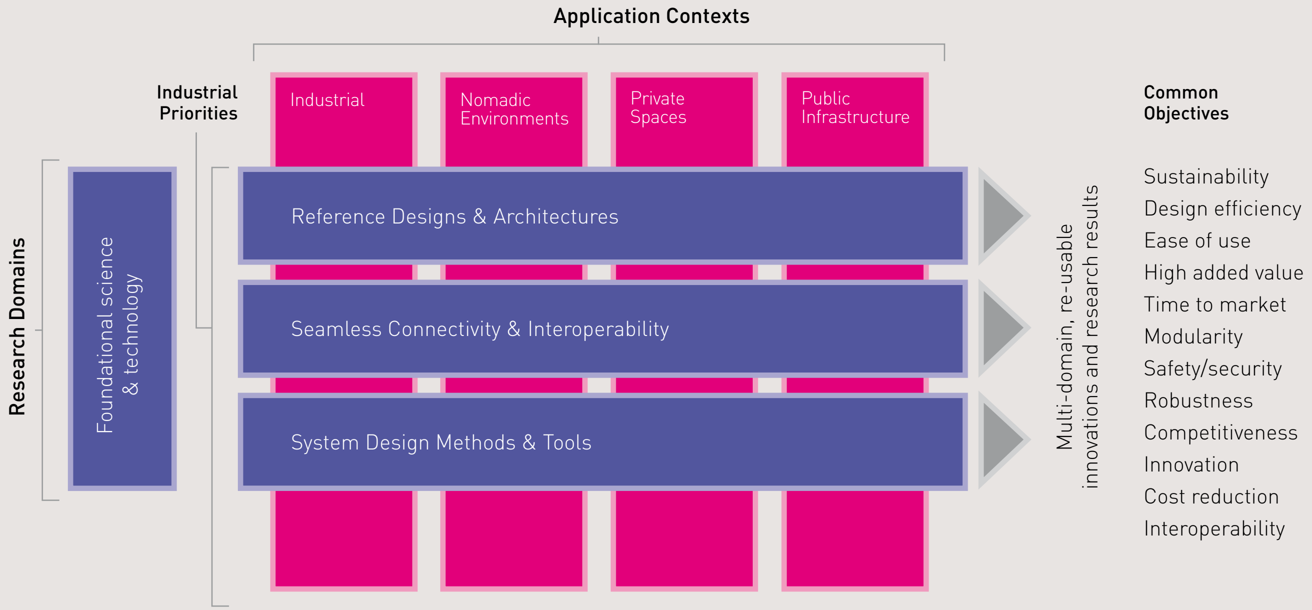


Figure: Relationship between the application and research dimensions of the ARTEMIS Strategy

This common technology is structured in three research domains, as a solid conceptual base for the diverse applications:

> *Reference designs and architectures*, to support product development in a diversity of application domains such as automotive, aerospace and nomadic environments.

> *Seamless connectivity and semantic interoperability* across application domains to support novel functionality, new services, and the formation of systems of systems to promote the emergence of services to enable the ambient, intelligent environment.

> *Systems design methodologies and associated tools* for rapid design and development.

Application-oriented research and development in these technological domains will be supported by generic enabling technologies derived from foundational science.

The relationship between the application and research dimensions of the ARTEMIS strategy is shown in the figure above.

ARTEMIS and the Societal Challenges

The analysis of the role of Embedded Systems in addressing the societal challenges shows that responses to those challenges require systems that must interoperate across many application domains.

The original ARTEMIS aim to achieve multi-domain compatibility, interoperability and even commonality was already moving in this direction. This Strategic Research Agenda goes further: the societal challenges will be used to structure the inherent technological issues into a concrete research and innovation strategy spanning multiple application contexts, with results that will benefit both society and the economy.

Scenarios have been developed to break down the complexity of these challenges to manageable and comprehensible pieces and map them to application contexts and technological domains.

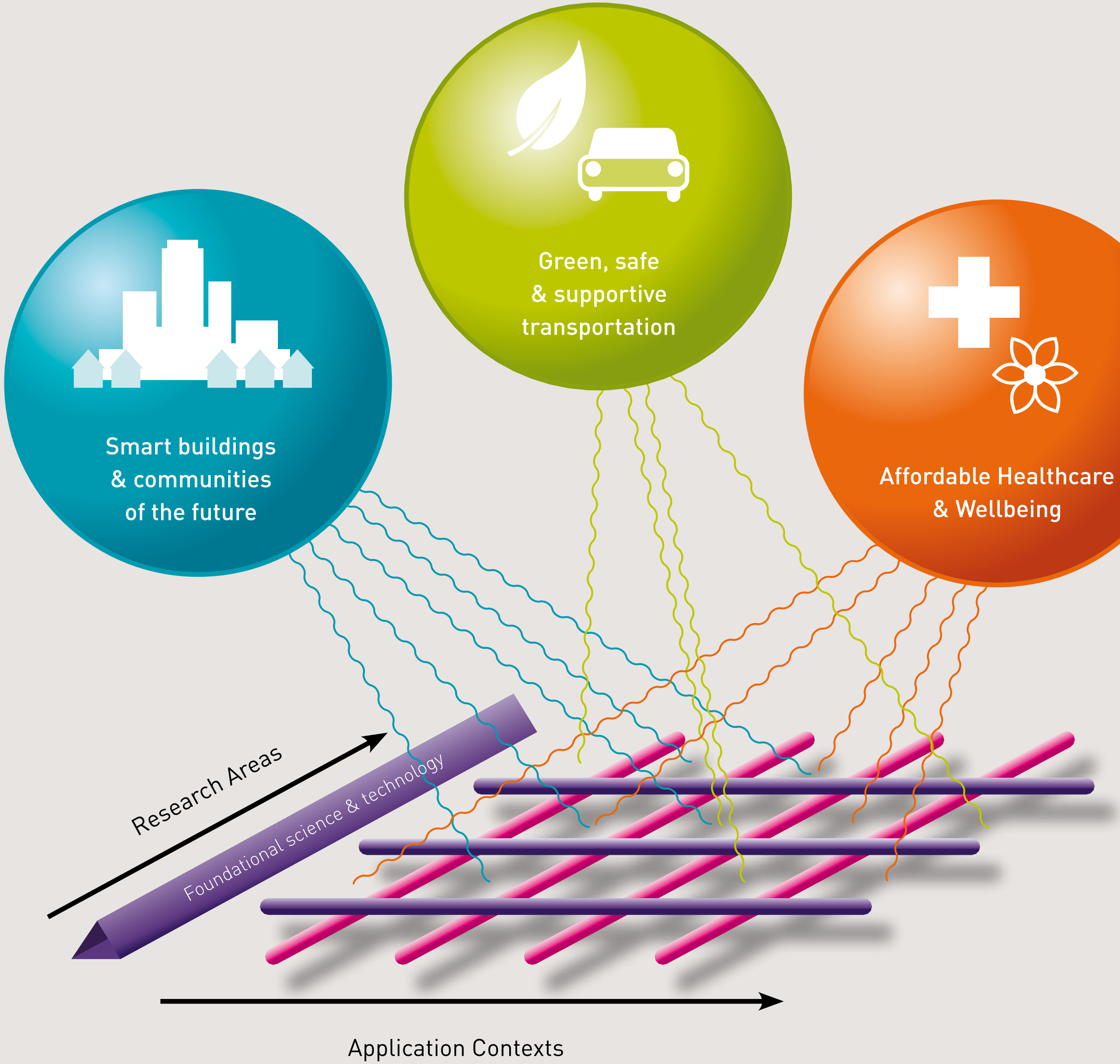


Figure: *SRA applications contexts, research priorities and societal challenges into perspective*

The matrix approach as presented on page 56 has now been extended to a three-dimensional representation, which puts applications contexts, research priorities and societal challenges into perspective.

Closer investigation of the societal challenges has highlighted the importance of interoperability, of system autonomy, of networking - including use of the Internet - and of the consideration of mixed criticality.

This 'bigger picture' for Embedded Systems implies change from local networks with local designer responsibility to open networks of embedded systems. This leads in turn to a change from single system ownership to multiple design processes and responsibilities involving many parties with conflicting objectives.

There is a change from static networked Embedded Systems to systems-of-systems which are highly dynamic and evolving and are never down. The convergence of applications on open networks introduces requirements for component and network safety, availability and real-time behaviour in areas where such requirements have not been an issue so far, such as in home networks and car-to-infrastructure communication.

Future internet will extend its role from a backbone of the information society to a communication and integration vehicle for a rapidly growing world of Embedded Systems that will far outnumber people using the Internet - leading European suppliers of Embedded Systems cores have already shipped over 18 billion embedded processors. The internet will become part of the seamless integration challenge and must be enabled to safely and reliably handle many different embedded applications. The internet will not replace current embedded system networks but connect such networks. Since Internet communication cannot be expected to reach the same quality as provided by current, dedicated, embedded system networks, Embedded Systems must be made more autonomous and robust to compensate for the reduced real-time and reliability guarantees, and must operate dependably even in the presence of network degradation and temporary failure.

> There is a change
> from static networked Embedded Systems
> to systems-of-systems
> which are highly dynamic and evolving
> and are never down.

ARTEMIS RESEARCH PRIORITIES

The main goal is to improve the business and competitiveness of participating industrial players. Consistent with achieving the high-level targets described on page 52, it is planned to reduce the lifecycle cost of Embedded Systems and time to market - in other words to provide practical answers to the pressing problems of poor productivity and quality of services caused by the growing 'productivity gap' and the increasing complexity challenges.

ARTEMIS highlights two parallel sets of research objectives:

> Technical solutions that form the basis of developing the pre-competitive *industrial* goals, by attacking the extreme complexity of new systems through improved design and implementation processes and tools, and
> Research into *scientific foundations and technology* that will offer completely new solutions to the technical barriers that hinder progress towards the application context's goals.

The research required to achieve these objectives falls into three main areas:

> Reference designs and architectures
> Seamless connectivity and interoperability
> Design methods and tools.

The main topics of research in each of these areas are outlined below.

REFERENCE DESIGNS AND ARCHITECTURES

The objective is the creation of an energy efficient generic platform and a suite of abstract components with which new developments in different application domains can be engineered with minimal effort. A well-conceived platform will also allow the addition of application-specific modules, thereby extending the reach of the reference design into more advanced and diverse application domains. They will challenge the functional and physical complexity issues and embrace all areas of the target application, also addressing functional and non-functional items such as:

> Composability - a scalable framework that supports the smooth integration and reuse of independently developed components is needed in order to increase the level of abstraction in the design process and to reduce cognitive complexity.
> Dependability and security - the provision of a generic framework that supports mixed criticality, safe, secure, maintainable, reliable and timely system services despite the accidental failure of system components and the activity of malicious intruders is essential.
> Certification - the control of physical devices and processes, e.g., office and shop-based digital pharmacy labs or service robots that interact with humans performed by Embedded Systems makes it necessary for the design to be certified by an independent certification authority. The envisioned architecture must support modular certification.
> High-performance embedded computing - for scalable multiprocessor computing architectures and systems incorporating heterogeneous, networked and reconfigurable components. The increase by several orders of magnitude of computing power will be key for achieving embedded intelligence in areas such as perception, multi-media content analysis, autonomy, etc
> Low power - the advent of Giga-scale SoC will require system level techniques for handling the power dissipation of silicon, such as power gating and integrated resource management.
> Interfacing to the environment - new ways of interfacing with the natural and the man-made environment, and in particular more intuitive ways for humans to interact with both technical systems and each other.
> Interfacing to the internet - the internet with its limited reliability and timing predictability challenges Embedded Systems dependability and end-to-end timing requirements. New communication protocols and control mechanisms

are needed to reach a suitable level of communication predictability and to adapt Embedded Systems functions to communication uncertainties.

