Embedded / Cyber-Physical Systems ARTEMIS Major Challenges:

2014-2020

2013 DRAFT Addendum to the ARTEMIS-SRA 2011

December 2013

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Editor: Laila Gide

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Executive Summary

AN OPPORTUNITY FOR EUROPE

Today Europe faces a number of Grand Challenges arising from inverted demographic curves, the constantly increased demands for non-renewable natural resources, the climate change and the constant expectations for improved quality of life, where the modern European social welfare model and its sustainability are threaten.
It is nowadays widely recognized that Embedded Systems technology is a crucial key enabling technology that forms the basis for the development of many innovative products and services in highly developed economies. They control almost all types of products with electronic devices, from a dishwasher to a building, from an electric drive to a production line, from a dashboard to a car. They enable new functionalities which differentiate these systems from earlier solutions and, thus, are a foundation of European industrial products **saving and creating millions of jobs in a highly competitive international market**.
From the available data, there is almost no application area or business sector, in which Embedded Systems have no direct or indirect impact on.

Markets trend analysis for different application areas indicates that in the last decades the Embedded Systems market has been growing faster than the traditional computing market:

- Approximately 2% of the sold microprocessors are used for IT and PC and 98% for the embedded systems such as cars, trains, medical devices, airplanes, household devices, traffic management systems, in mobile devices etc..
- Every year more than 3 billion Embedded Systems are integrated in the devices and other systems for a total market of about €160 billion[1].

In their report[2] **IDC** estimates that "……*the embedded system and semiconductor value chain is about $7.8 billion in 2010, and should grow at a compound annual growth rate of 7.6% over the next 5 years. By 2015, the overall value of these specific areas will reach $11.8 billion".*
IDC also points out that for embedded software… *"the price of the chip is being defined primarily by the value of the software"*.

In addition to the market opportunities, the economical and societal challenges shaping the Embedded Systems scene include the necessity to:

> **increase the R&D investments**[3] in Europe in order not to loose its present leading position,
> consider the impact of the new Internet economy, and the "**rise of the Embedded Internet**"[4]
> take advantage of the strong demand arising from the young generation to remain and stay connected to their communities **"the Always Connected Society"**.

[1] **Bitkom**. Eingebettete Systeme – Ein strategisches Wachstumsfeld für Deutschland Anwendungsbeispiele, Zahlen und Trends.
[2] **IDC Report**: Intelligent Systems- Next big opportunities.
[3] **ITEA ARTEMIS-IA High Level Vision 2030**: Opportunities for Europe, The impact of software innovation on revenue and jobs
[4] **Intel white paper :** the Rise of the Embedded Internet

ARTEMIS Vision

The ARTEMIS Vision developed in the ARTEMIS SRA in 2006 is to *"nurture 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"*.

The present document is an addendum to the still valid SRA 2011 sizing the opportunity to update it by taking into account new trends and evolution of technology, of industry and of society, with the same ambition to deliver an **overarching agenda that inspires research policies makers in Europe** and their work-programmes, mainly: the Embedded and Cyber-Physical Systems sub-programme of ECSEL JU the new Joint Undertaking, the EC H2020 work-programmes, the multi-national Eureka clusters ITEA3 and CATRENE programmes, as well as the national and regional research programmes.

The ARTEMIS 2006 vision is still valid, and since then a lot has been achieved: ARTEMIS has proved to be a unique programme that succeeded in few years to set the largest R&D projects in the area of Embedded Systems for safety-critical, high reliability systems that addressed main societal challenges such as mobility and transport, aging society, manufacturing processes, efficient building, and energy management.

In 2011 Vision, ARTEMIS SRA stipulates that *'In a world in which all systems, machines and objects become smart, have a presence in cyber-physical 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 ubiquity of the Embedded Systems, with their present and forecasted evolution, will have more and more impact'.*

But Embedded Systems/ Cyber-Physical Systems are now entering a new era, as the societal and economical challenges are not only of high industrial relevance for the **European growth**, **jobs and added-value creation, value chain and eco-systems strengthening**, but also as the technological responses have a strong impact on society and are shaping it.

The response to grand societal challenges[5] such as aging population, healthcare, energy, food and water supply, sustainable mobility and transport, highly depends on such large and open networks of Embedded Systems. **These Embedded Systems networks are now forming an invisible** '*neural network of society'* driving innovation on the level of society rather than that of a single industry.
From an Internet perspective, these trends are leading to the *Internet-of-Things* where billions of Embedded Systems are providing information about and interacting with the physical world that can be used in all kind of information systems. From the *Embedded Systems/Cyber-Physical Systems* perspective, this opens new opportunities in collaboration and control with **access to the big data in information systems**.

This leads to the **new area of** *Cyber-physical Systems* **(CPS)** where the networked embedded systems are considered an integral part of their physical surroundings opening new opportunities for powerful software systems. This enables new embedded system services by integration with services of the information systems infrastructure.

Internet-of-things, and consequently the Things of the Internet, and Cyber-physical Systems are complementary directions which together will help to shape a society where humans and machines increasingly interact to provide services and solutions to the benefit of society that are unthinkable with the present state-of-the-art technology.

[5] **ITEA ARTEMIS-IA High Level Vision 2030**: Opportunities for Europe, The impact of software innovation on revenue and jobs

ARTEMIS Priority Targets

Unlike the mainstream semiconductors' field that is governed by the relative stable Moore's law, **research and innovation in the Embedded Systems/Cyber-Physical Systems (ES/CPS) field follow a push-pull iterative cycle** to respond to user's needs, creating new products and services by:

> Exploiting the ever growing potential offered by the miniaturisation,
> Harnessing the complexity and matching the physical and cyber world,
> Seeking the grail of greater and better performance, of functional and non functional properties, such as the ease of use expected from the users, the reduction of time to market of new products and services,… but also energy consumption, autonomy, dependability, security, etc…

In order to address the challenge of reducing/ overcoming the fragmentation R&D investment, ARTEMIS Strategic Agendas targeted a selected number of industrial research priorities in order to reach critical mass and make the best use the available resources (human and financial) and to reinforce Europe potential and keep its advances.

For the coming period (2014-2020), the following priority targets are selected to guide the Embedded Systems/ Cyber-Physical Systems R&D programmes with the purpose of having greater impact and quick to markets results:

> **Exploiting the ubiquity of the Embedded Systems/Cyber-Physical Systems,** that goes far beyond that anticipated, where embedded applications are surfacing (emerging). Embedded Systems are now linking to the physical world (cyber-physical systems) and share all kind of networks (including Internet) and components in configurations whose conceptual structure have to map to their physical structure, with increased secure quality of services.
> **Exploiting the connectivity of the networked Embedded Systems/Cyber-Physical Systems,** as the neural system of society that should no longer be only considered in isolated application contexts but in relation to what they can offer for addressing today's and tomorrow's societal challenges.
> **Optimising the factor Technology Time to Market/Technology Time on Market,** that is continuously increasing and affecting new markets and products. Indeed, the development cycles optimisation and the 'cooperation speed' to transfer from basic research (academia) to applied research (Academia and public research institutes) and to industrial research (Large industry, OEM's and Supply chains and SME's) is a great challenge.
> **Mastering the complexity** while reducing the cost and increasing the performance is a key challenge: The **exponential potential increase brought by the semi-conductors miniaturisation** is creating great opportunities, and necessitating equivalent investment in the Embedded Systems in order to leverage the exploitation of the new potentials. Ensuring a correct and secure collective and autonomous behaviour of the heterogeneous interconnected elements will be at the core of the challenge. It will encompass a multi-disciplinary approach, various levels of tooling and methodologies.
> **Reducing and managing the energy and power consumption cost.** Power is now the major limiting factor in all computing elements. For data servers and HPC, the cost of the electricity bill and the capacity of cooling limit the capacity of the data centers. For mobile devices, autonomy is limited by the power consumption and even for cars this translates in non-negligible levels of CO_2 emission. For smart sensors, leveraging the energy of the environment (scavenging) or long autonomy on small batteries is mandatory.

ARTEMIS Innovation Strategy

ARTEMIS innovation strategy is three folds to respond to the societal challenges and to reach the set of targets described above:

> **Building on the leading positions where Europe is strong**, in specific technologies and in various application domains, particularly for the safety critical high reliability real-time secure applications in the field of automotive, aeronautics, space, health and production sectors.

> **Complement by creating new opportunities** for Europe to be positioned at the forefront of **new or emerging markets with high potential growth rates** to become among the world leaders in these domains and particularly target process industries, smart cities, energy generation and distribution, energy efficient buildings, environmental, food and agriculture.

> **Making a tentative comeback on the smart devices** to challenge the US and Asian actors, to reposition the European leadership.

The original ARTEMIS **Industrial Priorities** aim to achieve multi-domain compatibility and interoperability. In the 2011 update to the ARTEMIS Strategic Research Agenda, this strategy was taken further: the **societal challenges are 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**. Opening new applications contexts is also part of ARTEMIS Innovation Strategy to involve new actors from activities. Smart Cities, Environment and Agriculture, Food, etc … are amongst these new areas where ES/CPS are a determinant factor in their growth.

The ARTEMIS way is illustrated in the following figure:

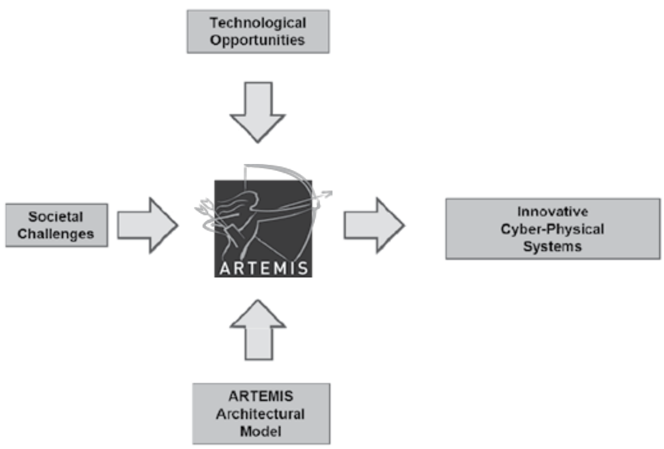


Fig 1.The ARTEMIS WAY

Societal Challenges are the key drivers for innovation in the application domains, being products or services.

For a significant number of Application Contexts, the ARTEMIS SRA addendum develops the expected evolution, the market trends and the arising technological needs and expectation from the Embedded Systems/Cyber-Physical Systems:

> **Efficient, autonomous and Safe Mobility,** including: automotive, aeronautics, rail, space, and also public transport, ships and waterborne, as well as multi-modal transport.

> **Wellbeing and health, including:** Care everywhere**,** home care**,** hospital care, heuristic healthcare **and** assisted living.

> **Sustainable Production, including:** Food production, semi-conductors, process automation, manufacturing, mining, oil and gas, chemicals, power plants/ energy conversion – renewable energy resources – biomass, biofuel, wind, sea, …, pharmaceutical, forestry, logistics.
> **Smart Communities, including:** smart, safe and secure cities, energy efficient building, green infrastructure (traffic management, lighting, water and waste management, and also smart GRIDS- smart metering's - energy suppliers, network operators and energy service companies - data infrastructures for Utilities –share infrastructures (including telecom), smart Spaces: Connected home - smart devices and services for low-level smart home functionality - home health services - home energy management and services- home monitoring - media equipment and content - market which will be worth $101 billion in 2013, assisted living and inclusive society and Integrated city-services

Technological challenges and Opportunities

In order to embrace the Embedded Systems/ Cyber-Physical Systems technology challenges for 2030, the present innovation strategy is integrating new technological opportunities and challenges, such as:

> The dynamic, autonomous, adaptive and self-organised Embedded Systems, and seamless and secure interaction of the Embedded Systems/Cyber-Physical Systems with their environment,
> The System of Systems functionalities and new paradigm design,
> The new and smart applications such as Cloud services,
> The data deluge and Big Data, detection of context and taking into a count of e.g human behaviour, and also automation and smart homes (e.g. automating daily routines) or smart cities (e.g. holistic traffic control, citizen safety, and energy efficiency).
> The new computing and multi-core…

Therefore the two dimensions ARTEMIS Matrix is evolving into the **Matrix 2.0,** in order to better tackle the research challenges, establish the main research directions (road-maps) and timeline to reach ARTEMIS targets and get expected impacts.

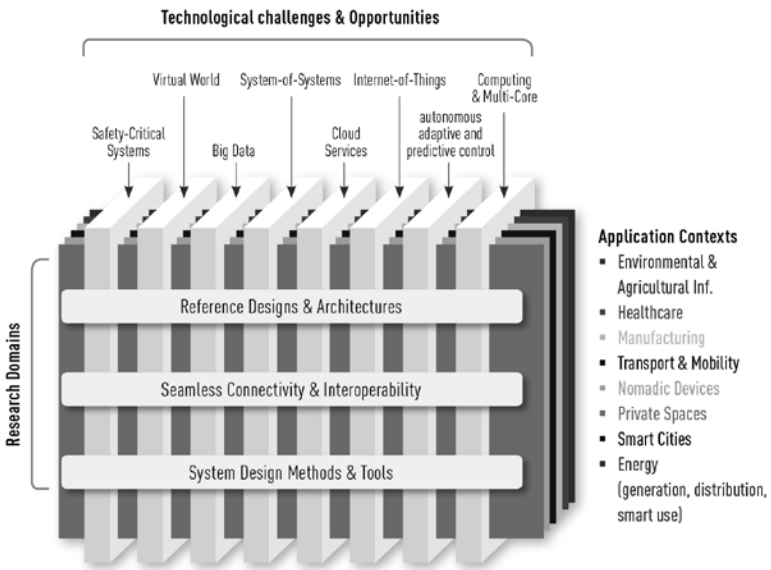


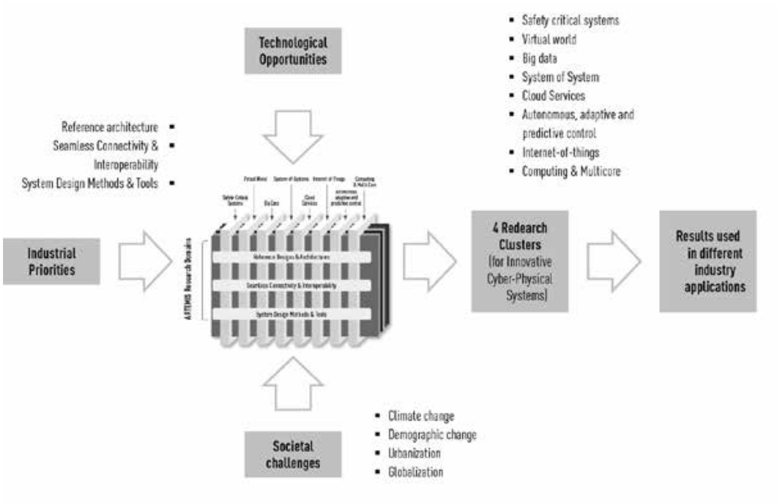
Fig 2 - ARTEMIS MATRIX 2.0

Strategy Implementation

The innovative strategy ARTEMIS mainly aims to overcome the plea of the Embedded Systems arena 'fragmentation' in all areas of the innovation chain and to counteract it: in research, in the supply chain and in the market. It is based on:

a) A top-down strategic road mapping and setting an ambitious set of high level objectives are defined in the SRA based on **the Matrix Approach** (presented above) in order to cut barriers **between application sectors** and facilitate **cross-domain sharing of technologies and research,**.
b) An implementation through a set of programmes: that scales from focused programmes to (such as the ASPs), to larger Think Big programmes (such as the AIPPPs) in the ARTEMIS JU.

This strategy proved to be successful as it allowed the emergence of an outstanding record of successful projects in the period since ARTEMIS has been running (from 2007 through out 2013).



ARTEMIS research directions and Road-maps:
From the list of research topics gathered in Annex 1 to the present document, the research direction road-mapping is drawn against the application and the technological challenges. The phasing is made by clustering these topics in four major themes and setting them along three phases:
> Phase 1: short term 2014-2017
> Phase 2: medium term 2016-2019
> Phase 3: longer term 2017-2020

Major Themes:
A- Architectures Principles and models for Safe and secure Cyber Physical Systems
B- System Design, modelling and virtual engineering for Cyber Physical Systems
C- Autonomous adaptive and cooperative of Cyber-Physical Systems
D- Computing Platforms and Energy Management for Cyber Physical Systems

A- Architectures principles and models for autonomous safe and secure CPS
- **Short term**: Defining global architectures principles, programming paradigms and frameworks for CPS taking into account safe and secure operation in non-deterministic environment. Consider certification requirements for these architectures.
- **Medium term**: Translating these principles into modular and composable reference architectures and protocols including monitoring and diagnosis as well as application independent software. Propose certification guidelines.
- **Longer term**: Adding cognitive users' model to the global CPS architectural models- extension to novel application contexts. Propose certification approach and evolution of standards.

B- System Design, modelling and virtual engineering for CPS
- **Short term:** Targeting CPS assisting users: assisting environment modelling, design space exploration, verification and validation methodology and tools for complex systems and environments as well as life cycle management.

- **Medium term**: Targeting semi-autonomous CPS: Adding virtual engineering, extending design space exploration to more complex systems for cost reduction/ Quality of Services trade-offs.
- **Longer-term**: Targeting autonomous (including bio-inspired approaches) CPS and modelling complex interactions with humans. Addressing engineering of fully self-reconfiguring CPS. Adopting novel formal verification techniques, including stochastic approaches. Developing of cross-sectorial usability.

C-Autonomous adaptive and cooperative CPS

- **Short-term**: Developing core enabling functionalities for efficient use of resources (computing, power,..) and for optimizing global application performance and life-cycle costs for semi-autonomous CPS.
- **Medium-term**: Adding adaptation and run-time optimisation capabilities, as well as reliable and trustable decision making and planning for safety-related autonomous CPS.
- **Longer-term**: Adding learning capabilities and distributed decision making, introducing attractive, intuitive and enhanced accessibility for users for autonomous CPS including Human Machine Interface/ World Machine Interface (HMI/WMI).