SEAMLESS CONNECTIVITY AND INTEROPERABILITY

Seamless connectivity is vital for future Embedded Systems. Its requirements pervade the middleware, operating systems and other functions required to link the physical world, as seen by the networked nodes, and also the higher layer applications, as well as hardware features needed to support an efficient and effective interoperability implementation. The following topics should be addressed in this area:

> Certifiable operating systems (micro-kernels and hypervisors) that can be distributed and composed, and are able to support dynamic reconfiguration.
> Opportunistic flexibility - taking advantage of the currently accessible opportunities e.g. network connection to a cloud, to dynamically improve the quality of service.
> Ubiquitous connectivity schemes that support the syntactic and semantic integration of heterogeneous sub-systems, under the constraints of minimum energy usage and limited bandwidth.
> Self-configuration, self-organisation, self-healing and self-protection of the computational components in order to establish connectivity and services in a particular application context, using knowledge autonomously acquired from the environment and enabling dynamic reconfiguration.
> Perception techniques for object and event recognition in order to increase intelligence in Embedded Systems and make distributed monitoring and control tasks in large-scale systems possible.

DESIGN METHODS AND TOOLS

Design methods and tools for Embedded Systems have to support the introduction of disruptive hardware and software implementation technologies and, together with appropriate architectural principles, enable the corresponding innovation promises from these technologies to be turned into real products. They must enable designers to handle the increasing complexity resulting from the technological evolution of embedded devices. They must also make best use of the existing array of formal, semi-formal, and experience based methods and tools, and enable integration of related tools into consistent tool chains and tool platforms. And they must take account of novel challenges coming from dynamically reconfigurable systems, increasing autonomy, and mixed criticality.

To manage architectural complexity during design while ensuring maturity at introduction under strong time-to-market constraints, methods and tools for Embedded Systems should bring innovations targeting:

> Multi-viewpoint engineering, and design exploration
> Incremental development, incremental validation, incremental certification, in particular for mixed criticality systems
> Early verification and early validation of non-functional properties
> Early detection of design errors and integration risks, in particular for mixed criticality systems
> Capitalisation of experience, and the embodiment of that experience in design rules.

The collection of novel tools and design flows to be developed is called the 'ARTEMIS Method'. This will require research into the following topics:

> Design tools that can be integrated into the core design process workflow that address heterogeneous structures, particularly power efficient mapping on heterogeneous multiprocessing devices and complex memory hierarchies.
> Certification of mixed criticality systems and the development of well structured safety cases such that the safety of a proposed design can be convincingly demonstrated.

- > Advanced control algorithms to find optimal operating points in Embedded Systems that are characterised by non-linear behaviour.
- > Embedded fault handling, relying on model-based fault detection at run-time, and associated algorithms for fault tolerance.
- > Design process management that addresses complexity, product hierarchy, supply chain and information flow management. The integration of models that look at the system from different viewpoints will be investigated. The interoperability between tools and procedures that are included in the 'ARTEMIS method' must be established.
- > Open interface standards, with agreement on the intellectual property rights of the specific tools developed to support it.
- > Traceability of component properties and their attributes, including safety and dependability, during development and integration.
- > Product lines of embedded systems.

FOUNDATIONAL SCIENCE AND TECHNOLOGY RESEARCH PRIORITIES

The scientific research that will be undertaken in ARTEMIS will provide a scientifically rigorous basis for the ARTEMIS reference designs, architectures, middleware and communication techniques. The results will be embodied in the methods and tools of ARTEMIS so that the artefacts produced with them will be guaranteed to have the required properties.

ARTEMIS foundational science and technology research will generate new solutions to recognised problems and will explore the 'unknown' so that a steady flow of innovative ideas in the field of novel Embedded Systems is maintained. In addition, participation in the ARTEMIS research programme will make a significant contribution to the education of a highly skilled, multidisciplinary workforce.

INQUIRY-DRIVEN FOUNDATIONAL RESEARCH AND TARGETED FOUNDATIONAL RESEARCH

ARTEMIS distinguishes inquiry-driven foundational research from targeted foundational research. Inquiry-driven foundational research tries to achieve a better understanding of the fundamental principles and processes that are at the core of a domain of science. Deep-seated innovations, accompanied by a strategic paradigm shift of the prevailing opinions, often have their origin in spontaneous insights gained from inquiry-driven foundational research. There are abundant examples in the history of science that major scientific breakthroughs are the unexpected result of an inquiry-driven research effort. While it is impossible to plan for concrete results in the field of inquiry-driven foundational research, it is planned to set aside a limited amount of resources for establishing a stimulating environment where the most creative European researchers from the field of Embedded Systems can work together and communicate freely in order to achieve a deeper understanding of the basic issues. Care must be taken that this free research climate is not undermined by unreasonable demands for short-term results or the pressure to support the prevailing current opinions.

In contrast to the *inquiry-driven foundational research, targeted-foundational research* is goal oriented. We distinguish between proactive and reactive targeted foundational research. Proactive *targeted foundational research* is focused on a specific set of targets that must be reached in order to bridge the gap between new insights gained from *inquiry-driven foundational research* and the starting point of a *pre-competitive research* effort. Reactive targeted-foundational research tries to find a science-based solution to problems that have been encountered in industry.

Both *proactive and reactive targeted-foundational research* will be organised collaboratively between academia and industry, where the lead will be with the scientific party that has a proven strong research record in the field of *inquiry-driven foundational* *research*. The planning for the field of targeted-foundational research must be flexible in order to be able to adapt quickly to the results emerging from the the *inquiry-driven foundational research* and to problems encountered in industry.

FOUNDATIONAL RESEARCH TOPICS

Foundational science and technology for ARTEMIS will address:

> bridging physics and computing: so that Embedded Systems will be context-aware and able to make optimum use of available resources – not just computational resources, but also time, space and energy, and sensing the context and dealing with material properties.

> hard real-time control: the automatic synthesis of control systems from abstract algorithms, taking into account distribution, heterogeneity, deferred implementation commitment and autonomous management of all types of resource. On multi-core and networked systems, hard real-time systems requiring worst case guarantees increasingly coexist with less demanding and less predictable soft real-time systems. Soft real-time systems often work with probabilistic guarantees and less accurately specified behaviour. New integration methods and validation approaches are needed to correctly and efficiently integrate such mixed real-time systems.

> mixed criticality systems: integration of applications with different safety requirements merged on the same embedded system components and communication channels require new approaches to integration, qualification and incremental certification.

> novel computing architectures that do not (necessarily) respect the conventions of data and instruction similarity, linear memory access, control flow priority and separation of data from semantics.

> self-organising and dynamically adaptive systems: to achieve predictable system properties from the complex composition of a heterogeneous set of (possibly unreliable) components with evolving functionality.

> modular, heterogeneous, composable systems and self-organising, adaptive systems: to achieve predictable system properties from the complex composition of a heterogeneous set of (possibly unreliable) components.

> dependability and security: radical design and verification methodologies that will enable correct-by-construction design with automatic co-verification so as to achieve an order of magnitude advance in productivity and allow privacy and content protection in dynamic and distributed environments.

Finally, several alternatives and emerging technologies allow many of the bottlenecks in existing architectures to be overcome. Examples of such technologies are emerging non-volatile memory technologies (such as PCM, MRAM, Memristors, etc.) and silicon photonics which have the potential to can increase the on-chip bandwidth communication by several orders of magnitudes. Mastering these technologies and studying their potential short and medium term impact on our systems is of vital importance for the European industry.

Technology domains and challenges

THE CHANGING CONTEXT OF EMBEDDED SYSTEMS RESEARCH

This version of the ARTEMIS SRA does not supplant the SRA 2006; the major challenges set out then are still valid. The search for architectural and design techniques to support design by composition and extensive re-use continues, as does the search for cross-domain solutions.

Instead, the ARTEMIS SRA 2011 modifies some of the existing challenges and introduces additional grand research challenges – referred to as 'major challenges'- so as to take account of the societal challenges and the ever-increasing importance of networked intelligence in the short, medium and longer terms.

These changes place increased emphasis on inter-operation across domains, with communication among an ever wider range of systems, sub-systems, devices and components from different providers, which means that the validity of the information and the functionality that they provide cannot be guaranteed. Yet the end-user must have confidence in the service with which they are provided.

This SRA also recognises that the abstractions that underpin present Embedded System design techniques are inappropriate for real-world system validation, since they decouple the computational domain from the physical domain in which we live. It also recognises that Embedded Systems should be considered as cyber-physical systems.

Open internet

There is a change from local networks with single system ownership (OEM) to open networks of Embedded Systems with multiple and distributed design processes and responsibilities involving many parties with conflicting goals and objectives.

At the same time, these networks are no longer predefined and static but are highly dynamic and evolve over time. Such widely connected systems are never down and must evolve in the field and at run-time. Many different functions converge on these open networks requiring different service guarantees which tend not to match the quality-of-service requirements of information services.

So, the Internet or similar open networks will extend their role from a backbone of the information society to a communication and integration vehicle for a rapidly growing world of embedded systems. There will be many more Embedded Systems using the Internet than people: they will form large systems-of-systems. Consequently, the Internet must include and match the specific requirements of such networked Embedded Systems (which is not the case today). If this goal cannot be achieved, the Internet will turn from being an enabler to an obstacle of Embedded Systems innovation.

Robustness, autonomy, and mixed critical systems

Despite highly dynamic functionality and topology, Embedded Systems networks must be robust and reliable. Trying to meet both goals for all applications would likely end in expensive and energy-inefficient solutions, if at all possible. New approaches including protocols, network control and hardware/software architectures are needed that can efficiently handle widely different application requirements and scale to large robust yet flexible networks. Robustness should extend to dynamically changing connections to support mobility.

Embedded applications with different dependability and real-time requirements will share the same network and hardware components. This can be concluded from several of the scenarios described earlier, such as in supportive transportation or care at home and everywhere. This convergence leads to the new challenge of mixed criticality systems and components, of incremental and evolutionary systems and of new architectures to support this mixed criticality. Such systems and components must be able to simultaneously serve different applications dependably, in real time, and meet energy requirements. The components and systems must, furthermore, be adaptable since the requirements may change over time.

It will not be possible to provide the required robustness and dependability at all times. In such situations, the local embedded system must be able to work autonomously on local resources and data. Autonomy is also increasingly important to adapt to changing application contexts and network environments. Features like self-protection and self-optimisation will support dependability as well as maintenance and configuration. These features will become a necessity with the growing number of Embedded Systems that cannot individually be controlled by individual people any more.

Real-life experiments in Living Labs

Besides the normal test and validation cycles in the normal design processes, Living Labs will become more and more necessary. Wikipedia defines a Living Lab as a user-centred, open-innovation[13] ecosystem, often operating in a territorial context (e.g. city, agglomeration, region), integrating concurrent research and innovation processes within a public-private partnership. Examples of a Living Lab are the High Definition Television experiments during the European Soccer Championships in Berlin and the Video on Mobile experiments during the Olympic games in Beijing. ARTEMIS will support the definition of Living Labs as an experimentation environment where new concepts can be validated in a real-life environment

[13] *In Wikipedia : Open Innovation is a term promoted by Henry Chesbrough, a professor and executive director at the Center for Open Innovation at UC Berkeley, in his book Open Innovation: The new imperative for creating and profiting from technology[1]. The concept is related to user innovation, cumulative innovation, Know-How Trading, mass innovation and distributed innovation.*

The concept is based on a systematic user co-creation approach integrating research and innovation processes. These are integrated through the exploration, experimentation and evaluation of innovative ideas, scenarios, concepts and related technological artefacts in real-life use cases. Living Labs enable concurrent consideration of both the global performance of a product or service and its potential adoption by users. This consideration may be made at the earlier stage of research and development and through all elements of the product life cycle, from design to recycling.

A Living Lab differs from a test-bed in that its philosophy is to change the role of user-observed subjects for testing modules against requirements into value creators that contribute to the co-creation and exploration of emerging ideas, breakthrough scenarios, innovative concepts and related artefacts. Hence, a Living Lab rather constitutes an experiential environment, which could be compared to the concept of experiential learning, where users are immerged in a creative social space for designing and experiencing their own future. Living Labs could also be used by policy makers and users/citizens for designing, exploring, experiencing and refining new policies and regulations in real-life scenarios by evaluating their potential impacts before implementation.

The Living Lab process, which integrates both user-centred research and open innovation, is based on a maturity spiral concurrently involving a multidisciplinary team in the following four main activities:

> Co-creation: bring together technology push and application pull (i.e. crowd-sourcing, crowd-casting) into a diversity of views, constraints and knowledge sharing that sustain the creation of new scenarios, concepts and related artefacts.

> Exploration: engage all stakeholders, especially user communities, at the earlier stage of the co-creation process for discovering emerging scenarios, usages and behaviours through live scenarios in real or virtual environments (e.g. virtual reality, augmented reality, mixed reality).

> Experimentation: implement the proper level of technological artefacts to experience live scenarios with a large number of users while collecting data which will be analysed in their context during the evaluation activity.

> Evaluation: assess new ideas and innovative concepts as well as related technological artefacts in real-life situations through various dimensions such as socio-ergonomic, socio-cognitive and socio-economic aspects; make observations on the potentiality of a viral adoption of new concepts and related technological artefacts through a confrontation with users' value models

The following specifies the major challenges for the technology domains that must be addressed by ARTEMIS in the light of recent changes in the short, medium and longer terms along a roadmap in accordance with the implementation programmes (being European, national or regional).

READ POINTER

ARTEMIS research priorities

> Reference designs and architectures

> Seamless connectivity and interoperability

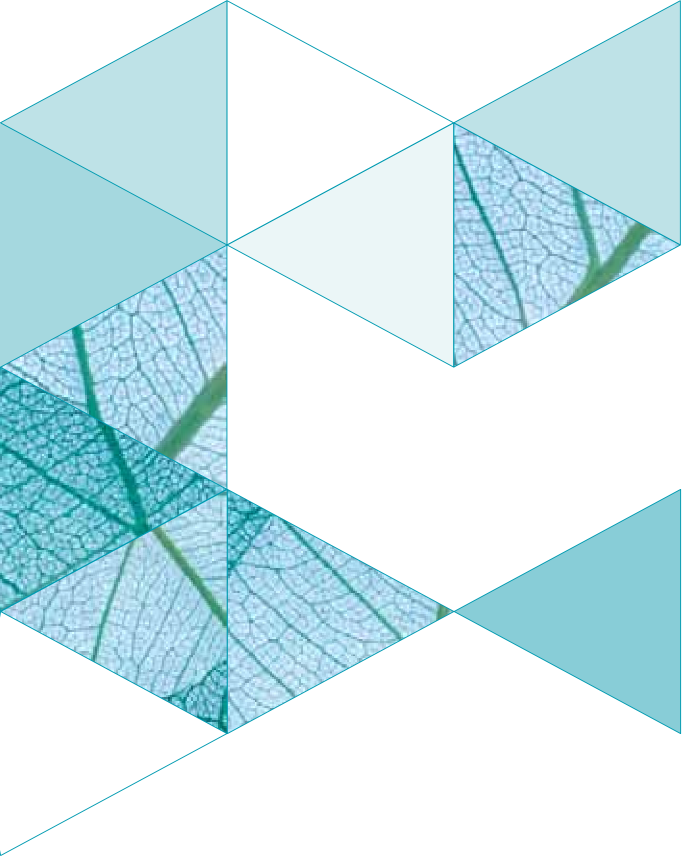
> Design methods and tools

> Foundational science and technology research priorities

Technology domains and challenges

> The changing context of Embedded Systems research

> Major Challenges for technological research



READ POINTER

ARTEMIS research priorities
> Reference designs and architectures
> Seamless connectivity and interoperability
> Design methods and tools
> Foundational science and technology research priorities

Technology domains and challenges
> The changing context of Embedded Systems research
> Major Challenges for technological research

MAJOR CHALLENGES FOR TECHNOLOGICAL RESEARCH

Embedded System architecture

The major challenge in the field of Embedded System architecture relates to development of a generic framework that supports the interoperability of a set of pre-validated components while making minimal assumptions about the internal structure and implementation of the components.

Architecture modelling and exploration solutions are needed to offer techniques, methods and tools to guide, optimise and assess systems/multi-systems and systems of systems architecture choices against business and operational criteria (e.g., cost, minimisation of system interfaces, mass, safety, reliability …).

Embedded System architecture will address the following research topics:

Architecture: composability, architectural services, legacy integration (hardware obsolescence), Architecture Description Language (ADL), cross-domain applicability, power management

Interface specification: operational specification, temporal specification, interface state, pre and post conditions, interface models, Interface Description Languages (IDL), rich interface specification. Networks and Internet-of-Things as communication channel.

Timeliness and power: WCET analysis, power-aware scheduling, dark silicon for power minimisation; Dynamic Voltage Scaling (DVS), power estimation, clock synchronisation.

Networking: on-chip networks, communication primitives, determinism, testability, diagnosis.

Systems design

The major challenge in the area of system design is to develop design methodologies and their associated tools to respond to the ever-increasing complexity of large systems. System analysis methods have to provide a usable suite of analysis methods covering all phases and all viewpoints in the development of safety critical embedded systems, including cross-viewpoint dependencies, enabling cost-efficient certification.
Structured design methods, such as model-based design and component-based design that lift the design process to higher level of abstraction are viewed as possible solutions for the rigorous design of dynamic embedded applications out of pre-validated heterogeneous components and for building reliable systems from unreliable components.

System design will address the following research topics:
Methodologies and tools: automated software synthesis, model driven design, platform-based design, middleware, operating systems, architecture-aware compilation, integrated design environments, virtual design analysis, simulation

Modelling: interdisciplinary modelling physical system, computer system, control algorithms, parametric optimisation, system architecture modelling and languages, electronic platform modelling, concurrent modelling, performance and resource models, multi-domain models, engine transmission modelling at the critical path for new model development.

Validation

The major challenge in the area of validation is the reduction of the overall effort required to demonstrate convincingly that a given quality level of a system service has been achieved. At present, the effort for validation and certification amounts to a substantial fraction of the development cost of large embedded applications.

Validation will address: formal analysis, modular certification, test bench for component validation, diagnostic, safety case analysis and FMEA.

READ POINTER

Major challenges for technological research:

- > *Embedded System architecture*
- > *Systems design*
- > *Validation*
- > ***Design for safety***
- > ***Dependability***
- > ***Communication***
- > ***Silicon scaling***
- > ***Heterogeneous parallel systems***
- > ***Sensors and actuators***
- > *Smart environments and systems*
- > *Man-Machine interfaces*
- > *Distributed computing platform*
- > *Self-organising and Autonomous systems*
- > *Systems of systems*
- > *Certification*
- > *Resource management*
- > *Energy and power*
- > *Interoperability*
- > *Tool integration*
- > *Cloud computing*
- > *From syntactic to semantic interoperability*

Design for safety

From the perspective of developing safety-critical systems, adequate solutions are required for ensuring dependability, e.g., through specification, architecture, and verification. Many safety-critical systems are subject to certification. Requirements management will be improved to ensure completeness, consistency, correctness, verifiability and traceability of functional and extra-functional requirements across the supply chain based on requirements formalisation and management. Challenges are:

- > Model-based design with standardised information flows between abstraction levels;
- > Model-based certification ;
- > Component-based design providing techniques, methods and tools to design, validate, verify, certify/qualify products made of available or new components in the context of safety-critical systems;
- > Methodology and tool support for building reliable systems from unreliable components, detecting conflicting requirements impacting safety, insuring testability and observability;
- > Adequate programming models for multi-processor systems-on-a-chip in safety-relevant embedded systems;
- > Modular certification;
- > Security aspects of safety-relevant Embedded Systems (e.g., protection of temporal properties of hard real-time systems, timing effects of security mechanisms);
- > Co-existence of new modelling and validation techniques and legacy practices;
- > Extension of the modelling and validation techniques from software intensive systems to mechatronics systems;
- > Integrated safety and Quality of Service (QoS) in Embedded System design;
- > Platform technologies for safety-relevant embedded systems: communication services, diagnostic services, robustness services, security services) as a stable baseline for the development of safety-relevant embedded applications.

Dependability

Major challenges in the area of dependability include the provision of a generic framework that supports secure and dependable, reliable and timely system services despite the accidental failure of system components and the activity of malicious intruders. This requires technologies for the dynamic reconfiguration of nearly autonomous sub-systems.

Information security deals with the intrusion tolerance, low-cost security, denial of service, authenticity, integrity and confidentiality. Detecting tolerant architectures will be essential for building economical giga-scale computing systems (IEEE134850). Security dependability will address the following research challenges/topics:

Fault tolerance: fault-hypothesis for different application domains, transparent fault tolerance, formally verified error-masking mechanisms, determinism at all system levels, consistent global state in distributed systems, fault-tolerant clock synchronisation, state-aware system design, reliability modelling, fast rebooting after failure.

Security: Information security deals with the intrusion tolerance, low-cost security, denial of service, authenticity, integrity and confidentiality

- interoperability between trusted and non-trusted environments;
- tamper-proof and tamper-resistant technologies from physical to software;
- enhanced technologies for fault adaptation, tolerance and recovery;
- flexibility and scalability to execute multiple and diverse security protocols;
- reliable operation despite attacks from intelligent adversaries who intentionally search for undesirable failure modes;
- seamless and secure interactions and cooperation of Embedded Systems over heterogeneous communication infrastructures, essential to implement the future concepts of the 'internet of things';
- Intrusion-proof architectures, allowing secure upgradeability, trusted dependable, reliable/resilient security/privacy evaluation (composable security and dependability).