D- Computing Platforms and energy management

- **Short term**: Addressing low power computing systems for global system view for energy management, while managing the complexity, reliability and security for mixed critical systems.
- **Medium term**: Extending to dynamic adaptation/selection of heterogeneous multi/many core computing resources to application needs. Focusing on "System level programming" with emphasis on portability, virtualization. Supporting global cooperative and distributed system debugging and validation.
- **Long-term**: Adding environment modelling in the loop (for predictive and adaptive computations). Adopting rule-based system behaviour construction and "programming". Proposing scalable and modular approaches for affordable qualification and certification.

ARTEMIS Innovation

ARTEMIS is above all **an Innovation Program around Embedded Systems**. As the term "innovation" is broadly used, the ARTEMIS program "innovation" is mainly connected to innovative technologies, ranging from fundamental and industrial research to experimental development of new products, processes and services.

The ARTEMIS strategy aims also to: "Build self-sustaining innovation ecosystems for European leadership in Embedded Systems", by stimulating the emergence of innovation ecosystems within the field of embedded systems in a number of business sectors, facilitating their integration into larger ecosystems, mainly through support of R&D projects.

Such R&D projects are generated through the responses to work-programmes that could be launched by the EC, the new JU, or National programmes.

For the coming period, ARTEMIS will endeavour in maintaining and further developing the ARTEMIS differentiators:

- An 'Industry driven' initiative,
- A unique example of tri-partite cooperation between the EU member-states, the European Commission and the Industry,
- Sustaining its focus on both business competitiveness and technical excellence,
- A descriptive 'Top-down' approach based on a Strategic Agenda, supported by a bottom-up expression of needs through Centres of Innovation Excellence.
- Keeping focus on large impact and market-oriented projects (such as the AIPPs);
- Having large footprint projects with support from smaller focussed projects, while ensuring the balance between different research's actors (large, mid and small industry as well as RTOs and Academic) to drive innovation,
- Actively supporting the creation of innovation eco-systems, particularly attractive for SMEs.
- Openness and complementarities with EU framework and EUREKA/ITEA programmes
- Seeking closer cooperation with the KIC ICT LABs.

These differentiators are "Innovation Accelerators" essential for technology developments and for becoming strong market influencers through business-driven engineering, by:

- using Centres of Innovation Excellence to collect, attract and retain skills and resources, which will form critical mass for sustainable innovation;
- supporting actions towards SMEs, by organising SME networking events and making the participation in R&D projects more SMEs' friendly;
- supporting standardization activities, combating today's market fragmentation and ensuring interoperability.
- encouraging sharing of research infrastructures, or other platforms,
- encouraging sharing of and contributing to tool platforms, and for setting sound business models to ensure their sustainability after their project's ends.
- Setting rugged, science-based engineering processes to embrace fast-changing requirements, and integrate multiple and diverse technologies and non-functional properties,

All these accelerators facilitate Innovation by:

- Reducing development costs and time,
- Allowing the pace of product-family roll-out to be governed by business needs (rather than engineering limitations),
- Lowering the threshold of product introduction in face of rapidly changing market needs,
- Increasing customer confidence, trust and acceptance.

The ECSEL JU Programmes

Stimulating the emergence of innovation ecosystems within the field of embedded systems is made through the **support of R&D projects – through either tri-partite or bi-partite funding -** in **a number of business sectors**, facilitating their integration into larger ecosystem.

a) The ARTEMIS Sub-Programmes (ASP) that embrace both technological and application-oriented development to facilitate the emergence of innovation ecosystems of pan-European scale.

b) The ARTEMIS Innovation Pilot Programmes were set after the ARTEMIS-IA 2011 Summer Camp, as anticipation to the H2020 KET initiative, while adapting this concept to the Embedded Systems field.

   The AIPPS *are targeting large scale integration projects* **to sustain the ARTEMIS innovation environment** through *creating new business innovating eco-systems by efficiently using of Public, Private Partnership funding and establishing a holistic approach to R&D& through projects of critical mass, reconciling the market silos/ business efficient approach with the cross-domain synergies.*

c) KETs/ multiKETs

   The European Commission has identified 6 Key Enabling Technologies (KETs) that are crucial to the development of the European economy.These Key Enabling Technologies should play a crucial role for insuring the competitiveness of European industries as a main driving force (enablers) for European R&D and innovation.

   Although Embedded Systems are not retained as such in the KET initiative, Embedded Systems are key enabler for efficient use and exploitation of these KETs in the ICT environment and for generating intelligent applications. Joining and contributing to these KETs is part of ARTEMIS Strategy to be developed and sustained during the H2020 implementation.

   Beside the KET initiative, the EC has also opened the possibility to set Multi-KET pilot lines, for topics that could be driven by a combination of technologies. **This mKET will be considered in ARTEMIS Strategy implementation as an opportunity to develop, jointly or separately with the AIPPs concept described above.**

The way ahead

In the second Interim evaluation report of the ARTEMIS and ENIAC JTIs, the panel confirms: "the significant value and achievements of the ARTEMIS and ENIAC JTIs and congratulates all JTI participants on their vision and dedication and contributions to JTI execution".

The report also advice that for the next JU, a *"European-wide ECS strategy should be devised and implemented"*. **The present up-date constitutes a valid step-stone to contribute in building such a common strategy to be** *"agreed upon by the EC and Member States and supported by industry, with a clear line of responsibility within the EC for its development and subsequent maintenance."*

1 Introduction

First published in 2006 by ARTEMIS ETP and up-dated in 2011 by ARTEMIS-IA, the pan-European ARTEMIS Strategic Research Agenda developed the ARTEMIS Embedded Systems vision and mission. It also defined the major challenges that have to be addressed in order to realise the industry-driven long-term vision and objectives of ARTEMIS Technology Platform in the fields Embedded Systems.

This SRA clearly mentioned, in the chapter Make it Happen, its ambition to inspire the research policies makers in Europe and their work-programmes, mainly the ARTEMIS JU work-programmes, but also the EC for EU Framework programmes, the multi-national Eureka clusters ITEA and CATRENE programmes, and national and regional research programmes.

The ARTEMIS first evaluation report highlights the fact that Strategic Research Agendas (2006) has 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 nano-electronics should continue to be coordinated on the European level."*

> **The ARTEMIS ETP SRAs are meant to help matching the allocation of programmes and resources to different technology and policy challenges.**

2 The ARTEMIS Way

The present document is based on the SRA 2011 edition while taking the opportunity to update it by taking into account new trends and evolution of technology, industry and society in order to inspire programmes as mentioned above.

ARTEMIS has proven to be a unique programme that succeeded in few years to set the largest R&D projects in the area of Embedded Systems for safety- critical, high reliability systems and that addressed main societal challenges such as mobility, aging society, manufacturing processes, efficient building, and energy management.[6]

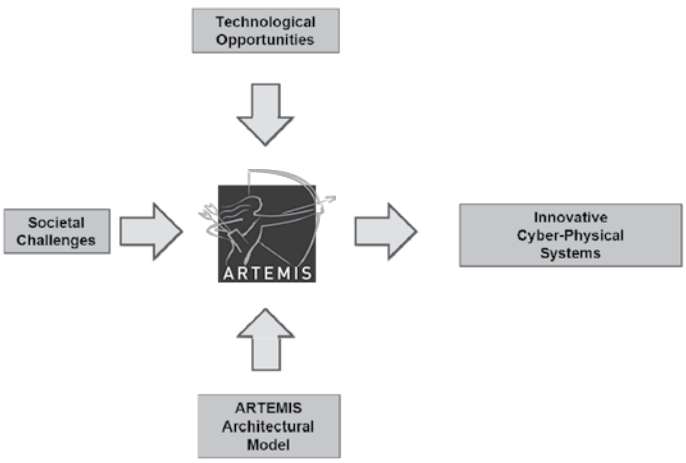
It is of major importance to maintain ARTEMIS approach in order to sustain the strong technological capability in Europe for the total value chain, on both the supply and the application sides of Embedded Systems by:

> **Overcoming fragmentation** in the European supply base for the components and tools of embedded systems.

> R**emoving barriers between application contexts** to yield multi-domain, reusable components and systems.

The original ARTEMIS **Industrial Priorities** aim to achieve multi-domain compatibility and interoperability. In the 2011 update to the ARTEMIS Strategic Research Agenda, this strategy was taken further: the **Societal Challenges** are 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. Opening new applications contexts[7] is also part of ARTEMIS Innovation Strategy to involve new actors from activities. Smart Cities, Environment and Agriculture, Food, etc … are amongst these new areas where **Embedded Systems, evolving into Cyber-Physical Systems** will be a determinant factor in their growth.

The ARTEMIS Way consists now of integrating the three drivers in order to deliver an innovative roadmap for developing and delivering Embedded Systems/Cyber-Physical Systems to serve various application contexts.



6 See ARTEMIS Book of Successes

7 See **ITEA ARTEMIS-IA High Level Vision 2030**: Opportunities for Europe, Version 2013

3 Embedded systems economic and societal challenges

3.1 Economic challenges

Since there is no commonly accepted definition of the term Embedded Systems, it is difficult to capture and forecast the market relevant data**.** Current forecasts differ in the predicted market characteristics. The available figures can be found in the Vision 2030[8] common to ITEA and ARTEMIS.

Amongst different reports and studies, a relatively realistic prediction of the global market volume for Embedded Systems expects it to amount about €71 billion (for 2009) with a market penetration of over 40 billion of Embedded Systems devices sold by 2020[9]. Cumulated average growth rates of up to 20% are predicted in market surveys (source: IDC, 2011).

From the available data, there is almost no application area or business sector, in which Embedded Systems have no direct or indirect impact on and markets trend analysis for different application areas indicates that in the last decades the Embedded Systems Market has been growing faster than the traditional computing market:

- Approximately 2% of the sold microprocessors are used for IT and PC and 98% for the embedded systems such as cars, trains, medical devices, airplanes, household devices, traffic management systems, in mobile devices etc..
- Every year more than 3 billion ES are integrated in the devices and other systems for a total market of about €160 billion[10].

From these markets perspectives, building ARTEMIS vision and strategy would take into account the following aspects:

Skill and knowledge in Europe
Asian leadership in consumer electronics and US in IT and traditional computing their fast growing number of scientists, engineers in BRICS Countries and lack of skilled persons in
Europe as a result of demographic change is challenging the European position.

As a major player Europe is still leading the ES Market. Share of R&D investments in Europe has been rising gradually up to 14 % (CAGR) in 2010. Other strengths can be named as the ability for public funding for ES and education of necessary skills. High-standard education level and close cooperation between Industry and Science, leading positions in profitable sectors such as automotive, energy, chemicals, etc. Almost every market study in the field shows that **if the amount of the current investments is not going to be increased in accordance with the societal and technological challenges this leading position can be lost easily.**

The new Internet economy
In the past years we have witnessed a dramatic shift from "computers" to "mobile devices". Smart phones and tablets now dominate the consumer market, while desktop computer sales are decreasing, leading to a "Post-PC world" with the key characteristic of pervasive connectivity. The next move is just coming with the Cyber-Physical

[8] **ITEA ARTEMIS-IA High Level Vision 2030**: Opportunities for Europe, The impact of software innovation on revenue and jobs
[9] ARCADIA report: Market trends analysis and application domains
[10] **Bitkom**. Eingebettete Systeme – Ein strategisches Wachstumsfeld für Deutschland Anwendungsbeispiele, Zahlen und Trends.

enabled world or 'Things of the Internet', where billions of devices, sensors, actuators, will communicate together, to servers and to humans forming what some people call the **"Industrial Internet"** (from General Electrics) or "Embedded Internet" (from Intel) revolution. *"The real opportunity for change is still ahead of us, surpassing the magnitude of the development and adoption of the consumer Internet. It is what we call the "Industrial Internet," an open, global network that connects people, data and machines. The Industrial Internet is aimed at advancing the critical industries that power, move and treat the world…. Machines will have the analytical intelligence to self-diagnose and self-correct. They will be able to deliver the right information to the right people, all in real time. When machines can sense conditions and communicate, they become instruments of understanding. They create knowledge from which we can act quickly, saving money and producing better outcomes." (from http://gigaom.com/2012/11/28/the-future-of-the-internet-is-intelligent-machines/). ""We are now on the threshold of a fourth phase in the evolution of the Internet. Intel calls this the "Embedded Internet", a network space where billions of intelligent embedded devices will connect with larger computing systems, and to each other, without human intervention. "(From Intel white paper "Rise of the Embedded Internet"). According to Cisco, "IoE Creates $14.4 Trillion of Value at Stake for Companies and Industries".* **This emerging revolution relies heavily on embedded systems technologies and to domains mastered by European technologies. It is of paramount importance that Europe takes a leadership role in this domain.**

Leadership of vertically integrated companies

In the domain of consumer electronics, companies that have gained control over the complete value chain (from hardware to end-user applications) have shown recently high success and seem to be more resilient to the economic crisis. Google, Amazon,... tend to extend their range to devices, even silicon design to retail shops or Internet shops, and for a some extent Samsung, Apple, IBM are moving for services. Both are creating an ecosystem and a customer lock-in over the complete value chain. In past years (decade), European companies generally became less vertical (Philips, Siemens, Thomson, …) and Europe is now full or horizontal specialization, which makes it difficult to compete because companies are squeezed between the economical pressure of providers and customers. **In a complete value chains, it is sometimes necessary to have less efficient parts - in order to gain an overall better efficiency.**

The "Always Connected Society" and the economic crisis

As highlighted in the ITEA/ARTEMIS 2030 Vision, the virtualisation of communities has changed our society and the way information and knowledge are exchanged, made available or shared: "Individuals are no longer individuals only, but they are part of social networks and entities. Web-based social and business networks serve as virtual communities in which individuals may even adopt a virtual identity" (RB). This trend will get even stronger as social media could also replace many of the traditional types of media. Its economical impact will shape the IT market in general and the Embedded Systems/Cyber-Physical Systems in particular.

However, this prediction of **the strong demand** of the young generation to remain and stay connected to their communities **(the Always Connected Society)** in any circumstances could be not fully justified as the impact of the economic crisis may, as recently observed, have a greater impact on the individuals' budget and weaker expenditures dedicated to communication than predicted/expected.

3.2 Societal challenges as opportunities

As stated in ARTEMIS SRA, *'One of the main reasons for the formation of ARTEMIS was the quest for greater economic growth in Europe. Today Europe faces a number of societal challenges arising from inverted demographic curves, the constantly increased demands for non-renewable natural resources, the climate change and the constant expectations for improved quality of life, where the modern European social welfare model and its sustainability is one of the major challenges facing the European.'*

These societal challenges have been also further developed in the Common ITEA/ARTEMIS 2030 vision published during their Co-Summit in Paris (October 2012)- An up-date of this Vision will be published during the 2013 Co-Summit.

They could be summarised as follows:

Societal challenge	Description
Climate Change	> 11 of the 12 years between 1994 and 2005 rank among the 12 warmest since weather observations began > Today we face the highest CO_2 concentration in the atmosphere for the past 350.000 years
	***ARTEMIS Contribution**:* > *Improved safe and secure mobility with efficient overall energy management, and* CO_2 *reduction, particularly for ICT products.* > *Process industry as an agile part of energy systems* > *safer, greener and inclusive mobility (harmonizing private and public transportation)* > *Smarter and sustainable production through industrial process automation, instant access to dynamic factory.*
Demographic Change	> Average life expectancy worldwide will increase to 72 years in 2025 from 46.6 years in 1950. - World population will grow from more than 6 billion now to 8 billion by 2025, - aging population causing raising cost of Healthcare - Solutions will be more and more centred around individuals needing excellent human system interaction
	***ARTEMIS contribution**:* > *Automated farming will increase agricultural productivity while respecting the 'green' principles.* > *Better and more affordable everywhere health care and health cure.* > *Robotic surgery will cure many fatal illnesses* > *Autonomous driving will increase mobility and safety of aging population*

Urbanization	> Today: 280 million people live in megacities (>10 million residents) > 2050: It is expected that 70% of the world population will be urban[1]
	ARTEMIS contribution*:* > *smarter and more secure cities- intelligent urbanisation.* > *On-line cars/ fleet management* > *Advanced driver assistance systems will reduce traffic fatalities and save significant costs* > *Autonomous cars, with Car-to-car/ car to infrastructure connectivity*
Globalization	> From 1950 to 2004, the volume of global trade has increased 27.5-fold > The number of global players has grown from 17.000 in 1980 to over 70.000 today.
	ARTEMIS contribution*:* > *the 'Always', better and faster connected world through intertwined systems.* > *Automated flying will take better usage of the limited airspace* > *Sustainable production: flexible distributed production/ manufacturing intelligence*
[1] PRB	

3.3 Economical and Societal Challenges driving Applications Contexts

Markets trends/opportunity and growth potential for a selected number of vertical application contexts

3.3.1 Efficient, autonomous and Safe Mobility

> Aircrafts
> Automotive
> Space
> Public transportation
> Railway
> Ships and waterborne
> Multi-modal transport

All transport related products and market segments are in the core affected and sometimes even determined by their content of electronic components and systems. Indeed, the major differentiating factor is more and more not inside the hardware itself, even if it is absolutely mandatory to have it, but differentiation is taking place through the content of the application software integrated the embedded systems or the cyber-physical systems. Without the "electronics" and consequently the embedded systems no modern transportation means will work!

The new trend is the connection of smart elements beyond the boundaries of the platforms (car, bus, truck, aircraft, railway, ..): The individual platforms are being connected to information coming from the outside world and react to this (car to x, SESAR, ..). More over: Some systems will even rely in safety critical manner on the availability and the correctness of this information. If, for example, inside SESAR the 4D flight path is adjusted following the information received through a wireless network, today's level of quality of service (QoS) is not at all sufficient for a bare extrapolation of e.g. an internet type of network. Issues like these need to be addressed to really be able to build next generation's networked and Cyber Physical Systems, esp. in transportation.

This vision will require enormous efforts in R&D in order to support all these interconnected services and keep the related infrastructure systems up and running. Such market view of "Industrial Internet" or "Embedded Internet" will revolutionize the markets and the society most likely even more than the introduction of the Internet caused or the start of mobile communication. It will be an endless source of business models that can be exploited as soon as the basis is laid and the appropriate systems are working to a high degree. The next ten to twenty years to come will show a quantum leap in automation of daily needed services happening. This will be denoted in the change of mobility making the combustion run vehicles more and more unaffordable and thus forcing other sources of energy to substitute or push towards other solutions and means to avoid physical transportation.