Communication

The major challenge in the area of communication is the provision of ubiquitous wireless connectivity under the constraints of minimum power consumption and limited bandwidth. The vision of ambient intelligence depends critically on the availability of such an information infrastructure.

Communication will address the following research topics: Low-power RF, discovery protocols, autonomous reconfiguration, peer-to-peer networks, communication support for standard protocols (WiFi, BluetoothTM, etc..); multi-hop sensor networks, MPEG standardisations.

Silicon scaling

The major challenge in the area of Silicon Scaling from the system perspective is to elevate the design abstractions to such a high level that the effective reuse of large and proven Intellectual Property Blocks can be realised. The determinism of the chips must be maintained in order to support effective system-level validation and certification.

The key to success in the Embedded Systems market is how to connect system knowledge with IC knowledge. The following research topics will be addressed :

On-chip networks, handling on-chip clock slew, power-optimised hardware-software design, power control of an entire SoC, scaling out architectures versus scaling up frequencies, application-specific micro-component architectures, architecture-aware compilation.

Heterogeneous parallel systems

On-chip heterogeneous parallel architectures are more efficient as the use of different IP blocks and accelerators may be adapted to the required computation needs. Use of dark silicon techniques should, however, ease the mapping of only active IPs or accelerators and contribute to the programming of such heterogeneous systems. Homogeneous parallel architectures (GPU, multicores, etc.) also raise the challenge of mapping parallel programs to the appropriate granularity of the parallel architecture.

Sensors and actuators

The major challenge in the area of sensors and actuators relates to the support of huge amounts of input and output data envisaged in the application contexts with minimal power requirements and fail-safe operation.

READ POINTER

Major challenges for technological research:

- > *Embedded System architecture*
- > *Systems design*
- > *Validation*
- > *Design for safety*
- > *Dependability*
- > *Communication*
- > *Silicon scaling*
- > *Heterogeneous parallel systems*
- > *Sensors and actuators*
- > ***Smart environments and systems***
- > ***Man-Machine interfaces***
- > ***Distributed computing platform***
- > ***Self-organising and Autonomous systems***
- > *Systems of systems*
- > *Certification*
- > *Resource management*
- > *Energy and power*
- > *Interoperability*
- > *Tool integration*
- > *Cloud computing*
- > *From syntactic to semantic interoperability*

A great variety of sensors and actuators are necessary for diverse applications. The following research topics will be addressed:
Sensors networks, MEMS technology integration, RFID (radio frequency identification) and biomedical sensors, voting actuators, autonomous sensors, energy harvesting technologies.

Smart environments and systems

The technical challenges may be summarised as how to create a consistent architecture for smart environments characterised by three equally important trends: multivendor interoperability, dynamic device configurations and extreme scalability. More detailed challenges are :

- > Interoperability of sensor and actuator networks up to the exchange of data with applications for mobile, home or back-end services (standardisation)
  Managing the permeating dynamics:
  - Construction of correct systems in the presence of concurrence; along with the analysis, programming and testing methodologies and tools;
  - The identity of the system when its components change;
  - Runtime reconfiguration, with the systems expected to be in a state of permanent reconfiguration;
  - Suitable programming models for dynamic concurrent systems with aspects of joining and leaving sensors and other devices or services ;
- > Sensor fusion and data fusion of data coming from multiple sensors;
- > Data management and service provisioning:
  - Ensuring the safety and privacy of relevant data,
  - Mobile, home and remote data management,
- > Energy management especially for sensors, actuators and wearable or portable devices;
- > Addressing heterogeneity resulting from the integration of multiple, independently evolving sub-systems;
- > Safe and secure ambient identification systems;
- > System and operational commissioning.

Man-Machine interfaces

The major challenge in the area of Man-Machine Interfacing is the provision of intuitive interfaces that blend naturally into a given environment and that are easy to use. This requires research into cognitive models and user behaviour. Man-Machine Interfaces have to blend naturally into the user's current environment, facilitate human and automation interaction and have to be easy to use. Transition from conventional unimodal, menu-based dialogue structures to polymodal, conversional dialogue structures is necessary. The user has to be assisted to define his/her own goals rather than to use predefined function calls.

Design principles, methods and tools are required in order to address human and automation interaction and the joint operation of both, rather than the traditional paradigm in which they are considered separate.

Research concerning cognitive models and user behaviour has to be done to determine the pool of goals that have to be expressed and to determine scenario-dependent dialogue structure.

Distributed computing platform

The design situation becomes more complex when functions no longer necessarily exist in a given, self-contained and unique piece of hardware, but are distributed over several physical instantiations that themselves may not have a unique function. In the future, therefore, more and more use will be made of "soft prototypes", where advanced modelling and simulation tools take the place of the hardware prototype. Techniques of device self-organisation are needed to guarantee the devices' capabilities to cooperate. In addition, conflict resolution methods have to be applied to solve conflicts between competing devices. Also middleware technologies must be developed that make the implementation possible in a distributed fashion. Only then the extensibility as well as the dependence of devices and device ensembles can be assured.

Self-organising and autonomous systems

Techniques of device self-organisation/autonomy are needed to guarantee the devices' capabilities to cooperate
The major challenge in the area of self-organising/autonomous systems relates to the reflection of the sovereign computational unit about its current situation and the devising of a plan of

actions such that a high-level goal can be decomposed into a set of goal-oriented steps that can be executed autonomously. These systems have to adapt themselves according to environment changes, the preferences of the user and the current user goals.

Technologies to be considered are:
Position awareness, time awareness, discovery protocols, plan formulation, sensors fusion, 'ways-and-means' modelling, neutral networks, expert systems or production systems.

Systems of systems

The available technology (e.g., the Internet) makes it possible to interconnect independently developed systems (legacy systems or constituent systems) to form new system-of-systems (SoS). The integration of different autonomous constituent systems into an SoS promises more efficient economic processes and improved services.

Examples: smart power distribution, vehicle-to-vehicle communication, electronic commerce.

The interconnection of existing legacy systems into an SoS opens a set of new research topics as many of the established paradigms of system building have to be reconsidered in the SoS environment, such as:

> provision of stable global SoS services, in the face of system failures, intrusions, and continuous system evolution;
> emergent behaviour and interoperability;
> rigid specification versus continued modification;
> validation and safety cases in an SoS;
> central control versus autonomous decision making and its effects on safety;
> composition by static integration versus dynamic interoperation;
> planned emergence versus unforeseen emergence;
> appropriate process model.

Certification (for mixed criticality); modular certification

The control of physical devices and processes, e.g., service robots and unmanned vehicles, which interact with humans, performed by Embedded Systems makes it necessary to certify the design by an independent certification authority. The envisioned architecture must support a modular certification: incremental development, incremental validation, incremental certification. The certification of mixed criticality systems and the development of well structured safety cases such that the safety of a proposed design can be convincingly demonstrated:

> Design for certification;
> Certification (for mixed criticality), modular certification;

Resource management

Particularly in support for deterministic behaviour, covering aspects such as energy management (including degraded mode) as well as resource management and virtualisation. The resource management will also have to address the energy harvesting in the sensor networks for optimal operation.

Energy and power

The general concern about environmental issues is a big driver for energy production and consumption. Energy management solutions: energy efficient OS, low-power compilers, design of energy constrained architectures, power modelling and estimation, management of energy sources (battery, harvesting, …), distributed energy management (wireless connectivity), user-centric power management

System level techniques to save energy such as clock gating, circuit design for ultra-low power consumption as well as self-configuring energy management systems choosing optimal configuration and operation mode and predefined strategies. Silicon scaling; energy aware system design proposing new methods, techniques and tools to support energy efficiency; system level energy management.

Interoperability

New applications and services will require new hardware and software with higher computational power and need for interoperability. Evolution and convergence of interoperability standards will enable effective collaborative processes and optimal operation building. The main trends are in design integration/planning information, real-time information and standardisation as well as protocols for real-time operation data, wireless protocols.

Tool integration

Improvements of both time-to-market and engineering lifecycle costs, including reduction of the cost of poor quality can only be achieved with the support of integrated tool chains and platforms. Configurable integration frameworks for tools will enable tools to be readily replaced within a tool chain. This will deal with existing issues such as tool obsolescence and tool lock-in, thus opening the tool market for newcomers and SMEs.

Specific emphasis must be placed on open tool chains for HW/SW co-design of heterogeneous embedded systems, including the life cycle support for the expected operational life time of the designs. Interoperability and standardisation are among the technology challenges.

Cloud computing

A well managed 'Cloud' promises computational services comparable to PC at a fraction of its cost. The division of work between a smart object and the cloud will be determined by the privacy and the energy considerations as well as aspects related to information security, autonomy, response time, reliability and cost.

From syntactic to semantic interoperability, ontology

The syntactic and semantic integration of systems developed in different domains will give rise to systems of systems that will provide emergent services of high utility. Developing ubiquitous connectivity schemes that support the syntactic and semantic integration of heterogeneous sub-systems and networks of Embedded Systems, under the constraints of minimum power consumption and limited bandwidth.

> Ontology driven development for Embedded Systems;
> Semantic Integration.

READ POINTER

Major challenges for technological research:

- *Embedded System architecture*
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- *Dependability*
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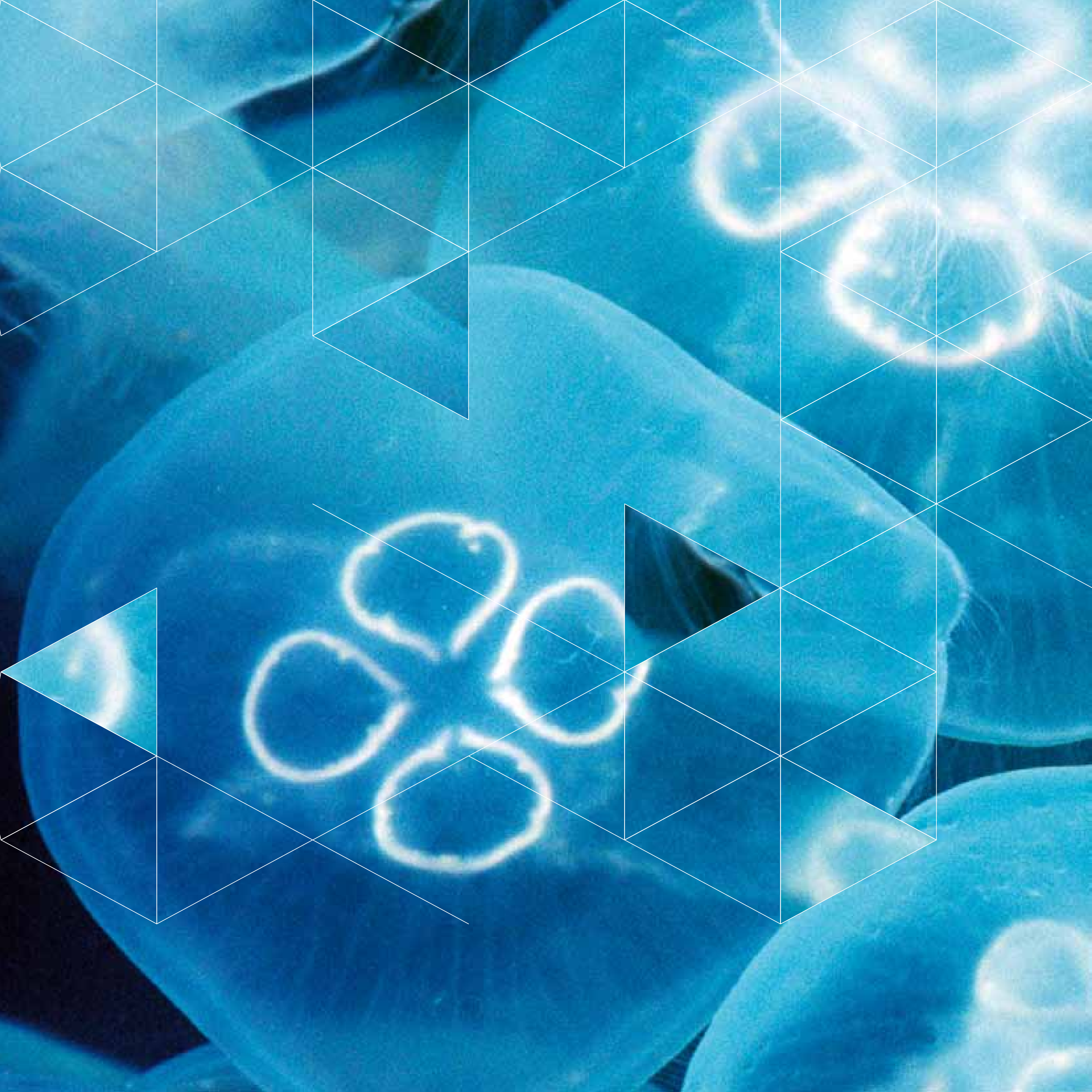


MAKING IT HAPPEN

SUSTAINING THE ARTEMIS INNOVATION ENVIRONMENT

The ARTEMIS Joint Undertaking has a specific responsibility to support the "creation of open innovation environments, promoting the participation of SMEs, developing standards transparently and with openness to international co-operation, dissemination and public relations".[14]

Innovation is not just invention. New technology is innovative only if it results in products or services that are actually used or in operational changes to the processes of production or service delivery. Many excellent technological developments, often representing leading ideas in their niche, fail to be embodied in such innovations because they do not address adequately the requirements of the target market. Such requirements are not just 'functional requirements'. They include cost, dependability, easy migration from existing technology, conformance with standards (and with new technology that might necessitate new standards or modification of existing standards), and compliance with regulation (possibly requiring modification of regulations, which can be extremely difficult).

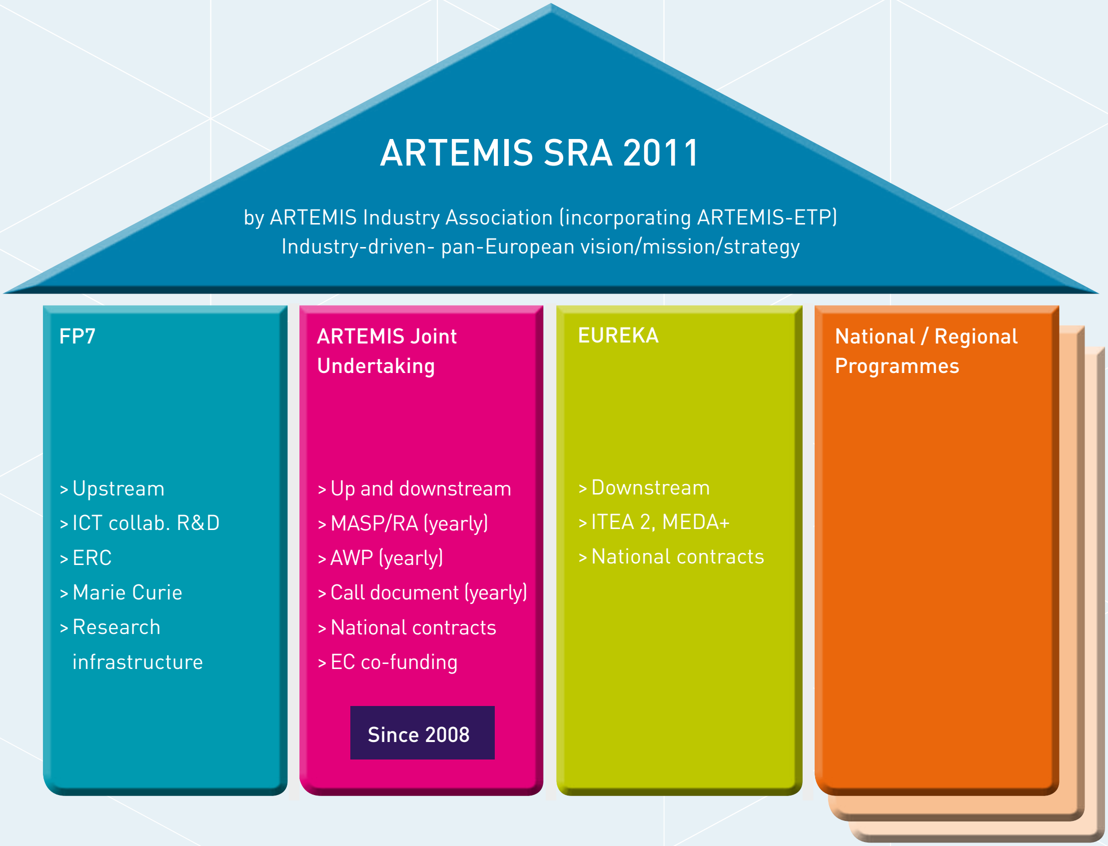
Many of these requirements can be satisfied cost-effectively only if there is a high volume of use - to justify investment in manufacturing equipment, to achieve manufacturing benefits of scale, to iron out production problems, to justify investment in education and training, to gain the dependability data to satisfy both consumers and regulators. The requirements include specific embellishments for usability or integration into an existing market context, the presentation of the product or service in a properly calibrated commercial context (business model), support and maintenance considerations, etc., especially when the technology is to be brought to market by a small company or institute spin-off.

ARTEMIS aims to ensure that the results of the R&D efforts engaged by all stakeholders translate into new products and market opportunities in a fast and effective way. This chapter of the ARTEMIS SRA sets out the ARTEMIS strategy across a wide range of topics that are not themselves part of research or technology development, but which sustain R&D and enable its exploitation to the benefit of the economy and society.

> ARTEMIS aims to ensure that the results of the R&D efforts engaged by all stakeholders translate into new products and market opportunities in a fast and effective way.

ARTEMIS will therefore establish a programme to stimulate Embedded Systems research-led innovation and to monitor and manage its progress. **To implement this programme, ARTEMIS - the JU and the projects supported by the JU - will need to work with appropriate communities and organisations.** Many of these are not part of the present ARTEMIS community, such as standardisation forums, education and training bodies, and trade and business organisations.

[14] *Extract from the Council Regulation setting up the ARTEMIS Joint Undertaking*


ARTEMIS SRA 2011
by ARTEMIS Industry Association (incorporating ARTEMIS-ETP)
Industry-driven- pan-European vision/mission/strategy
FP7
> Upstream
> ICT collab. R&D
> ERC
> Marie Curie
> Research infrastructure
ARTEMIS Joint Undertaking
> Up and downstream
> MASP/RA (yearly)
> AWP (yearly)
> Call document (yearly)
> National contracts
> EC co-funding
Since 2008
EUREKA
> Downstream
> ITEA 2, MEDA+
> National contracts
National / Regional Programmes

Many companies and universities that are active in the field of Embedded Systems are also active in other programmes like **FP7, the ENIAC Joint Undertaking, Eureka cluster programmes like ITEA2 and CATRENE, and national and regional programmes.**

ARTEMIS seeks to create synergies between these programmes for the goals described in this SRA and seeks their buy-in to this SRA, as an industry-driven, pan-European vision/mission/strategy and as one goal supported by different instruments.

CREATING NEW INNOVATION ECO-SYSTEMS

To overcome the barriers to innovation, the simple funding of a 'pre-product' phase is not what is needed. ARTEMIS aims instead to establish a new holistic approach to research, technology development, innovation and skill creation in a distributed industrial context of innovation ecosystems, encouraging both competition and collaboration.

ARTEMIS aims to ensure that there is a clear and obvious value chain, from the first steps of research all the way down to designing products and services available to all European players in the area of Embedded Systems. The players in such a value chain - research institutes, high-tech SMEs, large industrial companies - constitute an eco-system, i.e., a set of interconnected companies, specialised suppliers, service providers, research institutions, educational institutions, manufacturing, distribution and logistics capability in a particular field.

We do not expect competing automobile manufacturers or mobile phone designers to collaborate in their core areas of business. But it is important to understand that the full process of designing and producing a new car, aircraft or personal electronic device involves many intermediary technologies, products and services. Industrial groups have a clear benefit in pooling their resources to define and to create the tools and methods they need to drive their own innovation programs. Rather than waste resources developing proprietary design tools or non-standard middleware platforms, these industry players may gain a clear competitive edge by collaborating among themselves and with their technology suppliers (academia and SMEs) in the definition and implementation of technologies and products of common interest.

Another reason for collaboration is the growing trend towards communicating objects and systems. This trend makes it mandatory to share the right level of standards, technology and methods across different market sectors in order to guarantee interoperability of objects and devices in various environments - car, aircraft, home, office, etc. - while complying with the regulations specific to each environment.

In addition, one of the main purposes of ARTEMIS is to address the fragmentation in the existing market, and the concept of reference designs and interoperability across application contexts is intended to change the structure of the market.

ARTEMIS will therefore proactively stimulate the emergence of a new supply industry for the new components, the new connectivity and networking, and the new design too ls to support the new ARTEMIS design methodologies and new protocols for intellectual property management.

ALIGNING RESEARCH AGENDAS FOR EMBEDDED SYSTEMS IN EUROPE

A European innovation environment for Embedded Systems has to be created in order to facilitate and to support key aspects of innovation that are unaffordable in terms of skills and costs for most companies and especially SMEs.

This innovation environment will take advantage of the results of past EC IST/ICT Programmes and engage with ongoing programmes, more particularly with ENIAC and the trans-national EUREKA clusters ITEA2 and CATRENE along with the Competitiveness and Innovation Programme, the other Public Private Partnerships such as Factory of the Future, Green Car and Future Internet as well as the major national/regional initiatives. They all contribute to the emergence in Europe of a richness of competences, research networks, open source consortia, and regional clusters - or Pôles de Compétitivité - that has no equivalent in the world. This richness is an asset; it also poses a risk - the risk of fragmentation with, as a consequence, limited impact and lack of visibility from the rest of the world. ARTEMIS proposes on the one hand to organise and reinforce existing strengths in a consistent way; and on the other hand to develop new strength in areas where Europe is still lagging behind. **The 'vision-led approach' should yield a 'coherent set of result-oriented projects' achieving concrete ARTEMIS objectives.**

Recent European surveys have shown[15] and are analysing[16] the diversity and potential strengths of this innovation environment, made up of regional, national and transnational initiatives.
More than 30 initiatives have been identified in the ARCADIA report[17]. Most of these initiatives put effort in addressing the topic of transition from research to innovation, and foster the role of SMEs as a priority in this respect.
Supporting innovation eco-systems is a matter of networking and the selection of projects and actions to be funded, according to agreed research agendas or roadmaps. **ARTEMIS, through both ARTEMIS-IA and ARTEMIS JU, will monitor the creativity working groups needed to nurture this innovation environment by deploying the vision and by collecting and hosting a repository of accessible project results.**

While some initiatives leave a lot of freedom to the proposers regarding the challenges addressed and the way in which they do it, some others provide a prescriptive roadmap which serves as a common pathway for the issues and the ways in which they are addressed by research projects.