The increasing number of traffic participants and the increasing density of traffic will require advanced driver assistance systems that will on the one hand reduce the driver's stress and thus related numbers of accidents despite growing numbers of participants. On the other hand it will increase the comfort significantly.

In the area of railway the new means will make redundant line based control systems to large degree. Either wireless communication means can be used or lines from different other networks will be able to take such data traffic reducing the cost of running these systems significantly. In the same way industrial segments such as power generation will benefit due to installing their control lines via security protected Internet channels that even are able to have deterministic performance required for critical control communication.

The activities already started in the "Single European Sky" including free flight trajectories etc. will influence the innovation in the aerospace sector. In addition wireless communication will be coming up to be used in aircraft even for control functions. This will reduce the fuel burn due to weight reduction. Much more complex surveillance and air traffic control means will have to be in place to deal with increasing numbers of aircraft and in order to cope with the demands for decreasing delay times at the same time the number of flights is increasing.

The holistic approach of **safe and secure mobility** will have to satisfy all kinds of services, be it the private traffic (in the long run most likely in the e-vehicles or similar) or be it the public sector comprising urban public traffic up to railway and commercial air-transport or any other means. Such mobility will require significant amount of energy on the one hand and it will also require significant communication.

3.3.1.1 Automotive

Road transport is one of the most important economic sectors in Europe. The 27 EU countries have 5.000.000 km of paved roads and 45% of the goods transported in the EU are transported on these roads. Cars and busses account for 82% of passenger transportation.

The automotive sector directly employs 12 Mio people across the EU, which is equivalent to about 5.5% of the total EU employment.

25 - 30% of the cost of modern vehicles is caused by embedded electronics. In the year 2015 it will be 35 - 40% and even up to 50% seem reasonable in 2020.

The automotive sector has a turnover of over EUR 780 billion and represents about 8% of the European manufacturing value added. The trade balance of the automotive industry accounts for EUR 92 billion.

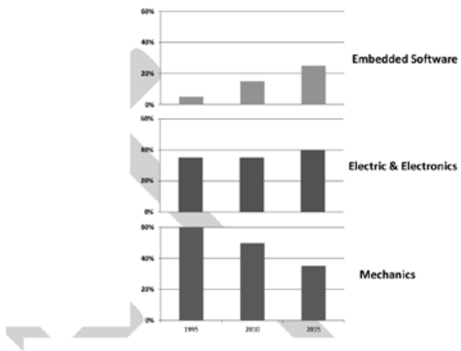


Figure 1: Percentage of domains in vehicle development (Source: A.T.Kearney Embedded Systems Study 2010)

The automotive industry faces significant challenges in the upcoming period: The road transport accounts for more than 25% of the total final energy consumption in the European Union and emits more than 70% of total CO_2 emissions of all transport sectors. More advanced and complex embedded systems will significantly contribute to the needed CO_2 reduction in order to reduce global warming.

The development of CO_2 reduced mobility leads to significantly more complex vehicles; hybrid powertrains, multivariable-controlled ICE engines, multispeed dual clutch or automatic transmissions, advanced driver assistance systems, … . All vehicle technologies with a potential of at least 40% fuel saving are based on embedded systems.

The next societal challenge in the automotive domain is safety. Currently about 31,000 people are killed in road accidents every year. Accident-free and autonomous automotive mobility are visions to become technically feasible, financially attainable and customer ready.

The increasing population leads to more automobile traffic under the constraint of limited space for new roads. The resulting traffic congestion costs the EU economy more than 1% of GDP.

In many emerging countries worldwide the automotive sector is seen as a key industry. Consequently European vehicle manufacturers and supply industry face increasing international competition.

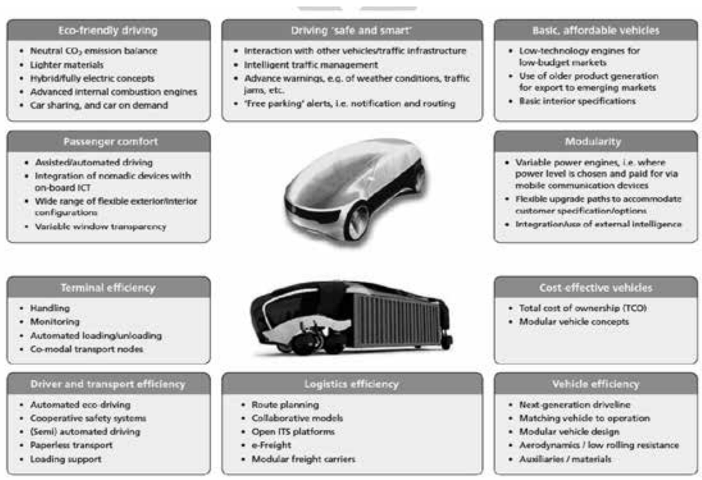


Figure 2: Future vehicle concepts (Source ERTrac)

EU transport policies aim at fostering clean, safe and efficient travel throughout Europe, strengthening the internal market of goods and the right of citizens to travel freely throughout the EU. The EC's White Paper 2011 includes 40 specific initiatives for the next decade that should increase mobility, remove major barriers and encourage growth and employment. At the same time it aims at dramatically reducing Europe's dependence on imported oil and at cutting carbon emissions in transport by 60% until 2050.

The ERTARC SRA stresses the idea of a systematic approach to address the Grand Societal Challenges. The ERTRAC guiding objective is a 50% overall efficiency improvement of the road transport system by 2030 compared to 2010 achieved by decarbonisation, reliability and safety targets.

Electric driving in local zero-emission areas depends upon embedded automotive systems enabling the integration of high and low voltage electronics, lifetime- and performance-relevant control of electrochemical energy on-board and hassle-free operation with intelligent charging infrastructure in world-wide variants.

70 - 90% of all innovations in vehicle development currently are based on embedded systems. Especially driving safety and always-on connectivity of cars and passengers are major customer benefits made possible through miniaturized sensing, computing, actuating and signalling devices. More and more societal economic, ecologic and individual added-value will be based on embedded systems in cars and trucks that are interfacing with data, software and embedded systems in their local and global environment.

Reliability, security and affordability of such enhanced driving services depend upon highly innovative hardware and software solutions, their rapid market volume penetration and future-prone modularity, open architectures and standard interfaces.

To achieve the targets in the automotive industry, nearly all new concepts and functions rely on superior functionality possible using embedded systems in nearly all major components of future vehicles as shown in figure 2. About 80% of electronic based functionalities in current vehicles are software based. 50 - 70% of the total development cost of automotive electronic control units is for software. The great technical and economic variance of on- and off-board, hard- and software, protected- and open-source solutions available to Engineering, Manufacturing and Service along the mobility value-chain will lead to a situation making the efficient and agile mastery of embedded systems complexity decisive.

3.3.1.2 Railway

The European Rail Industry is a key economic sector for growth, competitiveness and jobs (currently estimated at 400.000 direct and indirect jobs in the EU), one of the few industrial sectors in which Europe leads the world, supplying more than 50% of the world market for Rolling stock, Signalling systems and Railway Infrastructures.

Rail transport represents a major market opportunities for European companies, as world demand is forecast to grow at a rate of 2.6% in the world in the next years, although international competition is strengthening, as Asian countries are investing massively in R&D in support of their national industries.

Enhancing Rail transport is a policy priority for the EU, being at the heart of the European Commission's 2011 White Paper on Transport which aims at a competitive and resource-efficient European transport system, reducing greenhouse emissions by at least 60% by 2050 compared to 1990 ("Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system").

As the most friendly transport mode in terms of energy consumption and with average emissions at least 3-4 times lower than road or air transport, Rail is an essential part of the solution for how to achieve sustainable transport development in Europe, calling for a significant modal shift of the transportation of goods and passengers from road to rail.

Rail therefore faces in Europe the challenge to provide new affordable and attractive services leading to doubling the rail share of both the freight and passenger markets by 2050, corresponding to a growth of 300% of the rail freight and passenger market volumes, while the European high-speed Rail network will be tripled by 2030.

The shift towards Rail will be helped by its inherent qualities like safety, efficiency and convenience. Statistics indicate that in Europe accident levels are approximately 200 times higher in road than in Rail, making railway the safest transport mode for European passengers.

High-speed lines over distances of up to 800 – 1000 km have achieved a significant market success among European passengers for their convenience, outpacing aviation. A 400 km journey by high-speed train can be up to an hour faster than covering the same distance by plane, depending on the airport location and the capacity of the security control. In Urban mobility, metro and light rail systems have been recognized as an essential instrument for setting up new urban development and sustainable mobility paradigm.
To transform Europe's rail transport system, the European Commission's 2011 White Paper on Transport establishes new challenging goals concerning rail freight, high-speed lines, the upgrade of the standard European traffic management system, and the creation of a European multimodal transport information management and payment system.

In this challenging and competitive framework, ERRAC is calling for a dramatic increase of research efforts in order to develop innovative technologies and solutions to make Railway the most attractive transport mode in Europe by 2050 and allow European manufacturers to maintain a leadership role in the world, securing European jobs and know-how.

Strategic Rail Research Agenda Priority Areas

Roadmaps	Intelligent Mobility	Energy & Evironment	Personal Security	Safety & Homologation	Competitiveness & Enabling Technologies	Strategy & Economics	Infrastructure
WP01 The Greening of Surface Transport		✓					
WP02 Encouraging Modal Shift and Decongesting Transport Corridors	✓					✓	✓
WP03 Ensuring Sustainable (Sub)Uran Transport	✓					✓	✓
WP04 Safety and Security			✓	✓			
WP05 Strengthening Competitiveness					✓	✓	✓

ERRAC: Rail Route 2050: the sustainable backbone of the Single European Transport Area

According to ERRAC, focus areas of research and innovation should include:

- Safety and security, to maintain Rail as the safest transport mode. The reliability, availability, maintainability and safety of the railway system will increase. Intelligent infrastructure and rolling stock will be in place, able to autonomously monitor it and other system components. Stations have a new design with low or very low level of risk.
- Energy and the environment, as in 2050 rail will still be the most energy efficient and environmentally friendly transport mode. Trains will be quiet and no vibration will be perceived around the railway infrastructure. Railway energy networks will be managed as smart grids and the consumption of energy will be optimised, with smart energy on-board distribution, use and storage fully implemented. The energy efficiency of rolling stock will be significantly increased.
- Advanced Traffic Management & Control Systems, developing a new generation of signalling systems to enable intelligent traffic management and increase the reliability of connections and network capacity, paving the way for driverless operations.
- Solutions for a Seamless and intelligent Railway: passengers will be able to cross Europe in only a few hours thanks to seamless end-to-end journeys, all airports will be linked to rail, and co-modality will be easier. This will be performed by improved ticketing services, interoperability as well as better journey planning information. Crossing Europe means crossing borders, and interoperability will strongly improve by using new systems connecting trains and track.

From the above, it is evident the critical and growing importance of more powerful hardware platforms and software systems to enable the transformation of the railway system. Although there are no specific statistics, strong similarities with the automotive industry on the innovation impact of Embedded Systems should be expected.

Innovations based on Embedded Systems concern all the major areas of improvements of the railway system. For Safety, they are key in order to improve reliability, availability and maintainability of the railway system by using autonomous predictive diagnostic solutions performing continuous monitoring and testing of infrastructures and rolling stock, while, reducing hardware to be deployed on the wayside, further increasing reliability and affordability. To improve overall Security, innovative embedded solutions, for instance, will provide higher security of the entire containers transport chain or a lower level of risk in stations, physical security towards early warning of potential attacks must be strengthened

Traffic Management & Control Systems will require not only new technologies for high precision location of trains, but innovation will also be a key factor in increasing the affordability of such systems allowing their deployment in lines for high frequency commuter train service for which shorter headways and on-time performance are critical issues, if the required modal shift from road to rail is to take place. New Energy management and control capabilities will require innovations to allow its smart use, distribution and storage.

Therefore, a strong effort at European level in Research and Innovation in Embedded Systems is an essential condition to achieve the targets set by European railroad stakeholders to build the capabilities and the engineering tools needed to conceive, develop, test, validate and deploy richer and more complex systems and subsystems with safety critical properties.

3.3.1.3 Aerospace: "Customisable, time-efficient safe air transport

Aviation is a vital force for society and economy. It fulfils societal needs for suitable and sustainable mobility of passengers and goods over longer distances while enabling Europe to be connected to other continents and underpinning Europe's position as a geo-political power. Aviation generates wealth, employment and economic growth for Europe by contributing significantly to a positive balance of trade through export and by providing high added value and highly skilled jobs.

European aeronautics is a profitable and growing manufacturing sector with over 80,000 companies including a high number of SME (small and medium enterprises). Aviation provides highly skilled, sustainable, long-term employment, and about 12% of aeronautical revenues are reinvested in Research and Development, Supporting around 20% of aerospace jobs.

In Europe also the air transport sector support 8.7 million jobs overall, contributing nearly €600 billion to GDP. The significance of the sector is also demonstrated by the fact that in 2010 in Europe there were 606 million air passengers carried on 7.9 million flights. Europe has 701 commercial airports and 448 airlines with approximately 6600 aircraft in service and European air traffic is managed by 45 air navigation service providers.

The European aviation sector has much strength but also there is the possibility of improving this record. European aviation operates in a highly competitive, global arena, in fact other regions of the world, both established and emerging economies, have recognised the strategic nature of aviation and are developing capabilities along the entire value-chain from vehicles, through infrastructure, to services, all supported by significant investment. The threats from this competition are very dynamic and real, both internally within Europe and to its exports on global markets.

The main recognised challenges that had evolved during time address two parallel objectives: maintaining global leadership and serving society's needs. It has identified goals to reach these objectives and address the following main challenges:

- Meeting market and societal needs
- Maintaining and extending industrial leadership
- Protecting the environment and the energy supply
- Ensuring safety and security
- Prioritising research, testing capabilities and education.

As it can be understood, in these competitive scenarios and for facing these challenges there is a strong need for 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.

The avionics market trend is an always more frequent introduction of innovative solutions, together with cost and development cycle reductions. Avionics systems requirements follow a fast evolution, in particular as regard to increasing performances, and supporting new functions, while ensuring high levels of reliability and maintainability. Main challenges are related to the acceleration of technology cycles, the increased complexity of systems, the cost of software development, the context of extended enterprise, and the management of variants, including especially legacy products.

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3.3.1.4 Space

The global Satellite Market
The global space industry generated cumulated global revenue over $289.8 Billion in 201[11]. Space is a rather closed and yet heterogeneous market with a strong vertical integration that includes a wide variety of actors and products that can be summarised in four main segments detailed hereafter:

> Satellite Manufacturing (Satellite Manufacturing; Parts, Components, and Subsystems)
> Launch Industry (Launch Services , Launch Vehicles)
> Satellite Services (Consumer Services, Satellite Television/Radio, Satellite Broadband, Transponder Agreements, Mobile Satellite Services, Remote Sensing/Imaging Services, Space Flight Management Services)
> Ground Equipment (Network Equipment, Gateways, Control Stations, Consumer Equipment, Terminals/ Receivers/Dishes…)

In addition, the satellite industry is a subset of both the telecommunications and space industries it represents 61% of space industry revenues and 4% of overall global telecommunications industry revenues. The global satellite industry posted growth of 5% in 2011, matching growth in 2010 and following a steady growth since the beginning of the century.

11 Source: SIA/Futron - State of the Satellite Industry Report (May 2012)

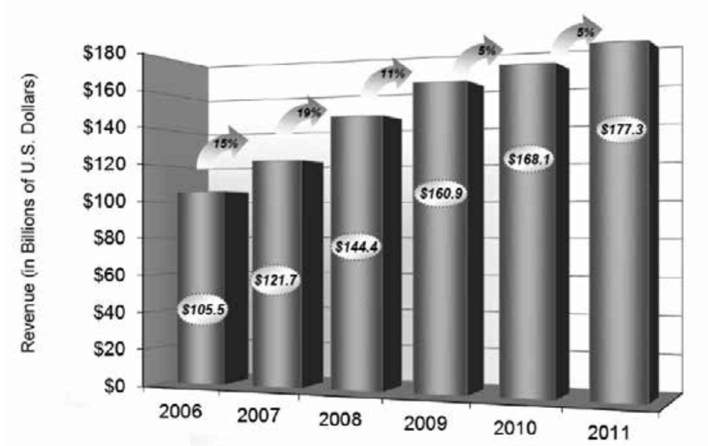

Figure 1 World Satellite Industry Revenues

Satellite manufacturing revenues grew 9%, from $10.8 billion to $11.9 billion. In this scenario, the revenue share is 50% for the US; Europe accounted for 32% of 2011 Satellite Manufacturing revenues while Asia accounted for 15%. Attending to the applications of the different satellite missions, of the 994 satellites on orbit, 38% are commercial communications satellites, an additional 20% are civil government or military communications satellites with the relative proportion comprised by communications satellites remaining consistent from 2011 to 2012.

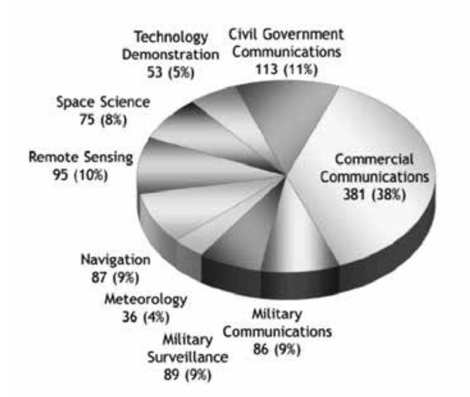

Figure 2 Satellites in Orbit by application

This wide application portfolio helps to maintain the steady growth of business as Global satellite industry growth continues at a steady rate of 5% with an even distribution among sectors: Worldwide Satellite Services revenues grew by 6%. Satellite Services is by far the largest segment, representing 61% of global satellite industry revenues, and remains the primary growth driver for other industry segments. Global Satellite Manufacturing revenues grew by 9%. Global Launch Industry revenues grew by 10% and Ground Equipment revenue growth rose 2%, reflecting steady demand for consumer and network equipment. This market evolution calls for a constant innovation process to cover the new needs appearing in all these applications. This need is reflected in an R&D expense that averages 10% of the business turnover of the sector distributed evenly between private and public initiatives.