Initiatives are either[18] using the ARTEMIS SRA 'top-down' as an explicit reference, enriched by specific priorities and more detailed on given issues relevant for their countries and members or[19] devising 'bottom-up' their own roadmaps by collecting topics and priorities from their members and possibly external experts.

[15] *COSINE2 : FP7 support action for Coordinating strategies for eEmbedded Systems in the European research area.*

[16] *ARCADIA : FP7 support action for Aligning Research Agendas in ARTEMIS*

[17] *ARCADIA Report: Survey and Assessment of the main initiatives in Embedded Systems*

[18] *Examples : PROMETEO, ARTEMIS Austria*

[19] *Example : SafeTRANS*

In the 'bottom-up' approach, the roadmaps (like the ITEA roadmaps[20]) are usually specific to the focus area of the initiative and/or to the region/country the initiative covers. In a second step, selected topics from these roadmaps that are identified to be of common interest (e.g., for other sectors, for other regions, etc.) may be exported to other relevant programmes or initiatives, including ARTEMIS.
ARTEMIS will establish more direct links with a number of regional and national initiatives. Large industry and academic stakeholders involved in ARTEMIS are often also contributing to national and regional initiatives, and providing consistent inputs in the technical and long-term visions, and in order to

> ensure the consistency of research agendas which is one condition for efficiency
> develop links with the SMEs

In addition, ARTEMIS will engage with and facilitate communication between all the relevant stakeholders - including industrial and educational institutions, standardisation bodies, regulatory authorities, and regional and national public bodies with responsibility for economic and social advancement - to establish policies and action plans to advance these aims.
By facilitating a more effective relationship between research and product development, ARTEMIS aims for the innovation environment are based on three founding principles:

1. To take advantage of and to build on existing achievements and capacities in the Member States and in Europe in terms of regional clusters, technical infrastructures, open source software organisations and research institutes dedicated to Embedded Systems technologies and applications;
2. To strengthen and reinforce each actor of the R&D value chain, whether large or small enterprises or academic research organisations;
3. To ensure consistency throughout the R&D value chain.

[20] *ITEA Roadmap: www.itea2.org/itea2_roadmap_3*

ARTEMIS will accelerate the pace of innovation. The ARTEMIS Innovation Environment will serve and support efficient execution of the ARTEMIS Strategic Research Agenda (SRA), enabling research achievements to be turned rapidly into innovative products, processes and services for the global market.

ARTEMIS will *'**lead the establishment of processes** to monitor progress toward JTI objectives'*[21] and will recommend follow-up activities of projects throughout their implementation to enable sharing and mutualisation of results between R&D projects, in order to boost the production of 'prototype results' on subjects such as development platforms, 'target platforms', architectures, models, methods, hardware, software, tools, documentation, libraries. Criteria of selection of such results should be motivated by their ability to serve markets and allow integration of a novel approach resulting from R&D projects into novel and innovative applications, products or services.

The IPR aspects will have to be set out to allow such sharing of results or mutualisation. The motivation is to go beyond the research activities and into market uptake, not excluding venture capital and risk-sharing investment strategies.

Commitment from the respective stakeholders for long-term funding of an agreed common agenda is necessary to achieve these ambitious goals and allow enduring strategic alliances among R&D actors necessary for developing and maintaining links between national/regional clusters and fostering collaboration opportunities among these actors.

ARTEMIS REPOSITORY

ARTEMIS will collect and host the open (or restrictedly available) results of ARTEMIS projects. Such results can be technology components (being HW or SW), complete systems, platforms, tools or methods.

The repository acts as source for key enablers for new initiatives inside the programme. Secondly, the results are especially promoted for wider usage as examples of new openings and or commonly used solutions in the area of Embedded Systems globally.

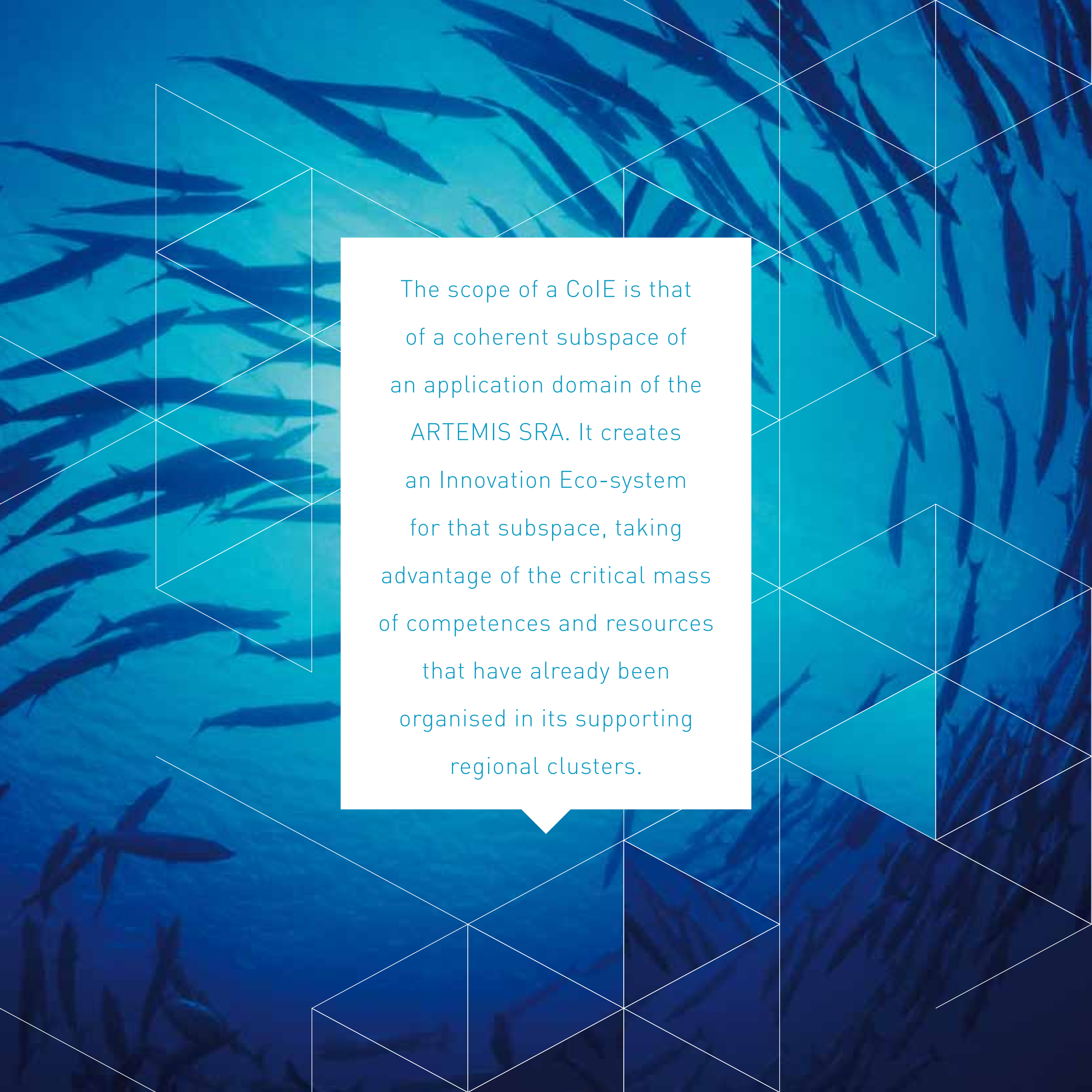
All ARTEMIS application sub-programmes should produce a small number of **'open'** key results. The principle of the repository should be a collection of such technology elements that have strategic value to European industry and innovation in the area of embedded systems. All ARTEMIS projects can propose their results to the repository, and the selection will be done by the ARTEMIS Repository Working Group. The interconnection with the other ARTEMIS Working Groups will enable real innovation dynamics to be created.

CENTRES OF INNOVATION EXCELLENCE

In order to meet the medium to long-term research needs of European industry, ARTEMIS will facilitate the establishment of a new infrastructure of Centres of Innovation Excellence (CoIEs).

ARTEMIS will focus on a small number of systems-oriented CoIEs of a multi-disciplinary nature (e.g. computer scientists, electronic and mechanical engineers, application specialists) well complemented with respected academic groups and in-house R&D groups within the industrial companies, and specialised in specific sub-domains. Their mission will be to pursue the implementation of industrial research visions, as expressed in the ARTEMIS Strategic Research Agenda that are too long-term, too ambitious or too risky for industry itself to engage. ARTEMIS CoIEs will focus European research efforts onto these industry-selected strategic domains and mobilise and integrate a significant critical mass for tackling

[21] *Recommendation N° 6 of "First Interim Evaluation of the ARTEMIS and ENIAC Joint Technology Initiatives"*



The scope of a CoIE is that of a coherent subspace of an application domain of the ARTEMIS SRA. It creates an Innovation Eco-system for that subspace, taking advantage of the critical mass of competences and resources that have already been organised in its supporting regional clusters.

the SRA challenges. They are instrumental in creating the new Innovation Eco-Systems that ARTEMIS aims to ensure.

The scope of a CoIE is that of a coherent subspace of an application domain of the ARTEMIS SRA. It creates an Innovation Eco-system for that subspace, taking advantage of the critical mass of competences and resources that have already been organised in its supporting regional clusters.

Several initiatives have already been launched by member states to create regional high-tech clusters, primary from CoIE such as EICOSE, Finnish SCSTIs, ProcessIT.eu or SafeTrans (as a member of EICOSE) that actively participate in a bottom-up approach to feed technical priorities into ARTEMIS and ARTEMIS-IA strategic planning instruments such as MASPs, RA and AWPs, but also others such the Pôle de Compétitivité in France, Pôle de Compétitivité "Point One" in the Netherlands, Kompetenz-Netze in Germany, the cluster of Strategische Onderzoekscentra in Belgium, and 'Silicon Saxony', the microelectronics cluster around Dresden in Germany. Several of these regional innovation initiatives address the application domains of the ARTEMIS SRA.

ARTEMIS will continue to cooperate and build on these existing regional clusters since it is important for the success of ARTEMIS that these regional innovation initiatives in Europe can participate to and be integrated into the ARTEMIS Innovation Environment.

Clusters of Innovation Excellence will contribute to ARTEMIS by:

- feeding domain-oriented requirements into the ARTEMIS Strategic Research Agenda via structured, domain-specific think-tanks;
- mobilising a critical mass at European level for driving a significant part of an application domain of the SRA;
- providing a focus for all the related capabilities required of an innovation ecosystem (education and training, a suitable domestic and social infrastructure, logistic infrastructure, etc.);
- establishing integration platforms, living labs and testbeds;
- providing business development instruments and spin-off environments;
- facilitating transformation of research results into innovative products (as part of regional, national and European programmes and as part of industry-funded JTI activities on innovation ecosystems).
- facilitating the transformation of research results into industrial deployment;
- guiding the identification of new product and market opportunities and helping in the preparation of business activities.

STANDARDS FOR EMBEDDED SYSTEMS

Future standardisation for Embedded Systems should be driven and directed by the stakeholders involved in technology and product development at an early stage to ensure that technological innovations reach their full market potential. Contributions to standardisation are currently fragmented over many bodies and consortia, many of which are dominated by major US companies. **The main objectives of ARTEMIS in the area of standards are:**

- **to favour open architectures in a context still dominated by proprietary solutions;**
- **to define and to promote a cross-sectoral approach.**

More specifically, in view of the ambitions of ARTEMIS to 'de-verticalise' the industry, a major role for ARTEMIS is to harmonise standardisation activities across the various domains of ARTEMIS in parallel with development of cross-sector technological solutions with associated standard specifications.

ARTEMIS will seek to promote standardisation so as to:

- aggregate demand to support innovation;

- facilitate interoperability and composability;
- enhance competition by differentiating products and services with measurement standards;
- both reassure the public and enhance competition (by enabling new market entrants) through standards for safety, quality, environmental impact, etc.;
- enhance industrial efficiency by the application of management standards that embody best practice;
- rapidly establish new markets to accelerate uptake of technology;
- open and enlarge markets.

The ARTEMIS Standards & Regulations Working Group will:

- maintain a standardisation policy in line with the ARTEMIS vision and ambitions;
- monitor the contribution of ARTEMIS research projects and ARTEMIS standardisation activities to achievement of the standards-related objectives of ARTEMIS;
- advise the ARTEMIS JU on the effectiveness of its standardisation activities and on how ARTEMIS might most appropriately participate in standardisation activities in order to achieve its aims;
- investigate scenarios for common reference architectures for Embedded Systems (e.g. ISO or other models) that will provide the vision, the priorities and the guidelines for the standardisation policy of ARTEMIS;
- make a direct contribution to the standards of European origin (ETSI, CENELEC, AUTOSAR …) and global standards (ARINC, ITU, IEC …);
- link with the existing domain specific (Aero, Automotive, Energy, Telecom, Consumer, Medical...) standard organisations and promote the ARTEMIS vision to them;
- put forward Embedded Systems specific IT requirements to the IT standard organisations (IETF, OMG, W3C…);
- interlink the activities of sector specific and cross-sector projects and establish an entry platform for them to participate in ongoing standardisation activities;
- support cross-sector topics such as a common terminology, cross-sector platform standards, and open source distribution.

In pursuit of these aims, ARTEMIS will build on the results of the FP7 Supporting Action 'ProSE' that has explored how ARTEMIS might best participate in standardisation activities to achieve its objectives[22]. *(ProSE in turn has built on the Standardisation Strategic Agenda published in December 2007 by the ARTEMIS Standards & Regulations Working Group.)*

TOOL PLATFORMS

At present, large-scale development environments come almost exclusively from a small number of non-European sources, while Europe has a large number of excellent suppliers - mostly SMEs - of tools for specific purposes. This situation has created on the one hand a strong dependence on external suppliers for the necessary tool frameworks and on the other a highly fragmented supply chain within Europe for often critical, specialised development tools. Often the market for these tools is limited because they are not readily interoperable with existing frameworks.

ARTEMIS proposes to establish Tool platforms. These will embody a common set of interfaces and protocols that will allow tool vendors to integrate their products into tool chains adapted to the specific needs of sections of the embedded intelligence applications market.

Unlike a complete design flow tool-chain, an ARTEMIS Tool Platform will not have a fixed or even physical existence. An ARTEMIS Tool Platform is not intended as a commercial entity. These virtual platforms are sets of commonly agreed interfaces and working methods, which may evolve and become more

[22] *ProSE: 'Promoting Standardisation for Embedded Systems', Project FP7-ICT-2007-2-224213*

refined over time, allowing specific tools that address a particular element or phase of a design flow to interoperate with other tools addressing the same design goal, so forming a complete working environment.

The demands on design tools can be very different between industrial sectors (indeed, even between companies within the same sector, due to product diversity), making a single ARTEMIS solution unrealistic. Therefore a number of ARTEMIS Tool Platforms are foreseen, from modelling platforms at various system levels, through 'glue' platforms for integration of heterogeneous systems, to project collaboration platforms and on-line content trading platforms.

The 'tool platform' concept includes a consistent tool chain with a capability for evolution and adaptation. A 'tool platform' may be a proprietary or open assembly of tools, used internally throughout one particular company, a commercial offer by one particular vendor or a set of tools from different vendors consistently adopted by a community of users in a particular application domain (for example, related to a domain-specific standard).

Alternatively, a tool platform can be built 'top-down' or 'bottom-up', keeping these existing tool chains as a reference. It may typically adopt some building blocks of the legacy tool-chain, leveraging their capability thanks to a more efficient environment (technical integration environment, and/or

> Therefore a number number of ARTEMIS Tool Platforms are foreseen, from modelling platforms at various system levels, through 'glue' platforms for integration of heterogeneous systems, to project collaboration platforms and on-line content trading platforms.

Tools developed in various research projects (not just those of the ARTEMIS JTI) can then be linked via these platforms into viable solutions as part of a complete chain. Existing tools, including commercial or open-source tools, can also be linked in.

The ARTEMIS strategy is to evolve from initially stand-alone projects to projects whose tools 'plug in' (perhaps using 'wrappers') to early emerging platforms and thence to ARTEMIS standardisation on some common interfaces leading eventually to projects that target their tools to interoperate via standard ARTEMIS interfaces.

commercial environment). The capacity to be hosted in a suitable technical and commercial environment will be a key enabler for such innovations to reach the market. In all cases, stakeholders must agree on technical prerequisites at some level of openness: sustainable toolset architecture, sustainable interface standards, proven interoperability techniques. ARTEMIS will support projects, adopting either the 'top-down' or 'bottom-up' approach to 'tool platform' construction. ARTEMIS will support initiatives to establish and enforce cross-domain and cross-project agreements on toolset architectures, interface standards and interoperability techniques.

REGULATIONS, SAFETY, SECURITY AND DIGITAL TRUST CERTIFICATIONS

In most application areas, the design, implementation and operation of Embedded Systems are quite properly constrained by European or international regulations concerning safety, security, digital trust and the environment. These regulations have strong cost impacts on the design and engineering processes. Being able to produce certified Embedded Systems at acceptable cost is a major competitiveness stake for several European industries.

However, the different sectors encompassed by ARTEMIS have different regulatory regimes that contribute to the fragmentation of the Embedded Systems markets, technologies, and research and development communities. Differing regulation in different sectors influences the nature of acceptable standards and the standardisation processes and leads to procedural and cultural differences that create barriers to cross-sector cooperation and sharing.
ARTEMIS will:

> **develop awareness regarding regulations and their impact, and forge links with the regulation authorities** to identify and work with them to overcome unnecessary regulatory barriers to the introduction of the new ARTEMIS technologies – particularly in safety critical contexts - and to accelerate harmonisation across Europe and internationally so as to overcome market fragmentation;

> **stimulate the creation of independent European certification bodies** when necessary. ARTEMIS will investigate the opportunities for European universities, research institutes and SMEs in this area;

> **stimulate development programmes** that will enhance the capabilities of the European industries in the area of certified Embedded Systems.

INTELLECTUAL PROPERTY MANAGEMENT

The programmes envisaged by ARTEMIS will entail highly complex arrangements of sharing of intellectual property among a wide range of participants. ARTEMIS will establish a reference set of rules for inter-company collaboration and for industry-academic collaboration that will serve as an industry model.

> Social innovation and empowering new user groups will be of major importance.

ARTEMIS will promote and facilitate the ***patenting*** of computer implemented inventions - also referred to as software-enabled inventions – where the protection of intellectual property will encourage investment. ARTEMIS promotes the licensing of key ARTEMIS results under fair, reasonable and non-discriminatory (FRAND) conditions.

OPEN INNOVATION AND OPEN SOURCE POLICY

Where previously companies relied mainly on internal knowledge bases, research and product development, they now see themselves as part of a network of private and public parties, cooperating in exchanging both technology (i.e., the IPR portfolio) and inspiration for marketing and product concepts. Open innovation can be defined as a component in a product, service or process done by somebody else without a contractual agreement with the *original equipment manufacturer (OEM).* Open innovation democratises innovation by letting basically anybody get his or her idea into use. At the same time, from the companies' point of view, it is outsourcing of R&D risk as no commitment has to be made before the finished result.

In the past, innovation done outside of the company usually did not fit the proprietary tools and processes. For open innovation they fit if we have three things in place:

1. **Technical enablers like architectures**, interfaces and tools to fit solutions done elsewhere
2. **Economic enablers** like incentive systems and market places for the developers of the components
3. **Social enablers** that create the shared interest of developers in the area relevant for the product, service or process

Social innovation and empowering new user groups will be of major importance. ICT innovation therefore entails the active involvement of industrial designers; it builds not only on technology but also on input from social sciences on new

business models and service concepts. User testing, user-driven development and real-world pilots for bringing services and solutions to fruition in an intuitive, enjoyable and playful way will be key competitive factors.

ARTEMIS is business model agnostic whether to use proprietary or open source software as long as the patented parts of key ARTEMIS results are open for others under FRAND conditions.

Many companies use proprietary and open source software in a balanced way; the pros and cons of either way depend very much on the type of business and the chosen business model. ARTEMIS will follow the following policy in respect of the appropriateness of open source:

ARTEMIS will promote and facilitate the creation of 'Open Source Eco-Systems', if appropriate, for the dissemination and commercialisation of the ARTEMIS technologies and services.
Sharing of not only cost but also of know-how and expertise is a good means to sustain economically viable product and software development, and preserve industrial activity in Europe.

The recognition that the major part of embedded software in products is common and non-differentiating across manufacturers, but needed as a basis for the remaining part of differentiating software, forms a basis on which sharing of software and IP can be established. To make such sharing successful, business models of the participants must be supported.

As stated in the ITEA Report on Open Source Software *"Open Source Software may well be one of the best tools to escape (at least partially) from the monopolistic position that certain giant non-European companies have established in areas that are key for European development and independence. …In particular, it may also be one of the best tools for preserving and strengthening European access to and control of basic software for Embedded Systems in those application areas (e.g. automotive) where European software companies have a strong position, and where other global suppliers aim to extend their monopolistic positions elsewhere."*

ARTEMIS will exploit this potential by:

> setting-up a European infrastructure to host and support OSS initiatives relevant to the ARTEMIS vision and priorities including the validation, certification and supply of OSS components.
> promoting whenever appropriate the creation of 'Open Source Eco-Systems' for the dissemination and commercialisation of the software technologies and associated services produced by ARTEMIS projects.

Where the objectives of participants and the market conditions are appropriate, ARTEMIS will also support the Community Source Software (CSS) model in which a community of like-minded companies, institutes and individuals agree on the scope, rights and obligations and the rules of participation. This can lead to higher efficiency and lower threshold for participation, with the element of trust that distinguishes a community from a completely open environment.