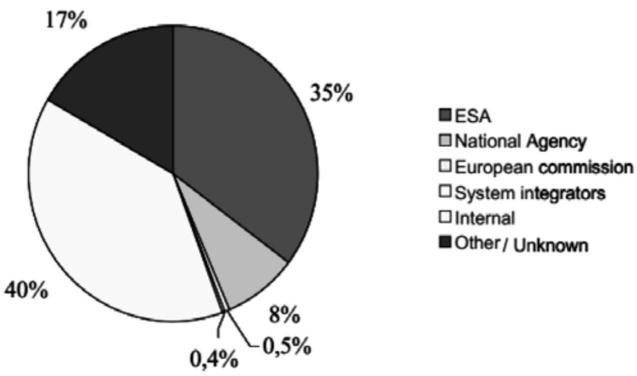

Figure 3 R&D Sources for European Space Industry (Source ESA)

EUROPE'S ROLE IN THE SPACE BUSSINESS

The European space manufacturing industry is a niche strategic sector, embedded in the wider European AeroSpace and Defence industrial complex, with a balanced eco-system including large industrial holdings, smaller space units, and SMEs.

The European Space Industry employs more than 35.000 people all over Europe with a high qualification profile, being more than 65% university graduates.

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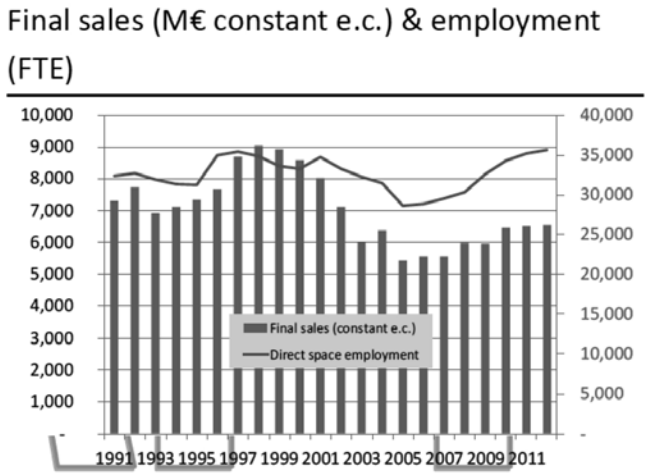


The space manufacturing industry is an infrastructure supplier. The sector operates at the higher end of the space value chain, and supplies to service providers and public institutions, spacecraft and launchers to their requirements. Industry is distributed across all Europe, with the main industrial sites located in France, Germany, Italy, and, to a lesser extent, United Kingdom, Spain and Belgium. Major significant changes occurred in the European space industry over the past decades.

At the top of the value chain (systems integrators), mergers and acquisitions have restructured the manufacturing sector. Strategies of vertical and horizontal integration have kept on as well.

European space industry products include military and civil systems. Civil system sales are still the vast majority of sales (89.4%). Satellite applications systems are the main source of in-come for the European industry (3.4 B€ i.e. 52% of final sales), and are also the main domain of exports (with 1.1 B€, i.e. 17% of final sales and 32% of satellite applications sales). The two most important segments in terms of income are telecommunications and Earth observation. Within satellite applications, positioning & navigation is the segment with less export sales, it is today limited to institutional customers in Europe (Galileo programmes). Telecommunications systems are more frequently exported than other systems, and in 2012 exports in telecoms represented 50% of total telecommunications systems sales.

Main customers for telecommunications systems are private and public satellite operators worldwide (almost 1.4 B€ sales, of which 50% are exports, mostly public operators) while European public agencies procure as much as 288 M€.

As to navigation/localisation systems, although it is the less important satellite application in value, it is gaining importance since a few years due to the ESA/EC EGNOS and Galileo programmes

Europe plays a very active role as provider of satellite solutions for non US customers in emerging countries. This role is permanently threatened by the still existing dependency in the parts domain to the US suppliers, especially in the area of high capacity, high reliability processing platforms. These US parts, due to the particular nature of the space sector and following commercial directives, are subject of ITAR license regulations that strongly limit the usage of these parts for commercial programmes outside a strictly European frame, impacting directly in the marketability of European products in the non US export market.

The impact of ARTEMIS in the SPACE domain

Satellites and satellite systems contain, by its own nature, different embedded systems ranging from the processors in the signal receivers or system controllers of the ground segment to the utmost critical on board computers or payload processors and controllers. This means that ARTEMIS scope of activities and challenges impact directly the space sector and this has been facilitated through a sound and stable participation of space actors in ARTEMIS projects. Direct links can be made between the space business needs in R&D&I areas in the following way:

a) **Methods and processes for safety-relevant embedded systems**: Satellite systems can be considered in most cases as safety critical and, due to their cost and unique nature. ARTEMIS developments will improve the dependability and safety of the critical processing elements of a satellite.

b) **Embedded Systems in Smart Environments**: Satellite geolocation services as well as data trunking for sensorized infrastructures can play a relevant role in future Smart environment. The ARTEMIS integrated view will allow to seamlessly integrated satellite communication and geolocation services in the future Smart Environment developments. The target is to guarantee that the Space link is as compatible and available as any other for this type of solutions.

c) **Embedded Systems for M anufacturing and process automation**: Space manufacturing is based on high reliability, full traceability processes. The integral system level view provided by ARTEMIS will greatly improve the development of complex Space Systems and Sub-Systems in terms of cost and efficiency.

d) **Computing platforms for Embedded Systems**: This area will have a deep impact in the definition of the next generation of satellite on board mission and data processors. Due to its conservative nature, Space flight processors call for a dramatic evolution where the activities in HW, SW and processes definition performed in ARTEMIS projects will help in driving a steady and reliable transition from present legacy single core processors to future MPSoC reconfigurable flexible architectures. This transition will rely more in the reliability, dependability and performance estimation algorithms developed by ARTEMIS' projects than in the actual performance of the selected devices. ARTEMIS will be also key to guarantee that future computing platforms to be used by European space actors are available outside the ITAR regulations frame, thus allowing the European industry to take a leading role in the export market.

e) **Embedded Systems for Security and Critical Infrastructures Protection**: as for b), satellite links can provide seamless, highly reliable, sabotage free connection capabilities for critical infrastructures. In addition to this, the intrinsic global coverage of satellite networks will allow the fast deployment of the proposed surveillance networks even in remote critical installations. This means that the satellite will be a direct mean of spreading the different ARTEMIS development to all European population, covering the remote and under-connected areas.

f) **Embedded Systems supporting sustainable Urban Life:** as for b) and e), satellite networks will play a relevant role in the extension and support of the Smart City paradigm in two main axes: First, once fully developed and deployed, the systems supporting the new Smart city solutions will need to be secured and its performance guaranteed. Satellite backbones will be the best option to provide emergency or backup connectivity to all the networks used to build the nervous system of these smart environments. Second, once deployed a series of services in the cities, the rest of citizens will demand the extension of these services to cover the entire European population. At this stage, satellite networks will provide its fast deployment and remote area coverage capabilities to comply with this requirement.

3.3.2 Wellbeing and health

Care everywhere

- Home care
- Hospital care
- Heuristic healthcare?

Assisted living

3.3.2.1 Healthcare

The challenges for society in healthcare are formidable:

- More demand: 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 in terms of our ageing population:
  - By 2045 more people will be over 60 than under 15 years of age, rising from 600 million to 2 billion in 2010

- Rise in number of patients with age-related, chronic and degenerative conditions.
- Healthcare professional staffing shortages rises, due to higher demand for patient attention
- Pressure towards more efficiency and effectiveness of healthcare: need to further improve hospital work flow efficiency, integration of diagnosis and treatment, quality assurance
- Skyrocketing healthcare costs: spending accounted for 9.5% of GDP on average across OECD countries in 2010. Globally, costs are expected to increase to 15% of GDP by 2015. In 2010, spending as a share of GDP was highest in the United States (17.6% of GDP), followed by the Netherlands (12%), France and Germany (11.6% each).[12]

Europe is challenged to find solutions and to overcome the technological barriers including:

- Personal: User acceptance :(user, patient, GP, specialist, nurses, doctors, pharma)
- Energy: energy scavenging, ultra low power design, reliable, high bandwidth, low power connectivity.
- Data management: data protection and privacy,
- Devices and systems:
- Processes

Healthcare needs to become more patient-centric, with a key role for medical technology supporting a patient throughout the phases of the care cycle:

- **Diagnostics:** move routine diagnosis to general practitioners, diagnostic centres or home care centres. Develop more advanced imaging and diagnostics technologies in the hospitals
- Accelerate transition from invasive, open surgery to **minimally invasive, image guided intervention and treatment (IGIT**). This will provide predictable procedure times, fewer complications, (much) shorter hospitalization with less personnel involvement and fast recovery of the patient
- **Hospital treatment:** time to treatment and hospitalisation time should be reduced drastically, through better use of available data and images, originating from heterogeneous sensors, devices and imaging equipment (see also IGIT above)
- **Home and community care:** introduction of lightweight monitoring devices to promptly detect any complication or relapse. Monitor chronic patients at home, and provide them with empowerment tools to avoid frequent medical visits

The ARTEMIS SRA 2011 solutions still apply and extended as follows:

(1) care at home and everywhere providing reduced cost of hospitalisation and the monitoring of elderly people requiring prolonged medical care using point-of-care terminals;
(2) Early diagnoses and prevention; including screening.
(3) Image Guided Intervention and Therapy preventing open surgery (with a lot of patient discomfort);
(4) Clinical Decision Support Systems supporting the specialist in optimizing his/her clinical work flow.
(5) Personal medicine, profiling people and develop a tailored cure,
(6) Use of wearable/implantable technology in monitoring, like smart clothing and smart fabrics and devices watched
(7) Intelligent catheters and in body sensors/actuators (e.g. drug delivery).

All these solutions should be reliable, secure and safe, which is a common theme within other industries. In other words, a cross industry approach in Europe will strengthen the European industry and employment.

3.3.3 Sustainable Production

A society creates value by mining natural resources, growing food, manufacturing products or delivering services. A society like Europe is not natural resource rich, and has maximized its food production. Service delivery alone has a limited potential in terms of employment and has less productivity improvement options then

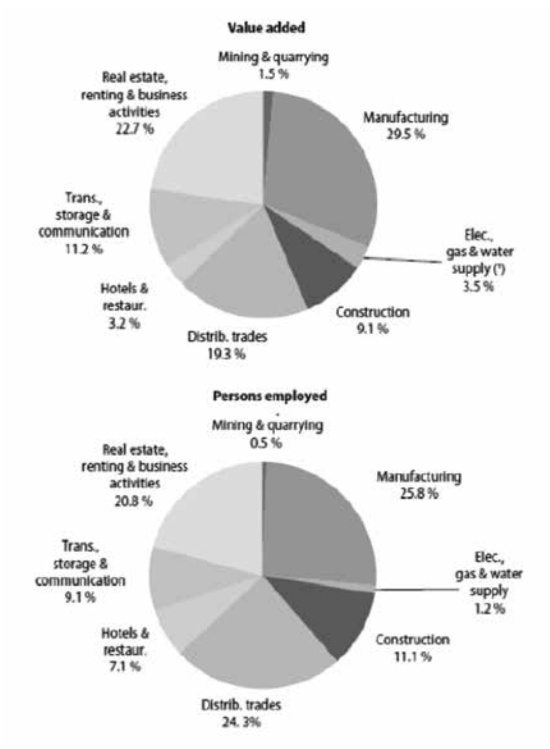
[12] *OECD Health Data 2012*

manufacturing has shown. Therefore manufacturing and process automation and improvements in both are essential for Europe to generate value for its people, buy the natural resources it needs, maintain the welfare of its people and protect its environment. Manufacturing and process automation enable many of the European Grand Challenges (climate change, energy and food security, health and an ageing population) at a scale that contributes to economic wealth whilst minimising environmental impact and creating a sustainable society.
In response to these megatrends and in line with the European strategy, European manufacturing and process automation will undergo structural transformations towards sustainable competitiveness. This will have impact in areas such as:

> Food production
> Semi-conductors
> Process automation
> Manufacturing
> Mining
> Oil and gas
> Chemicals
> Power plants/ energy conversion – renewable energy resources – biomass, biofuel, wind, sea, …
> Pharmaceutical
> Forestry
> logistics

Overall, the achievement of the identified transformations requires a coordinated research and innovation effort, where manufacturing and process automation challenges and opportunities are addressed by deploying successively the following set of technologies and enablers: advanced manufacturing processes and technologies including photonics, mechatronics for advanced manufacturing systems including robotics, information and communication technologies (ICT), manufacturing strategies, knowledge-workers and modelling, simulation and forecasting methods and tools.

Industrial process automation and manufacturing are an important sector for Europe. Many European companies are world leaders in terms of systems and applications development, supply, and usage. ABB is the world leader in process automation with a market share of 22%, followed by Siemens and Schneider Electric. The importance of manufacturing in Europe is highlighted in the roadmap from the Ad-hoc Industrial Advisory Group of the Factories of the Future PPP and EFFRA, the European Factories of the Future Research Association stating that around one in ten (9.8 %) of all enterprises in the EU-27's non-financial business economy were classified as manufacturing in 2009, a total of 2 million enterprises. The manufacturing sector employed 31 million persons in 2009, generated EUR 5,812 billion of turnover and EUR 1,400 billion of value added. The sectors' turnover grew from 2009 to 2010 by EUR 600 billion, up to EUR 6,400 billion. By these measures, manufacturing was the second largest of the NACE sections within the EU-27's non-financial business economy in terms of its contribution to employment (22.8 %) and the largest contributor to non-financial business economy value added, accounting for one quarter (25.0 %) of the total (source: Eurostat).



Eurostat Yearbook 2011], [Statistical Classification of Economic Activities in the European Community (NACE)], [Statistisches Bundesamt, Stand 01/2010]

According to the report "Implementing 21st Century Smart Manufacturing (2011)", over the last decade, the evolution in digital computing and communications has fundamentally changed the way manufacturing plants operate. Digital plants are creating new opportunities for the adoption of smart manufacturing techniques to support more agile operations and accelerated product and business cycles. Today, smart tools and systems are being used to innovate, plan, design, build, operate, maintain, and manage industrial facilities in significantly improved ways.

Some current and potential applications of Smart Manufacturing (SM) are suggested:

> Digital control systems with embedded, automated process controls, operator tools, and service information systems can optimize plant operations and safety.
> Asset management using predictive maintenance tools, statistical evaluation, and measurements could maximize plant reliability.
> Smart sensors could detect anomalies and help avoid abnormal or catastrophic events.
> Smart systems integrated within the industrial energy management system and externally with the smart grid could enable real-time energy optimization.

Technologies at the core of SM (Networked sensors, Data interoperability, Multi-scale dynamic modeling and simulation, Intelligent automation, Scalable, multi-level cyber security) collectively enable effective integration of the increasingly complex components that make up modern manufacturing systems. Continued advances in these technologies are needed to enable a substantially greater segment of industrial plants to take advantage of smart manufacturing concepts. These applications are important to all types of manufacturing regardless of operating structure:

(1) Batch operations for manufacturing products from a few material inputs in single lots or batches (e.g. pharmaceuticals, specialty glass, chemicals, semiconductors, and engineered materials),
(2) Continuous operations for manufacturing a wide range of products from few material inputs (e.g. chemicals, petroleum refining, steel making, pulp and paper and aluminum) and
(3) for Discrete operations for assembling products from a large number of components (e.g. consumer electronics, automotive, and equipment and machinery manufacture) and the size of the enterprises.

The roadmap from the SPIRE consortium (Sustainable Process Industry - European industrial competitiveness through Resource and Energy efficiency) states that the sectors united in SPIRE represent a major portion of the manufacturing base in Europe (EU27), including more than 450,000 individual enterprises. They hire over 6.8 million employees and generate more than 1,600 billion in turnover, representing 20% of the total European manufacturing industry, both in terms of employment and turnover. Industry accounted for more than a quarter of the total European energy usage in 2010, with a significant portion of that use occurring within the process industry.

The Factories of the Future PPP identifies and realises these transformations by pursuing a set of research priorities along the following research and innovation domains, all of them closely related to the progress on CPSs:

> Advanced manufacturing processes
> Adaptive and smart manufacturing systems
> Digital, virtual and resource-efficient factories
> Collaborative and mobile enterprises
> Human-centred manufacturing
> Customer-focused manufacturing

Drivers for innovation at manufacturing industry also include the needs to consider the efficiency of discretised processes as well as the economic sustainability of manufacturing. As indicated in the roadmap of Factories of the Future 2020 Sustainability is pushing for an extension of the life cycle itself, and to a change in manufacturing strategies towards "servitization": from product/services systems (product centred approach) to services through product (solution oriented approach).

Finally, according to the European study [Monitoring and control; today´s market, its evolution till 2020 and the impact of ICT on these], the major drivers for improved automation (monitoring and control) are energy efficiency, the cost of oil/gas, safety and security, the development of services and reliability. This study indicates that world market for the automation of process industries is 26,3B Euro where the European market share is 10B Euro. The annual growth rate for the European industrial process automation market is estimated at 6.9% through 2020, and the growth rate for manufacturing (including the manufacture of mining machinery) is estimated at 6.3%. The industry's primary challenges in the automation field consist of:
a) ALL IP and SOA architectures,
b) Complex systems optimisation, control and flexibility,
c) Flexibility, availability and maintenance control.

These areas are directly addressed in this roadmap. The study also notes that automation services predominate over automation hardware and software. This finding indicates that engineering tools and engineering efficiency will be of utmost importance for both end users and suppliers.

Manufacturing and process automation is very important for maintaining and further developing a competitive European process industry. The area is a global marketplace with potential for SMEs to grow by developing and commercialising innovations through corporate, university, college and institutional collaborations.
Another reference is the cooperation in SMIFU (Sustainable Mine and Innovation for the Future), which was led by the Rock Tech Centre (RTC, www.rocktechcentre.se), involved the mining companies LKAB, Boliden and KGHM and the suppliers ABB, Metso, AtlasCopco, Sandvik, Outotec, ÅF and AGH.

SMIFU conducted a pre-project with the following objectives: a 30% reduction in energy/ton of broken rock, a 30% reduction in man h/ton of broken rock, no human exposure in underground excavation areas and no accidents. Similar targets are established for other process industry segments. The general conclusion is that these targets can only be reached with a high degree of easy to use and easy to implement automation solutions.

To continue further development, favourable conditions must be created and maintained to ensure that the process industry's future challenges can be turned into opportunities.
> The process industry and its suppliers are important for Europe and crucial for the Nordic countries in terms of export value, employment, investment and sustainable competitiveness.
> Refining Europe's raw materials in an efficient and environmentally friendly way is a vital European and global concern.
> Increasing globalisation brings intensified competition to the process industry and its suppliers.
> Globalisation manifests ever-increasing demands on productivity, quality, yield, recovery and new products and enhancements.
> Environmental standards and regulatory frameworks are setting new, challenging and important demands.

Based on high-level goals and global trends identified and the current state-of-the-art, a gap analysis have been made resulting in identified "white areas" that require further development. These "White Areas are expressed through a number of Ideal Concepts that are connected the critical development of embedded system technologies as illustrated below.

The Ideal Concepts (IC) are:
1.Instant Access to a Virtual Dynamic Factory: *To have instant, organisation-wide, and inter-organisation access to a virtual real-time plant to provide the right service to the right people at the right time."*
2. Increased Information Transparency between Field Devices and ERP : "*To enable full interoperability and configurability with zero-configuration characteristics between computational devices from different organisational levels using open network and communication technologies.*"
3. Real-time Sensing & Networking in Challenging Environments: *Real-time measurement of any parameter of interest, anywhere in an operating industrial process, to increase knowledge and improve automation performance.* "

4.Production Industry as an Agile Part of the Energy System: "*To make process industries a natural part of the energy systems to maximise the utilisation of energy resources and reduce environmental impact.*"
5.Management of Critical Knowledge to Support Intelligent Decision Making: :" *To apply integrated knowledge-based systems with Advanced Analytics and self-learning capabilities. The right information in the right form to the right people at the right time in the right place to support maintenance-related decision-making on different organisational levels and reliable KPIs for sub-processes*"
6. Automation Service and Function Development Process: " *Industrial process automation service and function engineering that is capable of meeting the challenges from globalisation and technology trends.* "
7.Open Simulator Platform :" *To optimise the efficiency of simulation-based development through full interoperability between simulation tools over the complete development process*"
8. Automation System for Flexible Distributed Manufacturing:"*To have production capacity "anywhere for anything" to meet the rapid fluctuations in production requirements in a cost-efficient way.*"
9. Balancing of System Security and Production Flexibility: "*To ensure production availability, plant safety and supportive advanced risk management through system-wide information assurance, data validation and reliable communication*"
10.Human-Machine Interface and Machine-Machine Communication: *"To communicate across organisational levels and between geographically distributed sites and create a human-cantered work environment"*

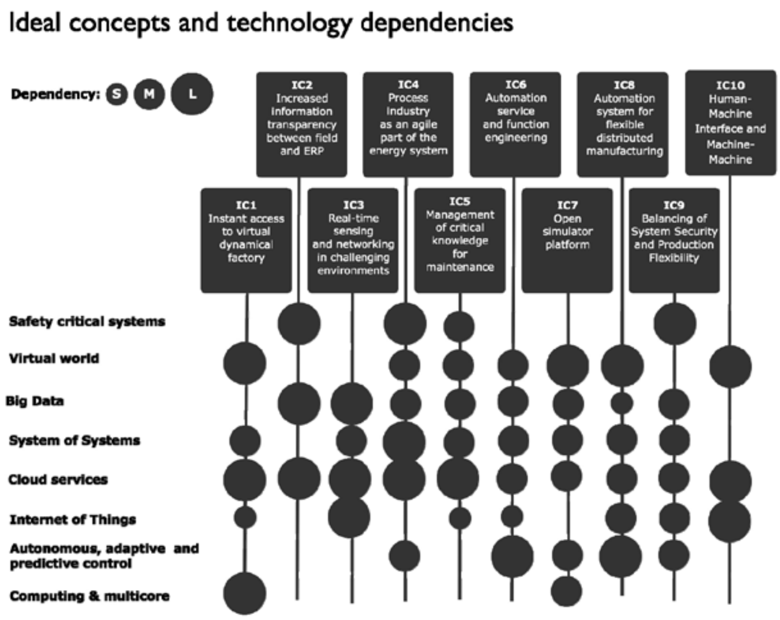


Figure Ideal concept connected to critical developments of embedded system technologies

The **Energy Domain** will by a much higher degree be profiting from small distributed power suppliers connected to a smart grid system. This will included renewable energy production such as wind power and photovoltaic power plants alike potentially millions of small photovoltaic systems like potentially mounted on e-vehicles. An e-vehicle might be operated during rush hours but might be parking in the sun during the entire day time. This could generate more energy than the e-vehicle requires to charge after its morning drive. Such energy could be fed into the system meaning that positive and negative flow of energy and, alike, billing information to be exchanged autonomously. E-Vehicle batteries could also deliver energy to homes during peak hours, reducing therefore the requirements of dimensioning all the energy networks and production for peak consumption.
On the other hand a significant amount of communication will be required in order to perform all the control function in the generation and in the management of the energy remotely.

Sustainable Production within ARTEMIS
Accelerating IT development in the area of Sustainable production continues, some.examples[13]:

> Artificial Intelligence: High-frequency trading, Software agents, Natural language
> interpretation, Machine translation, Procedural storytelling, VR-only lifeforms, Machineaugmented
> cognition
> Internet: Cloud computing, Cyber-warfare, 4G, Mesh networking, Internet of things,Virtual currencies, 5G, Reputation economy, Interplanetary internet, Remote presence, Exocortex
> Interfaces: Multitouch, Gesture recognition, Speech recognition, Augmented reality, 4K,
> Haptics, Holography, Telepresence, Immersive virtual reality
> Sensors: Depth imaging, Near-field communication, Pervasive video capture, Biometric sensors, Smart power meters, Biomarkers, Machine vision, Computational photography, Optogenetics, Neuroinformatics
> Ubicomp: Tablets, Volumetric (3D) screens, Flexible screens, Boards, Picoprojectors,Eyewear-embedded screens, Context-aware computing, Fabric-embedded screens, Reprogrammable chips, Skin-embedded screens, Retinal screens
> Robotics: Appliance robots, Smart toys, Robotic surgery, Self-driving vehicles, Powered exoskeleton, Commercial Unmanned aerial vehicles, Domestic robots, Swarm robotics, Embodied avatars, Utility fog

3.3.4 Smart Communities

Smart Communities:
One of the important themes in societal challenges is the concept of smart communities, as it interacts with different domains, as e.g. efficient and safe mobility, wellbeing and health, smart cities, and many others.
By 2050, 80% of the population will live in cities and the common theme of smart and secure cities will be among the main drivers for economic growth and for tackling the societal challenges.

Cities of the future will heavily rely on large invisible networks of embedded systems. Energy and water supply, distributed energy generation and storage, mobility, healthcare, or security systems will 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. The embedded systems networks will further collaborate with the information infrastructure of the city. At the same time, privacy will have to be protected. The city of the future will allow the inhabitants to live and work in energy neutral buildings, to efficiently travel, to do secure transactions and to enjoy their lives.

In the concept of Smart cities many key trends in ICT will be combined simultaneously. Smart cities will rely on intelligent communicating systems running distributed applications. This will pose new challenges to the supporting CPS and ES technology. New business opportunities are likely to occur on the borders between these technologies and by combinations of different technologies. And since Europe has the lead in many technology domains underlying novel applications in Smart and Secure Cities, Europe is in an excellent position to exploit the new business opportunities enabled by CPS and ES technologies.

Since such large scale applications, involving many concurrent users and devices, large real-life test-beds will be essential to test and fine-tune the technology, the applications, check the reliability of such systems and explore options for new business models. Test-beds implemented in Europe's cities may serve as showcase to support the marketing of our leading-edge industry.

[13] Source : ProcessIT presentation (Page: 4 | 2013-04-23 | © ProcessIT Innovations) – Envisioning Technologies http://envisioningtech.com/envisioning2012/?ncid=edlinkusaolp00000008

In the concept of Smart Communities many key trends in ICT will be combined simultaneously, and will be key driver for R &D&I in the cities:

> Smart living
> Smart and efficient building:
> Green infrastructure (traffic management, lighting, water, waste management, …)
> Smart GRIDS- smart metering's - energy suppliers, network operators and energy service companies - data infrastructures for Utilities –share infrastructures (including telecom).
> Smart Spaces: Connected home - smart devices and services for low-level smart home functionality - home health services - home energy management and services- home monitoring - media equipment and content - market which will be worth $101 billion in 2013.
> Autonomous and Robotic Systems
> Assisted living and inclusive society
> Integrated city-services

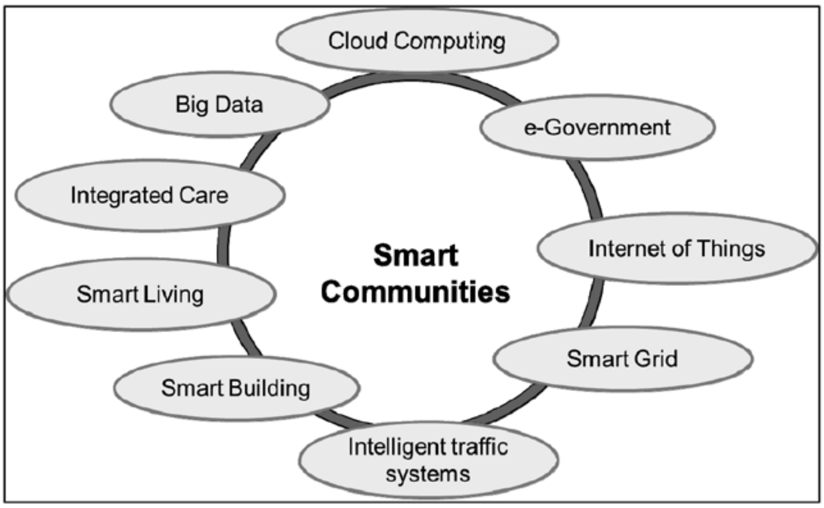


Fig 4 – the Smart Communities Domain

3.3.4.1 Smart living

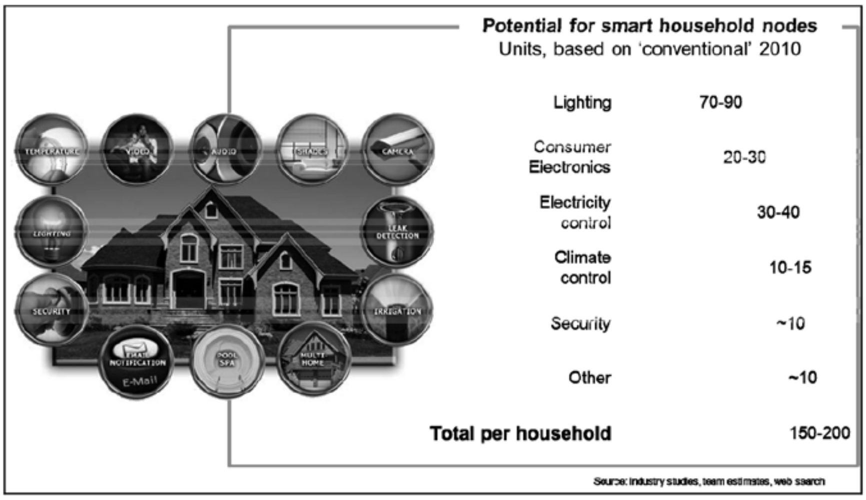
Smart living will rely on many intelligent communicating systems running distributed applications. This will pose new challenges to the supporting Embedded Systems /Cyber-Physical Systems technology, but, more important it will create options new business opportunities.

Since such large scale applications, involving many concurrent users and devices, large real-life test-beds will be essential to test and fine-tune the technology, the applications, check the security of such systems and explore options for new business models. Test-beds implemented in Europe's cities may serve as showcase to support the marketing of our leading-edge industry.
Key technology challenges for CPS and ES systems that shape the Smart City are (but not limited to) Energy Efficiency, Connected devices, Security and Health. The sharp increase in numbers of embedded systems in daily life calls for a constant attention for energy efficiency, to keep the total energy consumption on this planet ecologically manageable.

The ever growing numbers of communicating devices that run both open and confidential and private applications over internet require extensive understanding and research to support security and ensure privacy protection. Examples are mobile phones running e-banking and e-government apps, wireless sensors systems that monitor critical infrastructures such as streets, traffic lanes and the smart grid. But also apps for smart metering for energy consumption control or control secure access to buildings and require both secure applications and tamper-proof hardware.

3.3.4.2 Efficient and smart Building

The market opportunities related to energy efficient buildings in the ARTEMIS context should focus primarily on embedded software for integrated building management systems (linking systems controlling lighting, heating, ventilation, and air conditioning, low- and DC-voltage networks, security, …). The issues for these integrated building systems should cover aspects such as connectivity (communication), system security, scalability, sensing and more, touching ultimately on data processing and management, algorithms for optimized building efficiency and additional service proposals.



Smart building includes, at the communication level, home networks that are interconnecting various sensors spanning from lighting to media and consumers electronics and other smart household nodes, to the external networks from the neighbourhood level to the wide area networks
The market opportunity is therefore the sum of each of these individual aspects' market opportunities (where Philips can provide figures as to professional lighting systems including lighting controls) in building controls, sensor networks.

Lighting controls in North America alone will be worth $3B in 2016, of which more than 50% was office and industry (excluding specifically residential and outdoor). This includes sensors, user interfaces and control systems, which will need functionality based on embedded software to be integrated into building automation systems.

3.3.4.3 Smart Spaces

New Opportunities
Public spaces and places such as streets, parks, shopping centres, etc. is a big opportunity for smart spaces. The services in such places can only emerge if the information of them is available. This information should be opened by embedded and Cyber Physical Systems.

The opening and especially making the information available requires investments on the infrastructure of these places in a form of embedded systems and connectivity. The current list of industries does not include clearly this kind on new systems.

Probably the reason is that so far these have been more or less ad hoc systems built by smaller companies, if even existed. The nomadic/Internet is most close to this, but not the same.

European opportunity could be based on enable innovative collaboration platforms that are based on loosely coupled systems with standardized flexible interfaces.

We have been practicing this in EU collaboration for years and it differs from "winner takes it all" approach in US and "Government tells you what to do" approach in Far East (This may be a little overstatement, but anyway).

New Challenges
The visions of smart cities, smart environments, and smart places in general will introduce new challenges of systems:

- communication with other systems
- interoperability issues
- possibility to reuse existing infrastructure, i.e. exploiting Internet of Things and Internet of Services and the open data in Internet

Heterogeneity and diversity of Cyber-Physical Systems and computation systems will be a real challenge for developers of smartness. No real tools or methods exist:

- Managing mixed criticalities in a situation where systems are composed of various independent subsystems.
- Modelling, design and test of systems composed of various, heterogeneous s and possibly autonomous subsystems
- combination of various methods and practices, e.g. languages, tools, simulation models , testing …
- Energy consumption challenges in everywhere.

3.3.4.4 Smart Lighting

The advent of Solid State Lighting is much more than the introduction of a new efficient technology. With LEDs lighting becomes digital, unlocking opportunities unprecedented in the lighting domain. Digital lighting allows providing illumination when and where needed by the user in support of his tasks at hand.

Digital lighting is realized by combining LED sources with adequate sensors, control systems, algorithms and software systems. The lighting systems of the future will be ubiquitous finely meshed networks. While in a first stage the challenge will be to create systems able to serve functional illumination needs, next to the non-functional requirements, e.g. easy commissioning, latency, reliability and data security, in later stages lighting will become a sensing system sharing its information with other systems in the built environment.

Here a clear distinction should be made between the two major lighting application domains, i.e.: indoor lighting as integral part of buildings and outdoor lighting as dominant component of the urban infrastructure. In both cases we are dealing with completely different value chains, targeting distinct applications and services. Indoor lighting will be integrated with HVAC, blinds, surveillance and access control, driven by energy efficiency, comfort, health & well-being and personal security. Outdoor lighting on the contrary will be combined with traffic management, crowd control and event management in order to improve the accessibility of cities and the logistics in an urban environment.

In order to make this happen the development and validation in real settings of open system architectures for Solid State Lighting must be high on the innovation agenda. Actions should address specific lighting requirements in relation to the control network, as mentioned above, as well as the development of related electronic and photonic devices. Proposed architectures should allow for interchangeability of the components by standardisation of their interfaces. Actions should involve players from micro-electronic and lighting industry, along with relevant parties of the value chain.

From the 2012 update of the McKinsey report " Lighting the way: Perspectives on a global lighting market" it becomes clear that control offer the highest growth potential in the lighting domain and its sales volumes is bound to surpass the one of light sources beyond 2020.

	Unit of measure	2011	2012	2016	2020
Total new installation market	M€	46.891	50.179	63.023	75.403
Lamp/module level	M€	4.054	5.093	8.078	10.366
Driver level	M€	3.964	4.44	7.323	10.770
Fixture level	M€	37.08	38.545	43.572	46.561
Lighting control system level	M€	1.794	2.101	4.051	7.705

The report referred to above encompasses the market of components and systems. In the future the shift from lighting controls to light management will trigger the development of lighting as a service. It will be much more about understanding the business processes of the building owners, cities and service providers than about the local lighting application. Companies exploring this kind of services are already entering the market, e.g.: Digital Lumens, Cavet Technologies, Easylite LLC, Fifth Light Technologies and Redwood Lighting.

3.3.4.5 Autonomous and Robotic Systems

Aspects of autonomous systems and robotic systems are usually addressed in areas such as autonomous driving or autonomous rail functions, and also in ground, maritime, aerial or underwater domains.

But there is much more impact in autonomous and robotic systems in a cross-domain manner and in issues like cognition, perception, vision, machine understanding, man-machine and machine-machine communication and interaction, safety and security of such systems and environments, and last but not least "certificability" of such systems are critical challenges and somehow generic in their nature (i.e. domain-independent). This allows handling many topics independent from the application and justifies treating it as a separate research area.

In fact, safe and smart autonomy can bring benefit to a wide variety of domains, for instance

> **Automotive**: autonomous cars could increase road safety and optimise traffic density. In addition, the market potential increases, because also persons without driver licence can use cars. Besides conventional traffic, sectors like farming, building and mining will also profit from autonomous vehicles and machinery.

> **Rail:** for economic reasons, more and more lines in zones with low passenger volume are abandoned. Equipping such lines with low-cost small autonomous trains could allow revitalisation of the affected zones and support quality of life there.