For OSS, ARTEMIS will take advantage of existing OSS leading organisations relevant to the scope of ARTEMIS[23] rather than set-up new organisations.

For CSS, ARTEMIS will encourage communities and will solicit best-in-class approaches to provide their infrastructure to support such communities.

[23] *These include, for instance, the Object Web Consortium for middleware technologies; Eclipse Foundation for System Design technologies; OSCI (Open SystemC Initiative); OSDL (Linux) and the SCILAB Consortium for mathematical libraries.*

The ARTEMIS open-source policies and action plans will capitalise on the results of R&D Communities, avoid non-differentiating redundant work through the use of common IP and re-use of IP, prepare future products or services for SMEs and package available software components from the research projects in the framework of the SRA.

INDUSTRY-ACADEMIA COLLABORATION

ARTEMIS will actively facilitate productive engagement and interdisciplinary working between industry and academia in several ways - not just through its collaborative research programme, but through innovative infrastructural mechanisms for coupling academia and industry in research and development, and through engagement of industry and academia in joint education and training initiatives.

RESEARCH INFRASTRUCTURE

In fields such as high-energy physics, it is recognised that large-scale infrastructure is essential. Such infrastructure typically requires investment of resources beyond those available to any single company, institute or even country. Market forces do not prevail in such fields. Large-scale infrastructure is also understood to be necessary in, for instance, semiconductor manufacture, though here there is greater reliance on market forces, given the stratification of the market. The use of large-scale infrastructure is less obvious in Embedded Systems research and development, but there is certainly one area of Embedded Systems development where such infrastructure has been beneficial and could in future be critical to the success of RTD investment. This is the area of large-scale test facilities, to enable extensive user tests to be conducted before embedded electronic products go to market.

Some companies have invested in such infrastructure. In the days of Alan Kay, Apple had its 'playpen' to see how children would interact with the Macintosh while, more recently, Philips has created a 'HomeLab' where psychologists, sociologist, communication specialists and engineers analyse the way family members interact in a 'normal' home environment with prototype products containing embedded systems. Such single-company initiatives are important, but have major drawbacks: their application space is limited (e.g. the HomeLab is limited to the private space), and SMEs, research institutes, universities and certainly competitors have very limited access to the facilities created by these companies.

Moreover, such single-company facilities are of relatively limited scale: to establish the viability and trustworthiness of the Embedded Systems solutions to the major Societal Challenges addressed by ARTEMIS will require major multi-domain, multi-sector test-beds.

ARTEMIS will:

- establish a process for the regular review of the potential for research infrastructure in each domain of the ARTEMIS SRA (applications and technical domains)
- identify existing research infrastructures in academic or industries contexts that are of interest for the execution of the ARTEMIS SRA and that could be shared;
- identify the potential for the creation of new facilities, or improvement of existing facilities, in order to address specific areas of the research agenda, and help the stakeholders to establish action plans for their creation, including identification of financial support[24].
- establish models for the ways in which such shared facilities should be managed and the conditions under which they are accessible to different potential users, both within the European Innovation Environment and beyond.

[24] *Note that support for research infrastructure is within the remit of the European Investment Bank.*

EDUCATION AND TRAINING

The European landscape of universities and research institutes specialised in the field of Embedded Systems is still highly fragmented with national champions, sometimes several, in each Member State. The Networks of Excellence ARTIST 1 and ARTIST 2 have begun the process of creating a community and a shared scientific vision, while ARTEMIS, through this Strategic Research Agenda and through existing ARTEMIS activities such as the various 'Chambers' of its Governing Body, the annual ARTEMIS Conference and the annual ARTEMIS Summer Camp, have enhanced the building of an 'ARTEMIS' Embedded Systems community.

However, even ARTEMIS, ARTIST 1 and ARTIST 2 have had only limited reach. ARTEMIS will therefore build on the work so far, and especially on ARTIST 1 and ARTIST 2, to facilitate productive engagement of industry and academia to match the pace of evolution of educational systems and curricula to the rapid evolution in technologies. ARTEMIS will overcome the gap between the theory of academic education and the practice in industrial application. ARTEMIS will facilitate the development of new combinations of skills so that hardware designers will be able to appreciate the possibilities or limitations of software, and vice-versa. ARTEMIS will break down the present distinctions between system architects, hardware and software engineers, and promote a more holistic approach to system design.

ARTEMIS will:

- establish a network that taps into highest level of competence;
- have international scope;
- facilitate cooperation between academia, industry and other stakeholders.

The network will be focused by engaging the participants in:

- maintaining the long-term research vision of this SRA for Embedded Systems in Europe;

- establishing a vision for education and training in Embedded Systems and ..
  - establishing model curricula;
  - providing training for industrial engineers;
  - establishing quality standards for education & training (criteria for accreditation).
- developing an international collaboration programme in Embedded Systems.

Specifically, ARTEMIS will:
- develop courseware, establish graduate study programmes and industrial 'summer schools', and a Distinguished Lecturer Programme;
- support, recognise and promote the definition of curricula dedicated to Embedded Systems technologies and engineering;
- establish ARTEMIS Chairs on Embedded Systems within leading European universities; establish a series of joint industry academic workshops on 'Hot Topics in Embedded Systems' (e.g.: Beyond Autosar);
  - facilitate joint PhDs with industry (with joint funding and sharing of results);
  - establish joint graduate schools (building on existing models);
  - facilitate job rotation with industry (both ways).

As a new dissemination channel ARTEMIS will use **EIT ICT Labs** of the European Institute of Innovation and Technology (EIT) in bringing the ARTEMIS results quickly to the curricula of students, to the knowledge of SMEs and to the products of European industry. EIT ICT Labs represent two thirds of the European R&D into ICT in universities, research institutes and the industry.

SME SUPPORT

In the ARTEMIS eco-system model, high-tech SMEs are expected to play a key role in the capitalisation and dissemination of the technologies resulting from the execution of the Strategic Research Agenda. With respect to the large industrial companies participating in ARTEMIS, SMEs have relationships in different phases of the value chain:
- SMEs are research partners of large industrial companies in the upstream part of the value chain: they enable larger companies to reduce their technology acquisition costs while at the same time enabling access to a broader range of innovation;
- SMEs are technology and services suppliers of larger companies in the downstream part of the value chain;
- SMEs are the seeds of future large companies.

It is of major importance for the building of the ARTEMIS eco-systems that strong user-supplier relations are built at all stages of the value chain, avoiding disconnection between the different stages.

ARTEMIS support for SMEs will follow the model of the French initiative 'SME Pact'[25]. ARTEMIS will:
- promote SMEs by helping them to be become more visible while helping large entities by identifying technological providers for their direct or indirect purchases. This will be achieved by presentations to large entity signatories by panels of SMEs on a specific technology topic[26].

[25] *The SME Pact is a pilot action implemented in France since 2005. Focused on SMEs with a strong growth potential, it is a voluntary commitment made by large public or private entities to strengthen their relationship with innovative SMEs. As a support measure, large companies and large public bodies are provided with schemes allowing them to work with the best innovative SMEs. A set of indicators is established in order to monitor the share of SMEs in procurement of innovative products or services.*

[26] *First instances of such meetings were organised jointly by ARTEMIS and the High-Tech Federation in June 2005 in Paris and in May 2006 in Bilbao.*

- help SMEs to overcome legal barriers to participation in the ARTEMIS ecosystem by explaining to larger entities the difficulties encountered by SMEs, establishing model contracts and model IP agreements, and providing individual support to SMEs in the framework of their contractual relationships with large entities. 'Lessons learned' from these activities will be published in the ARTEMIS annual report[27].
- facilitate purchasing of SME products and services by sharing of best practice on:
  - acquisition procedures adapted to the specificities of innovative SMEs;
  - incentives to main suppliers to involve innovative SMEs in their proposals;

> ARTEMIS will help Europe to develop 'brain magnet' capabilities to draw the participation of the best brains in this area throughout the world.

  - limitation of the risk taken by all parties;
  - incentives to purchasing departments.
- establishing service and support actions to:
  - cluster SMEs according to ARTEMIS segments;
  - devise a growth strategy to maintain competence in Europe;
  - provide business development support;
  - interface with the European Investment Bank and other financial institutions that can provide guarantees for SMEs;
  - facilitate access to EC instruments ("take up" actions, EC structural funds...);
  - broker initial contacts with investors.

[27] *If the companies involved will allow it*

INTERNATIONAL COOPERATION

International Collaboration can encompass a wide range of activities, from the organisation of technical meetings, high-level meetings, conferences, schools, and joint international projects. These may have various aims, including education and training, dissemination, definition of standards, and development of joint R&D activities.

The added value of collaboration should become visible through:

- the opening of new markets, such as Asia, based on existing strengths and fostering ARTEMIS standards as a worldwide basis;
- international inward investment in European research labs;
- compensation for weaknesses in specific areas where there is no European equivalent;
- mutualisation of resources for the development of non-differentiating (business-wise) technologies;
- completion of the resources available to research ecosystems;
- the establishment of critical mass to enable significant technological and societal change.

International Collaboration should fit into a global win-win strategy for achieving the participants' long-range aims. Defining such a vision and strategy is important for guiding international collaboration.

ARTEMIS will build on European strengths that include:

- innovative ideas leading to international standards;
- an approach based on good appreciation of theoretical foundations;
- ability to attract and retain top researchers in embedded systems.

ARTEMIS will define 'modalities' for interaction between the European R&D community, and the main international players in the area, including research institutions, professional organisations (ACM, IEEE), standardisation bodies (e.g.: OMG, IEEE), large consortia, funding agencies (e.g.: IST, NSF, DARPA).

ARTEMIS will help Europe to develop 'brain magnet' capabilities to draw the participation of the best brains in this area throughout the world. To this end, ARTEMIS will develop and communicate its Vision and Strategic Research Agenda globally. The creation of Centres of Excellence, and increased international visibility through communication, the website, and the Annual ARTEMIS International Conference will be among the tools to foster this collaboration.

Acknowledgements

ARTEMIS Industry Association gratefully acknowledges the contributions made by the following persons and groups in producing this ARTEMIS Strategic Research Agenda 2011:

- Group of Experts:
  - Ronald Begeer
  - Luca Benini
  - Ad ten Berg
  - Gerard Cristau
  - Heinrich Daembkes
  - Rolf Ernst
  - Alun Foster
  - **Laila Gide**
  - **Tatu Koljonen**
  - Hermann Kopetz
  - Vera Lauer
  - Rudy Lauwereins
  - Petri Liuha
  - Bob Malcolm
  - Patrick Pype
  - Juha-Pekka Soininen
- Other experts
  - Ger van den Broek
  - Tullio Salmon Cinotti
  - Armando Colombo
  - Werner Damm
  - Jerker Delsing
  - Andreas Eckel
  - Anders OE Johansson
- ARCADIA project
- EICOSE
- ProcessIT. EU
- ProSE project
- SafeTRANS

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PRINTED AND BOUND IN THE NETHERLANDS

Verhagen Grafische media - Veldhoven, the Netherlands

First edition, April 2011
www.artemis.eu

ISBN/EAN 978-90-817213-1-8

ARTEMIS