> **Aerospace**: flying is already automated to some degree. Nevertheless there is a lot of interest in enhanced autonomous functionalities in particular for UAVs (unmanned aerial vehicles). There are a lot of civil applications such as "flying postmen" in emergency cases or in scarcely populated or hardly

accessible (e.g. mountainous) regions, or monitoring and security surveillance, where autonomous flying vehicles could play an important role.

> **Healthcare**: at least two major areas can be identified where robotic systems can help to tackle growing issues. Our aging society demands increased home care capabilities with parallel decrease of young people being able and willing to carry out the corresponding tasks. Home care robots can help to close this gap. Additionally, hospital and medical processes increase in complexity, which increases the risk of human faults. Support of smart autonomous systems can increase safety and efficiency there, as for example robotic scrub nurses that deliver surgical instruments more precisely to surgeons than human nurses under stress.

> **Manufacturing**: industrial automation is actually the leading application domain of robotic systems. It is, however, increasingly confronted with the demand for high flexibility. One consequence is the quest for enabling close cooperation of robots with human experts. Today, this is usually impossible due to safety reasons, because in general existing industrial robots possess too little sensory and intelligence to safely avoid collision with humans, which, due to their weight and speed, would easily cause severe insults.

> **Domestic applications, smart homes and cities**: In the "private spaces" domain as well as in the co-operative application of home appliances in communities, autonomous systems can serve a huge set of autonomous tasks. Simple examples like lawn mowers and cleaning machines do already exist, but many other applications can evolve from advanced service robots in homes, buildings, cleaning, maintenance and repair in difficult to access areas, for emergency and rescue services, means of in-house and local transport and the like.

3.3.4.6 The Cloud Computing Domain and communication capability

The **Cloud Computing Domain** will provide the platform where all intense computation can be conducted on and large quantities of data can be stored. It will mainly consist of the providers that invest and run in keeping their systems up to date and operational. They will also drive the innovation in this sector concerning investments made. In case they are ready to spend budgets to enlarge their systems and to enhance their portfolio of services etc. in the long run, the innovation can sell and it will most likely be sustainable.

Based on that, the **communication capability** will offer their service to connect all possible means of embedded systems in a wider sense and will encompass the Cyber-Physical Space. For example, the communication domain will support:

- Remote operation of electronic devices (home equipment such as washing machine or a heating system, medical devices for the elderly society, etc..
- Security services execution (e.g to support billing transactions in order to pay for the services selected, but also to protect the privacy and malicious intrusions)
- Joint operations(e.g. communications interoperability between different Public safety actors to accomplish a joint security mission)
- Suited communications service for harsh environments (e.g; high –capable SATCOM links for isolated or disrupted areas).

In context, it will be priorities innovative communications solutions providing maximum flexibility / reconfigurability, low energy consumption, high resilience, automatic adaptability to CPS' needs (cognitive capabilities) and, when necessary, high capability to deploy advance services.

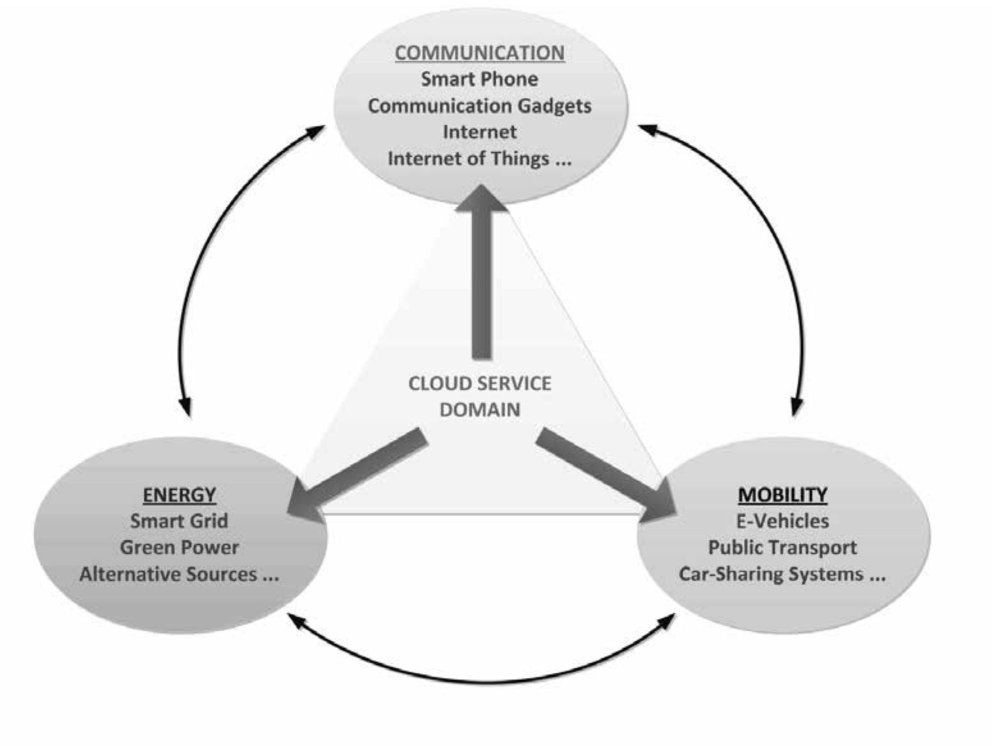


Fig 3- Cloud service domain

4 The ARTEMIS Vision and ambition

It is nowadays widely recognized that embedded-system technology is an enabling technology that forms the basis for the development of many innovative products and services in highly developed economies. They control almost all technical systems from a dishwasher to a building, from an electric drive to a production line, from a dashboard to a car. They enable new functionalities which differentiate these systems from earlier solutions and, thus, are a foundation of European industrial products saving and creating millions of jobs in a highly competitive international market.

And most importantly, **Embedded Systems are a European success story**.

The ARTEMIS Vision developed in the ARTEMIS SRA in 2006 is to *"nurture 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"*.

'In a world in which all systems, machines and objects become smart, have a presence in cyber-physical 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 ubiquity of the Embedded Systems, with their present and forecasted evolution, will have more and more impact.'[14]

This vision is still valid, and since then a lot has been achieved, but Embedded Systems are now entering a new era. Originally locally connected and dedicated to single functions and technical systems, such as a car, an aircraft, or a production line, they are now starting to be connected over large and open networks including the Internet. Formerly independent systems collaborate to form smart buildings, smart communities, smart energy grids, enable smart mobility, to just name few examples of the economic and societal changes Europe is facing. This development is not only of high industrial relevance (European growth, job creation, added value, value chain), but has a strong societal impact. The solution of societal challenges such as aging population, healthcare, energy, food and water supply, sustainable mobility and transport, highly depends on such large and open networks of embedded systems. These embedded systems networks are now forming an invisible *neural network of society* driving innovation on the level of society rather than that of a single industry. This development is elaborated in the ARTEMIS SRA, with many examples and use cases.

Everything that can be automated will be automated: The functionalities to be automated will be more complex due to the increasing computational capabilities, decreasing cost of hardware and expanding availability of information. Increase in computational capabilities result from development in integration efficiency, e.g. multicore systems, and parallel computer approaches, e.g. data centres. Increasing complexity is due to increasing amount of data, where Big Data and Internet of Things are the main contributors, and due to increasing complexity of functionalities to be automated. Traditionally automation has been applied in controlled or very predictable environments, but this is changing to a situation where detection of context and taking into a count for example human behaviour are important. Automatic car (e.g. Google car) and smart homes (e.g. automating daily routines) or smart cities (e.g. holistic traffic control, citizen safety, and energy efficiency) are examples of these. This will mean that the concepts of smart spaces should be linked in addition to factories and robotics to local digital services as well.

Two main trends will define the new era of embedded systems:

[14] ARTEMIS SRA 2011

- *the integration of functions across application contexts on large and open platforms*, and
- the *combination with the Internet and its information and computing resources*. An application will not anymore be localized in a single device, but distributed over a range of devices interconnected even on a large distributed geographical area.

From an Internet perspective, these trends will lead to the *Internet-of-Things* where billions of embedded systems will provide information about and interact with the physical world that can be used in information systems. From the *Embedded Systems* perspective, this opens new opportunities in collaboration and control with **access to the big data in information systems**.

This leads to the **new area of** *Cyber-physical Systems* **(CPS)**[15] where the networked embedded systems are considered an integral part of their physical surroundings. Two types of CPS can be identified, (1) *control intensive CPS systems* utilizing the new opportunities for innovations in control, such as in sensor networks, smart energy grids, or traffic management, and (2) *software and communication intensive CPS*, which utilize the new opportunities for powerful software systems that enable new embedded system services by integration with services of the information systems infrastructure, such as to control complete airports.

Internet-of-things, and consequently the Things of the Internet, and Cyber-physical Systems are complementary directions which together will help to shape a society where humans and machines increasingly interact to provide services and solutions to the benefit of society that are unthinkable with state-of-the-art technology.

But, unlike the semiconductors field that is governed by Moores' law, research and innovation in the Embedded Systems field follow an iterative cycle, responding to user's needs, exploiting the ever growing potential offered by the miniaturisation, harnessing the complexity, matching the physical and cyber world, the seeking the grail of greater and better performance, functional and non functional, such as the ease of use expected from the users, reduced time to market… but also the energy consumption, autonomy, dependability, etc.
In order to address the challenge of reducing/ overcoming the fragmentation R&D of investment R&D focus the investment, ARTEMIS Strategic Agendas targeted a selected number of research priorities to reach critical mass and make the best use the available resources (human and financial) in order to reinforce Europe potential and keep its advances.

For the coming period (2014-2020), the following priority targets are selected to guide the R&D programmes with the purpose of having great impact quick to markets results:

> **Exploiting the ubiquity of the Embedded Systems/Cyber-Physical Systems,** that goes far beyond that anticipated, where embedded applications are surfacing (emerging). Embedded Systems are now linking to the physical world (cyber-physical systems) and share all kind of networks (including Internet) and components in configurations whose conceptual structure have to map to their physical structure, with increased quality of services.

> **Exploiting the connectivity of the networked Embedded Systems/Cyber-Physical systems – as the neural system of society**, that should no longer be considered only in isolated application contexts but

15 Cyber-Physical Systems (CPS) refer to next generation embedded ICT systems that are interconnected and collaborating including through the Internet of things, and providing citizens and businesses with a wide range of innovative applications and services. These are the ICT systems increasingly embedded in all types of artefacts including our clothes and our own body, and making "smarter" and more comfortable our personal devices, our homes, cars, transport systems, offices, factories and cities, etc.
Often endowed with control, monitoring and data gathering functions, CPS need to comply with essential requirements like safety, security and near-zero power consumption as well as size, usability and adaptability constraints. To maximise impact and return on investment in this field, the following challenges must be addressed:

> De-verticalising technology solutions with CPS platforms that cut across the barriers between application sectors including mass consumer markets.

> Bringing together actors along the value chain from suppliers of components and customised computing systems to system integrators and end users.

> Creating new ICT Platforms for both vertical and core markets from automotive, health and energy to wireless communications and digital consumer products and services.

in a holistic view to address today's and tomorrow's societal challenges.

> **Optimising the factor Technology Time to Market/Technology Time on Market,** that is continuously increasing and affecting new markets and products. Indeed, the development cycles optimisation and the 'cooperation speed' in transfer from basic research (academia) to applied research (Academia and public research institutes) and industrial research (Large industry, OEM's and Supply chains and SME's) is a great challenge.

> **Mastering the complexity** while reducing the cost and increasing the performance is a key challenge: The **exponential potential increase brought by the semi-conductors miniaturisation** is creating great opportunities, and necessitating equivalent investment in the Embedded Systems in order to leverage the exploitation of the new potentials. Ensuring a correct and secure collective and autonomous behaviour of the heterogeneous interconnected elements will be at the core of the challenge. It will encompass a multi-disciplinary approach, various levels of tooling and methodologies.

> **Reducing and managing the energy and power consumption cost.** Power is now the major limiting factor in all computing elements. For data servers and HPC, the cost of the electricity bill and the capacity of cooling limit the capacity of the data centers. For mobile devices, autonomy is limited by the power consumption and even for cars this translates in non-negligible levels of CO_2 emission. For smart sensors, leveraging the energy of the environment (scavenging) or long autonomy on small batteries is mandatory.

5 ARTEMIS Innovation Strategy and Research Road-map

5.1 Innovation strategy

The Cross-domain approach: reducing the fragmentation, better leverage on investment, cross fertilization
ARTEMIS innovation strategy is to challenge the application contexts, based upon exploitation of European strengths and opportunities by:

> **Building on the leading positions where Europe is strong**, in specific technologies and in various application domains, particularly for the safety critical high reliability real-time applications in the field of automotive, aeronautics, space, and health sectors.
> **Complement by creating new opportunities** for Europe to be positioned at the forefront of **new or emerging markets with high potential growth rates** to become among the world leaders in these domains and particularly target process industries, smart cities and energy efficient buildings, environmental, food and agriculture.
> **Making a tentative comeback on the smart devices** to challenge the US and Asian actors and reposition the European leadership.

The original ARTEMIS industrial priorities aim to achieve multi-domain compatibility, interoperability, and even commonality was already moving in this direction. In the 2011 update to the ARTEMIS Strategic Research Agenda, this strategy is taken further: the societal challenges are 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. **ARTEMIS should lead to a "virtual verticalisation" of the European industry to make it competitive – at least in the consumer domain – to the big vertical non-European companies**.

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 and interoperable 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. Get access to information systems and in turn the information systems get access to the embedded systems which now enable the internet of things. **Networked embedded systems will, in effect, become the neural system of society.**
> Embedded Systems/Cyber-Physical Systems technology should 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

For the successor programme, it is forecasted (recommended) to adopt this strategy approach as:

o It is inclusive of technology, of market and of society
o It is flexible, open and dynamic to adapt to the continuously evolving challenges in the areas of major changes

5.2 Strategy implementation

The innovative strategy ARTEMIS, developed in the SRA 2006 and confirmed in the SRA 2011, mainly aims to overcome the plea of the Embedded Systems arena to counteract 'fragmentation' in all areas of the innovation chain: in research, in the supply chain and in the market. It is based on a top-down strategic road mapping and setting an ambitious set of high level objectives built on **the Matrix Approach** in order to cut barriers **between application sectors** and facilitate **cross-domain sharing of technologies and research**.

5.2.1 The Matrix approach

The successive ARTEMIS Strategic Research Agendas identified three main areas of research where the applications contexts/domains should share communalities and synergies to overcome the fragmentation and create critical mass for the investments and to embrace the technology challenges for 2030 for embedded systems, such as:

- architectural models and principles allowing new functionalities and performance
- Safe and secure by design, based on interoperability standards for systems and design tools
- Situation aware for distributed real-time and highly certified operations
- Interconnect, to enable the development of new and smart applications and to create solutions to the areas of major change
- Dynamic, autonomous, adaptive and self-organised ES
- Seamless interaction of the ES with their environment
- Optimised and consistent processes and tools

These three research areas are the **Industrial Priorities**:

- Reference designs and architectures
- Seamless connectivity and interoperability
- Design methods and tools

They are complemented by a fourth area that addresses foundational research, or the more up-stream research.

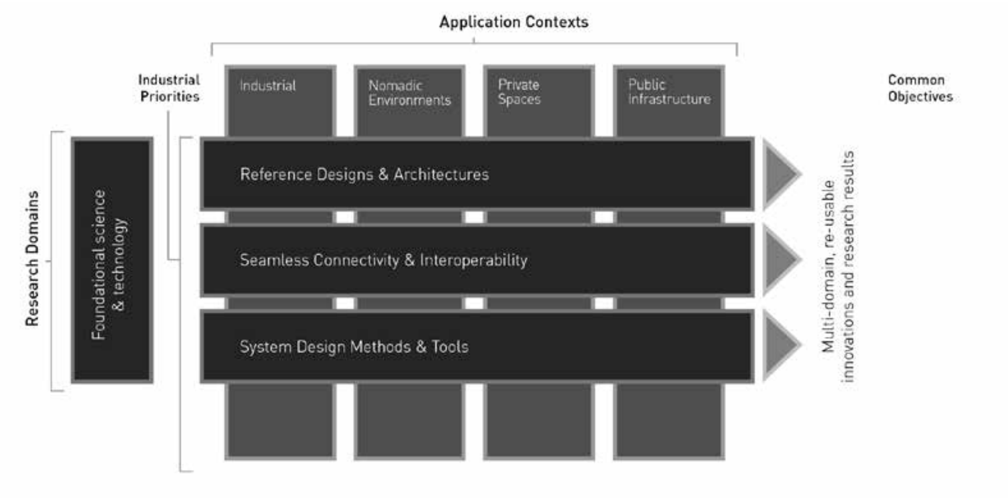


Fig 5- SRA 2011 Matrix

5.2.2 ARTEMIS MATRIX 2.0

ARTEMIS Strategy developed in the SRA 2006 and reviewed in the SRA 2011 is to also embrace the main societal challenges for driving innovation and supporting the development of high-value added Embedded Systems solutions that are reusable across a wide range of application sectors that can be integrated to respond to a number of societal challenges.

An extensive description of the role of the **Societal Challenges as drivers for Europe growth** has been developed in both the SRA 2011 and in the ITEA/ARTMIS High Level Vision 2030 such as: the inverted demographic curves, the constantly increasing demands for non-renewable natural resources, the expectations for supporting and even improving quality of life, and climate change.
To deliver the expected services and solutions, a number of **technological challenges and opportunities** are considered:

- o Safety-critical Secure Systems
- o Virtual World
- o Big Data
- o Systems of Systems
- o Cloud Services
- o Internet of things
- o Autonomous, adaptive and predictive control
- o Computing & Multicore

The matrix approach has therefore evolved into a three dimension **ARTEMIS MATRIX 2.0** integrating the **societal challenges**, the **technological challenges** that are also cross cutting with respect to ARTEMIS **Industrial Priorities** and targeting the **Application Contexts**:

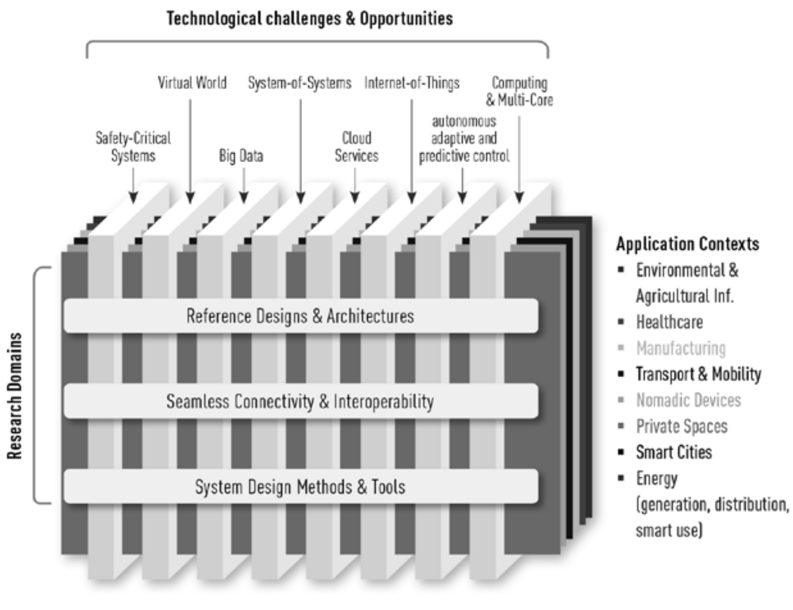
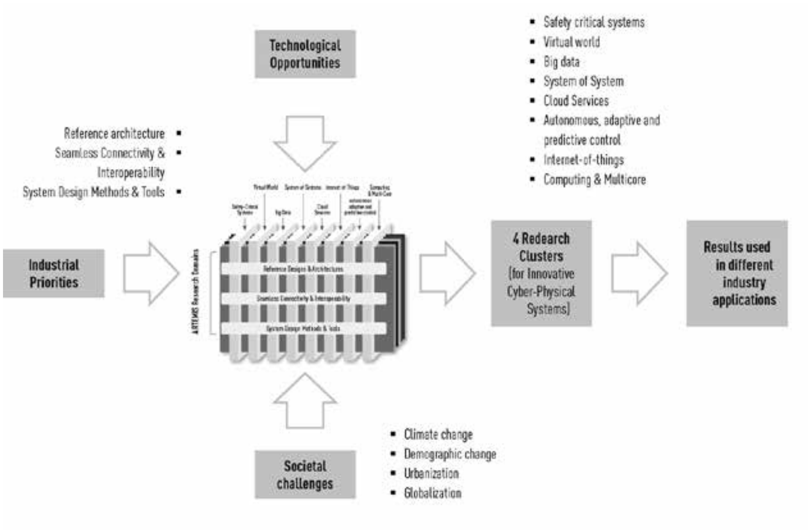


Fig 6- The ARTEMIS Matrix 2.0

This 3D matrix will deliver the major ingredients for innovative, efficient and safe Cyber Physical Systems and is now in the heart of the ARTEMIS WAY



5.2.3 Strategic Research challenges

5.2.3.1 Reference Design and Architecture

As mentioned above, it is nowadays widely recognized that embedded-system technology is an enabling technology for the development of many innovative products and services in highly developed economies. The bottom-up development of many product families over the past twenty years has led to a fragmented market with a multiplicity of incompatible hardware and software elements. In order to reduce the effort required for establishing the desired interoperability of these diverse products and to be able to take full advantage of the enormous economies of scale of the semiconductor industry, the **introduction of cross-domain generic platforms for embedded systems** is a technological and economic necessity as it has a high impact on many application domains (automotive, aerospace, health, etc …)

However, the following application domains Automotive, Avionics, Space, Healthcare, Manufacturing, Nomadic, Private Spaces and Public Infrastructures have different requirements in terms of dependability, time on market, and compliance with domain standards. This naturally leads the semiconductor industry to develop domain specific complex electronic components. Each new generation of components typically brings more computing power, communication capabilities and storage amount, as well as reduction of size and weight – direct consequences of Moore's which are welcomed by most application domains. But Moore's law does not naturally bring, at electronic component level, any direct improvement of features such as observability and support for diagnosis, behavioural determinism and support for certification, support for dynamic reconfiguration and for application-level power management.

Architecture Framework(s)
It is our vision to foster carry-on-activities that build upon to previous ARTEMIS SRAs in architectures and frameworks as well as novel frameworks of design principles and reference architectures allowing and supporting the quick and efficient realization of these new use cases. In addition, the quick realization of improvements of existing systems with new and novel functionality shall be envisaged. Such frameworks shall then be casted into a pool of industry standards and best practice documents to further stimulate the ubiquitous mass adaption of embedded systems in existing, emerging, and future markets.

The key research challenges identified for these generic platforms is about architecting, that include highly relevant subjects spanning from composability, scalability, networking and security, robustness, diagnosis and

maintenance, integrated resource management, evolvability, self-organization… that cannot be handled in separation but through a system design approach.
In particular three immediate embedded system challenges need to be resolved by such a framework:

1. complexity management of the interactions between individual embedded systems and to/with the infrastructure (up to the cloud) such that they can form a coordinated entity.
2. complexity management of the interactions of basic building blocks from which an individual embedded system is composed of.
3. novel and improved concepts for world-machine interaction (WMI), e.g., improved image recognition systems for advanced driver assistance systems, or to guide a pedestrian in a smart city.

With the rapid increase of processing power, communication technologies, and improved energy management in embedded systems **we more than ever need to strive for elegance in architecture and design of these complex interactions such that we can guarantee a system's correctness by construction and efficiency of design at reduced cost**.

Despite the overall commercial risks associated with improper system operation, as embedded systems more and more operate in combined safety-related and security-related domains, the absence of such a framework even poses safety and security threats to society: malicious attackers and intruders to large systems such as energy grids (compared to threats in smart grid activities), improbable corner cases, or environmental variations can exploit weaknesses in the interactions that lead to system failure.

System complexity
Interconnected distributed computing systems have grown to the scale where developers need to coordinate large numbers of different communicating applications running on thousands of processors at once across massive data sets.

The complexity increase caused mainly by the increased communication inside and between devices and systems imposes new challenges for system development**.**

> Increasing openness and interconnection (e.g., traffic control) while retaining security and safety properties
> Providing safety and enabling certification (ISO 26262) in highly complex and non-deterministic environments
> Cooperation in the entire development process
> Self-Maintenance of CPS
> Optimal partitioning of real-time workload between field devices and the cloud
> Wireless techniques and protocols for real-time control traffic
> On-line evolution of large real-time systems
> Emergent behaviour caused by the interaction of autonomous agents

Complexity management of the embedded systems interactions
Building reliable distributed embedded systems in highly complex, closed-world applications such as airplanes is now better known. However, we do not fully understand, today, how to efficiently translate the established architectures and design principles to more open-world applications, e.g., control applications that connect to the Internet. While in the closed world embedded systems typically need to satisfy real-time and robustness/fault-tolerance requirements, additional flexibility/plug'n'play, coping with variable latency and bandwidth and security requirements are imposed by open access.

Hence, a first level of complexity of the interaction stems from the intertwining requirements of the real-time, fault-tolerance, security, and flexibility/plug'n'play domains. A second level of complexity is imposed by low HW/SW/energy footprints, as typically required for embedded systems. A third level of complexity is imposed by growing bandwidth demands even in embedded systems, e.g., there are systems that require uncompressed real-time video transfer to achieve ultra-low latency. A fourth level of complexity is imposed by an industry trend towards converged communication networks, i.e., single converged networks need to transport mixed data with vastly varying requirements in the above mentioned domains . The combination of the four levels of complexity, as outlined above, demands the close cooperation of European industry, universities, and research laboratories to systematically elaborate a framework of design guidelines and reference architectures and platforms. In particular the following questions need to be addressed:

> How can we build (potentially large-scale) embedded systems with configurable properties in the real-time, robustness/fault-tolerance, security, and the flexibility/plug'n'play domain?
> What are the methods and means and which tools are required to guarantee that a system satisfies the requirements?
> How can we build systems of embedded systems (SoS) such that the properties of the systems are composable?
> How can embedded systems reliably interact with each other considering (partly) connectivity over the Internet resulting in the Internet of Things (IoT)?
> How can embedded systems interact with existing standards in the IT industry such as IEEE and IETF standards? In particular, how can we ensure interoperability between embedded systems and the IT world?

Energy efficiency

Systems today are limited in their performance by power used or dissipated. In order to make progress a number of fundamental issues need to be solved as indicated by the HiPEAC roadmap (http://www.hipeac.net/roadmap).

A major paradigm shift is now taking place in microelectronics. While Moore's law will keep its pace, continuing to double the transistor density, it will only allow for a minor increase of clock frequency and decrease of power dissipation per transistor. **This evolution signifies the end of "Dennard scaling" and the resulting impact of "Dark silicon".** The power density now is growing with the linear dimension of transistors, therefore limiting the number of devices that can dissipate power on a chip: even if it will still be feasible to pack more devices on a chip, the power dissipation of each device will not be reduced accordingly due to the end of Dennard scaling. Since we are already pushing the limits of power dissipation/consumption on a chip, it will no longer be possible to power on all transistors on future chips simultaneously. Doing so will either dissipate too much heat or consume too much energy. This inability to turn on all of the transistors on a chip is known as "Dark Silicon".

One important contributor to power consumption is the cost of communication: Transmitting a bus outside a SoCs costs several orders of magnitude than computing operations on the same data width. An important challenge is therefore to avoid unnecessary data communications both by clever data placement or new innovative architectures (computing near or in memory).

For the industrial research many challenges exist in energy consumption that has a background in new combinations of technology in new applications, new form-factors of devices enabling new applications etc.

Adding increasing amounts intelligence to products also increases energy consumption. One example of additional intelligence is observed in Intelligent Traffic Systems where cars communicate mutually and with roadside systems, eventually culminating in autonomous driving cars where much additional compute power will be required. To keep the additional energy consumption within acceptable limits, <u>new challenges for energy reduction</u> of the implementation occur.

Computing architecture

One of the major challenges in computing today is the lack of scalability. The computing system and processor manufacturers have to scale the computation power by adding more processor cores into systems because of the end of the Dennard's scaling: as frequency cannot be increased significantly to increase performance, this is realized by increasing the number of processing elements. Multicore and multiprocessor systems do have processing and storage capacity, but this capacity is very expensive and difficult to exploit at the software level.

The programming of these systems has turned out to be a nightmare and it is stretching the skills of programmers beyond acceptable levels.

Programming paradigm has to change. The current multicore design and programming approaches do not scale with the technology. We simply have to start the transition to parallel programming. This is going to be a major challenge for the industry. Even worse, due to the energy efficiency, coprocessors and heterogeneous hardware are on the way to keep increase in performance while limiting energy consumption. This heterogeneity adds even more burden to the software tools and programmers. The current existing solutions are going to be a heavy burden, and the current programmers and engineers should learn a new way of thinking.

In practise this will involve the development of real heterogeneous parallel processor and memory architectures and management programming approaches, the development of parallel programming languages and design methods, and setting up respective education. Effort should be put on piloting the new approaches, because this is a radical disruption for the industry. It is a step that needs to be taken even though nobody in industry wants to do it.

Multi/many core systems / System-on-a chip/ Network-on-a-chip.
New means for interconnectivity of computing elements in embedded systems such as Internet of Things (IoT), the strengthened use of multi/many core systems, System-on-a-Chip (SoC) heterogeneous systems embedding MEMS and other sensors and Network-on-a-Chip (NoC) technology, and low power wireless technology promise a significant leap forward for the embedded systems industry and the services that embedded systems will provide to society.

One problem for advanced SoCs is that the cost of the advanced process technologies required continuing Moore's law is growing exponentially. This cost is doubling every four years, making the continuation of Moore's law not only a technical challenge but also an economic and political one. On top of that, the non-recurring engineering costs of designing new chips are also growing rapidly due to the complexities of increasing levels of functional integration and the difficulties of managing smaller transistors. One potential solution is the use of silicon interposers to integrate heterogeneous devices (various dies of various functions made of possibly different technologies) on the same substrate. This allows for cheaper dies (using only advanced processes for the most performance-critical dies) and more diversity (by integrating circuits that require optimized processes, such as analog, digital, photonics, and sensors). Silicon interposers do not require the most advanced technology nodes, and therefore can be built in existing fabs.

Through different combinations of dies, we may be able to regain the chip diversity lost due to the increasing costs of chip design. This also drives new challenges in standardization, modeling, and programming for realizing these complex systems in a package.

A logical continuation of Moore's law is to stack dies and interconnect them in the vertical direction. This enables to change architectures by physically reducing the distance between different devices by stacking, e.g. memories on processors and therefore increase bandwidth while reducing energy for communication.

But these new features, as well as the promises of a continuation of Moore's law over the next 7 years, need to be exploited in the context of stable, sound architectural principles.

In spite of the variety of contexts and requirements, all ARTEMIS application domains are facing similar architectural issues:
> Distribution of processing capabilities between local resources (close to sensors, embedded in personal devices, on board vehicles) and remote resources (hosted by a shared infrastructure)
> Ensuring security, acknowledging the reality that most subsystems are directly or indirectly connected
> Implementing the trade-offs between fault prevention and fault avoidance for safety critical system
> Implementing self-diagnosis and dynamic adaptation capabilities

These are some of the generic reference design and architecture issues. Only a cooperative approach between:

> application domains system integrators (mastering the possible system design trade-offs)
> technology providers of the execution platforms (semiconductor industry, software/middleware vendors)
> academic partners (providing the needed mathematically sound principles) is in our opinion able to yield actual cost-effective technical innovations.

Moore's law (in terms of quantitative benefits) is not a sufficient answer, for most domains. Of course, it is possible to use some of the additional computing capability to execute additional software to face the new challenges (e.g. use firewall layers to improve security). But as a rule, the end-users are expecting the "useful" capacity of the final products to follow Moore's law. **Hence architectural means, including the appropriate hardware support, must be imagined and developed.**

Foundations for embedded systems architectures are available. They need to evolve, at least to be able to address the scale of the considered architectures - large, distributed, possibly dynamically reconfigurable sets of embedded systems.

It will be necessary to make parallel programming as simple as sequential programming. However, most contemporary parallel languages are primitive and low-level: they are cumbersome and require intricate knowledge of the execution model of the machine to fully optimize the performance. Most critically, they do not provide portable performance between different hardware platforms. Although there has been progress over the last decade, the challenge of enabling cost-effective, portable and efficient multi-core programming is still a primary concern in computing systems. Adding heterogeneity, dark silicon, and scaling to high core counts only makes the challenge more daunting. Debugging is also a nightmare due to a dearth of advanced debugging tools for heterogeneous, parallel and distributed systems.

5.2.3.2 Seamless Connectivity & Interoperability

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 are in effect, become the **neural system of society**.

Ubiquitous connectivity

The major challenge in the area of communication is the provision of ubiquitous connectivity schemes (wire or wireless) that support the syntactic and semantic integration of heterogeneous sub-systems under the constraints of minimum power consumption and limited bandwidth usage. The vision of ambient intelligence depends critically on the availability of such an information infrastructure as the Internet communication cannot be expected to reach the same quality as provided by current dedicated embedded system networks. Embedded systems must therefore 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.

By nature, internet communication cannot be expected to provide the same quality as dedicated Embedded Systems networks. Therefore Embedded Systems must be made more autonomous and robust to compensate for the reduced real-time and reliability guarantees, operating dependably even in the presence of network degradation or temporary failure. The safe and secure operation of such increasing complexity will impose huge challenges on design, operation and interoperability of Embedded Systems, be it in software, electronics, sensors, actuators or a combination of those.

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.

Embedded Systems/Cyber-Physical creating smart services
Embedded systems are increasingly connected to networks and Internet and the trend is going to continue. The consequence of network is that the systems are exploiting the information from Internet and even interaction with other systems in creating their services.

Models of **Embedded Systems/Cyber-Physical Systems** comprise models of the environment. Such models will need to take a closer look at the interface between the analogue and the digital world, since the state of the art in this area still leaves many issues open. For example, control theory needs to take a closer look at the implications of discretization.

In the future the **Cyber Physical System** research should focus on building services in smart spaces based on the capabilities of CPS and promoting the interoperability of CPS as objects or nodes in Internet. The research is going to direction of interoperability, development in semantic web, open data, and linked data.

In case to really benefit from the added value of networking (similarly as stated in Metcalfe's law) the approach requires a common infrastructure in addition to M2M solution islands as well as a [global] systems for giving digital identities for Things, address resolution services, and support for management the information. These issues are analogues to the Internet and should be handled in an open way so that smart services could be created and innovated on top of it. This should be a major topic for EU to be solved in a way that supports the emergence of new businesses.

World-machine interaction (WMI)
Situation-awareness and reliable interpretation of real-time images will become more and more relevant to a large class of embedded systems such as driver-assistant systems in vehicles, and also through interfaces that are more natural for humans like in real life and use more and more natural sensory interaction, understand the intentions, and deliver personalized and unique responses.

For ARTEMIS a particular research challenge is to reliably construct for an embedded system an accurate real-time representation of its environment. This construction is easy if the environment consists of real-time entities such as valves as the embedded system can accurately measure its current state. The construction is significantly more complex in dynamic situations in which not even all real-time entities are present all the time, e.g., a driver-assistance system may observe an object (the real-time entity) on the road, it needs to internally classify that indeed the object is a pedestrian (the real-time image) and if necessary perform appropriate actions such as to initiate an emergency break. The following are research challenges that need to be addressed:

- How can we build real-time images from inherently inaccurate information?
- What are the guarantees that we can give for such real-time images?
- What aspects of state-of-the-art embedded systems need to be improved to increase the guarantees on the real-time images?
- How can we build a reference architecture that deterministically delivers real-time images?
- What are the nobs and dials (design guidelines) that we can use as a trade-off to increase the level of determinism for real-time images?

Human interaction with CPS16
To fully exploit the capabilities of CPS and facilitate a broad user acceptance, new approaches, solutions and technologies are required in the interaction between humans and computers.

If the goal is to use the networked environment as an enhancement of human capabilities, the current "human-in the loop" approach (enabling the operations of machines) is not enough and it needs to be replaced by a new paradigm where humans and computers cooperate in carrying out complex tasks or easing the performance of more traditional ones (often named Human-Centred Computing).

Human-Centred Computing requires the development of new interaction system designs, software and technologies to build up specific properties like **situation awareness** (to optimize the cooperation between humans and computers in highly dynamic environments), **adaptability** and **individualization** (to cater for different situations, personal preferences, capabilities and expectations). A wide user acceptance requires also an attractive and intuitive **user experience** providing gratification and enjoyment, and enhanced **accessibility** to fulfil user expectations and capabilities in the different application environments. The system should also be able to ensure **privacy**,

To achieve these properties, a substantial research effort is needed to develop interaction technologies exploiting emerging computing infrastructures (e.g. cloud computing or others specific of user environments), wireless networking and advanced integration capabilities.

With the goal of providing seamless interactions, a range of key technologies need to be addressed like voice, vision, gestural input, retina-integrated displays and brain-machine interfaces. Multimodal integration of these technologies is required to reduce user workload, to enable the sharing of capabilities between humans and machines and support each other, which forms highly dependent on the specific environment (from home to factories and other professional environments, from automotive and other transport means to education, and so on).

Autonomous and cooperative systems
These systems require solution of the following common issues and challenges:

> *Safe and robust environmental perception of environment*. Robust recognition of the environment is one of the most complex tasks a robotic system has to handle. While for restricted environmental conditions (e.g. limited number of objects, simple scenery structure, constant and well-defined illumination) good results can be achieved today, existing solutions exhibit little robustness in more open environments. Three major aspects have to be considered:
  - *Dealing with complexity*. Solutions will only work when they can cope with arbitrary complex situations and scenarios in real-time.
  - *Sensor data fusion*. Combination of several sensor modalities are seen as important means to dealing with complexity and increasing robustness, but also implies new issues to be solved.
  - *Robustness verification*. Due to the complexity of input data, assessing application-specific robustness requires appropriate V&V methods.

> *Learning and adaptive behaviour*. It is impossible to implement all potentially required behaviour in advance. Instead, autonomous robotic systems must be able to adapt to changing environments and learn to understand and cope with complex situations. As for perception, novel analysis and testing methods are needed to verify that learning and adaptive systems are sufficiently safe. On-line verification is an example for such a technique.

16 *[Ref: Software Technologies - The Missing Key Enabling Technology: Toward a Strategic Agenda for Software Technologies in Europe, ISTAG, July 2012]*

- *Advanced mobility and manipulation capabilities*. Interaction with humans, underwater inspection of ship hulks, or maintaining wind energy plants require special capabilities of ego-motion and manipulation, e.g. finding flexibly and in real-time safe path of a grasping tool for moving a glass of water.
- *Cooperation*. It involves communication and interaction. In particular cooperation with humans requires solution of several issues, such as understanding humans (e.g. gestures, mimics, or verbal expressions) and informing them about the robots intents (verbally and non-verbally). In contrast to HRI (human-robot interaction), RRI is considered less critical, because wireless communication over standardised protocols is regarded as sufficient in most cases.

5.2.3.3 Design methods and tools

The design methods and tools are about engineering and development processes.

ARTEMIS approach to the realization of the objectives for system design methods and tools is to address the following priorities:

- Advance methods and tools through implementation of the tool reference framework, **and interoperability Standards**
- Achieve end-to-end process optimisation through realisation of a model-based design flow.
- favour low-cost development and reuse by implementing complete Model-Based Design software “factories” that enable verification activities previously performed at code level to be performed as much as possible at model level
- mastering earlier in the lifecycle the quality of ever more complex software appears as being equally critical,
- qualification and certification issues pose a significant challenge, as even though domain-specific standards do exist (DO-178B for avionics, IEC 61508 for rail, industry and automotive, ITSEC for security-related matters and in particular smart cards…), there is little cross-domain fertilization of methods and tools.

This is summarised in the 2 major folds:

Research towards implementation of the Tool Reference Framework/platform	**Research into End-to-End Process Optimization**
Architecture Tools o Capabilities engineering o Environmental Modelling o Functional Design Tools o System Architecture, Co-Design , Distribution Design, Implementation & Verification Tools o Application Software Design & Verification o Hardware-related Software Design & Verification o Application Software Code generation, IDEs, Compilers… o Hardware Design & Verification (Behavioural Synthesis & Signal integrity) o Real-time Operating Systems Integration Tools o System Integration & Testing o Simulation & Virtual prototyping Transversal Tools o Certification, Safety Planning o Requirements and Traceability Management (including Use Cases) & Configuration Management, Methodology, & Life Cycle Management o Tool Integration, Frameworks…	Model-Based Design Flow Optimisation o RTE Architecting Techniques & Patterns o [Meta]-Modelling for RTE o Engineering Continuum & Impact Analysis o Model transformation to Reuse o Use of heterogeneous &multi-domain models (continue efforts) Model-Based Validation & Verification Flow Optimisation o Early Design Validation Support o Early Product Validation Support o Formal Proof Techniques & Support o Mixed Real and Simulated prototyping o Validation Strategy optimization o Automated connection between modeling and V&V tools Global HW+SW Solution Verification & Optimisation o Decision Aids for Solution Emergence o Integration of behavioural synthesis with HW design tools o Timing & Power & Resource Consumption Verification & Optimization o Hardware/Software Optimization

5.2.3.4 Fundamental Research

R&D cycles, prepare the future, no fixed boundaries.

Processing the Data Deluge[17]
In 2010 the world generated over 1.2 Zettabytes (10^{21} bytes) of new data, 50% more than it had in all of human history before that. There will be an exponential growth of data coming from data sensors and IoT. Processing storing and retrieving all those data in due time is a phenomenal challenge that we are facing but also the source of great opportunities.

Most of the data are unstructured or coming from the physical world (like video, audio, various signals). Exact interpretation is difficult, like image analysis and recognition. The systems will have more and more to analyze these data, like for self-driving vehicle, surveillance, robotic applications, smart-*, …

For processing those data, exact computation with a lot of accuracy is not always necessary. Several approaches

[17] From HiPEAC vision for advanced computing

and techniques should be developed to reduce the power, or increase the density, of processing engines, taking advantage of "less accurate" processing.

"Programming" future applications spread across different distributed, parallel and heterogeneous systems:

Another challenge is programming a network or system of computing systems (as is done in data centers, and between mobile devices and sensing devices) where an application is in fact the result on more or less coordinated interdependent programs interacting with each other and distributed onto different systems and programmed with different approaches.

There is also need for new tools and techniques that provide power and performance portability, analyzes software providing high-level feedback to developers and runtime systems, and enables porting of legacy applications to modern hardware. The programmer should only express the concurrency of the application, and leave to the tools the mapping of the concurrency of the application into the parallelism of the hardware. Run-time adaptation and machine learning has demonstrated a high potential to improve performance, power consumption and other important metrics. Virtualization is a step toward hardware independence but further progress is required to cope with truly distributed and heterogeneous systems.

Optimizing data movement and communications:
Today data movement uses more power than computation. We are now living in a world where *communicating and storing data is more expensive* (in both power and performance) *than computing* on it. To adapt to this change, we need to develop techniques for exposing data movement in applications and optimizing them at runtime and compile time and to investigate communication-optimized algorithms.

Managing complexity by giving the "What", not the "How":
Classical approaches use an explicit declaration of how to perform tasks (typical *imperative programming*), but it might be time to reinvest in paradigms where, instead of instructing the machine on how to perform its tasks, we only specify the goal(s) or the objectives. *Declarative programming* (like database query languages - e.g., SQL, regular expressions, logic programming, and functional programming) falls in this category, together with other approaches like using Neural Networks. Those approaches are promising to cope with the complexity of programming large-scale parallel and/distributed systems. Most of them can be easily mapped to parallel systems.

Developing new computing modalities:
Techniques, such as biologically inspired approaches, approximate algorithms, stochastic and probabilistic computing, have the potential to produce more energy efficient systems by relaxing accuracy requirements for processing "natural data". Similarly, as more and more applications are about intelligent processing, the application scope of neural networks inspired technologies become significant for pattern recognition in unstructured data. Smooth integration of these approaches with classical ones, while keeping a certain level of trustiness is worthy investigation.

Learning and Reasoning System

Algorithms for concept formation and data structures for knowledge representations such that self-aware systems that learn about their environment and autonomously plan to achieve a given goal can be constructed. This technology will be important in the area of machine vision and robotics.

Adaptive Morphic embedded Systems
Address the issue of self-adaptive and self-configuring behaviors implying close cooperation between application software and architectural support mechanisms. Demonstrate the compatibility between such innovative dynamic behavior and the predictable system constraints.

5.3 Roadmap implementation

The ARTEMIS implementation roadmap ambition is to address numerous technical and technological opportunities relating to various Application Contexts that in their turn are encompassing Societal Challenges that will spur on European competitiveness:

The aim of ARTEMIS roadmap activity is to provide a scale for the technological opportunities versus the timeline and budget estimation. It is inspired by the SafeTrans Road-map (see Annex 2), particularly in the partitioning the research challenges.

5.3.1 Innovative Cyber-Physical Systems roadmap

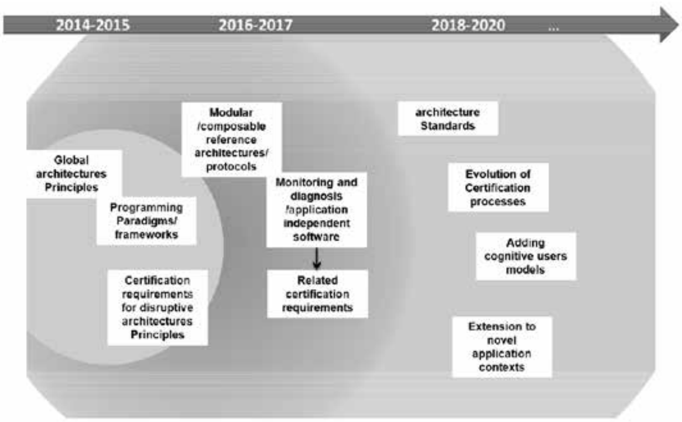
In order to deliver a set of solutions creating an innovative environment, research directions are selected and organised along a road-map composed of four clusters and along three phases:

- o Phase 1: short term: to be launched in 2014-2015
- o Phase 2: medium term: to be launched in 2016-2017
- o Phase 3: longer-term: to be launched in 2017-2020

A - Architectures Principles and models for Autonomous Safe and secure Cyber-Physical Systems

- **Short term**: for defining global architectures principles, programming paradigms and frameworks for CPS taking into account safe and secure operation in non-deterministic environment. Certification requirements for disruptive architectures principles are considered at this stage.
- **Medium term**: for translating these principles into modular and composable reference architectures and protocols including monitoring and diagnosis as well as application independent software; for producing certification guidelines when appropriate.
- **Longer term**: for producing architecture standards and evolution of certification processes when relevant; for adding cognitive users' model to the global CPS architectural models, targeting extensions to novel application contexts.

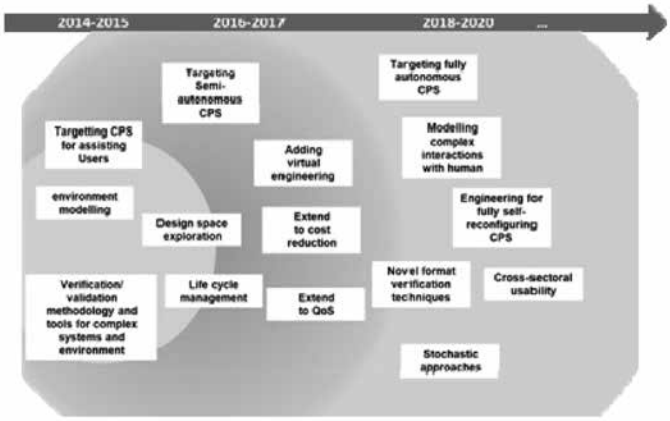
The ambition of this cluster A is to define principles and models encompassing a wide range of applications. Adoption of computing technologies from cluster D, and feedback from autonomous adaptive and cooperative CPS (cluster C) should be considered along the phases of the roadmap.



B-System Design, modelling and virtual engineering for Cyber-Physical Systems

- **Short term:** for targeting CPS for assisting users: integrating environment modelling, design space exploration, verification and validation methodology and tools for complex systems and environments as well as Life cycle management.

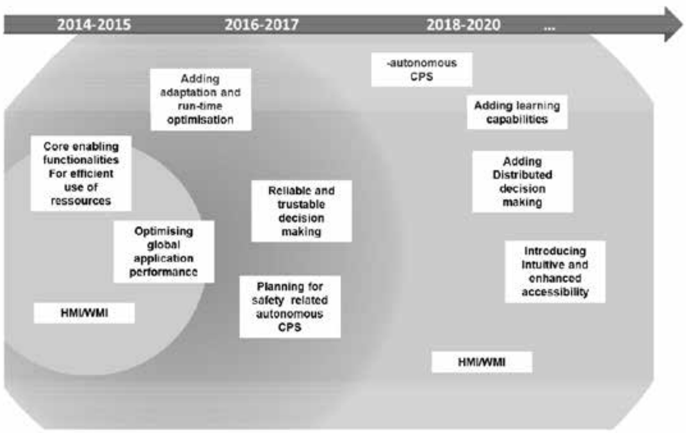
- **Medium term**: for targeting semi-autonomous CPS: adding virtual engineering extending design space exploration for cost reduction/ Quality of Services tradeoffs.
- **Longer-term**: for targeting fully autonomous (including bio-inspired approaches) CPS, modelling complex interactions with humans. Addressing engineering of fully self-reconfiguring CPS, adopting novel format verification techniques, including stochastic approaches, developing of cross-sectorial usability.



C-Autonomous adaptive and cooperative Cyber-Physical Systems

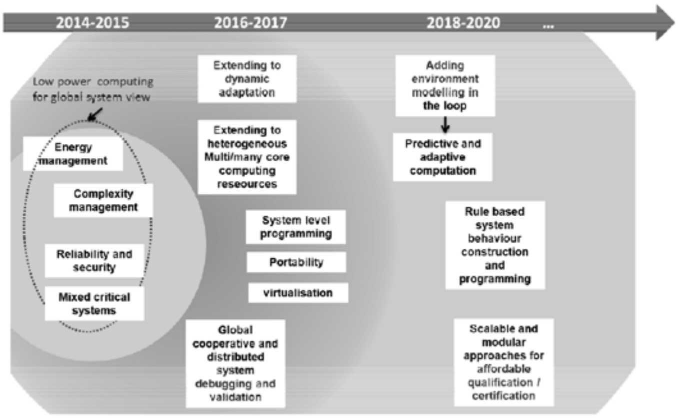
- **Short-term**: for developing core enabling functionalities for efficient use of resources (computing, power,..) and for optimizing global application performance and life-cycle costs for semi-autonomous CPS.
- **Medium-term**: For adding adaptation and run-time optimisation capabilities, as well as reliable and trustable decision making and planning for safety-related autonomous CPS.
- **Longer-term**: For adding learning capabilities and distributed decision making ; for introducing attractive, intuitive and enhanced accessibility for users for autonomous CPS including Human Machine Interface/World Machine Interface (HMI/WMI).

This cluster C may consider different applications contexts and objectives, for example home context (aiming at assisted care) or road traffic (aiming at autonomous cars). For each application context, the phases of the roadmap should be mapped to specific end-user functionalities.



D-Computing Platforms and energy management

- **Short term**: for addressing low power computing systems for global system view for energy management, while managing the complexity, reliability and security for mixed critical systems.
- **Medium term**: for extending to dynamic adaptation/selection of heterogeneous multi/many core computing resources to application needs. Focusing on "System level programming" with emphasis on portability, virtualization. Supporting global cooperative and distributed system debugging and validation.
- **Long-term**: for adding environment modelling in the loop (for predictive and adaptive computations). Adopting rule-based system behaviour construction and "programming". Proposing scalable and modular approaches for affordable qualification and certification.



The above road-map is derived from the Research Topics table attached in Annex 1[18] by clustering them as follows.

Research Challenge	Expected Impact (Sub-Challenges)	Ph1 2014 - 2015	Ph2 2016 - 2017	Ph3 2018 - 2020	Cross reference to Annex1
A–Architectures Principles and models for Autonomous Safe and secure CPS					
A.1 Providing safety and enabling certification (e.g., ISO 26262) in highly complex and non-deterministic environments	Enable validation and certification with affordable costs				2.1
A.2 Enable the secure and safe convergence of safety-critical systems and consumer IT	Principles and architectural framework for combined safety-related and security-related domains				3.3
A.3 Reference Architectures for single safe and secure CPSs	architecture principles and programming paradigms; reference architectures; design patterns, HW/SW co-design; Special focus on: reference architectures for seamless interaction and autonomous control Interfacing CPSs to advanced materials, photonic and biotechnological components Handling cloud-machine-interaction service platform architectures for cooperative cyber-physical services **Applications (e.g.:** automotive, aerospace, smart buildings, smart health, smart production, energy efficiency, food chain,)				1.2 ; 3.1
A.4 Monitoring and diagnostics in CPS	On-board diagnostics for detecting malfunction of systems during operation; Software methods for real-time data plausibility checks of generic inputs; Modular data acquisition for generic inputs				2.3; 2.6; 2.7
A.5 Reference Architectures for secure and safe cooperative CP-SoS	Safe and secure middleware and OSes, Digital identities for things Architectural principles for secure, robust, reconfigurable, dynamic System of Systems and CPS; special focus on: reference architectures for seamless connectivity and interaction reference architectures for adaptive, predictive and autonomous control reference architectures for inter-CPS semantic interoperability and trust **Applications (e.g.** smart cities, smart districts, smart co-mobility, smart buildings, smart health, smart production, energy efficiency, food chain,)				1.2; 3.1; 3.2; 2.5

[18] **In Annex 1 timeline and budget are also indicated.**

Research Challenge	Expected Impact (Sub-Challenges)	Ph1 2014 - 2015	Ph2 2016 - 2017	Ph3 2018 - 2020	Cross reference to Annex1
A.6 Reference Architectures for new industrial use-cases - users driven design process	Novel models and reference architectures based on the requirements of novel industrial applications		FALSE		3.4
B - System Design, modeling and virtual engineering for CPS					
6. Modeling and simulation techniques for efficient methods (including RTP) and tools .	Reduced cost and cycle of system design. Manage the complexity increase of 100% with 20% effort reduction				
B.1 Life Cycle management for CPS-based products	Interoperability of tools throughout the entire product life-cycle; full traceability, Improved logistic support (e.g., configuration management);				4.6
B.2 Virtual engineering of CPS	Multi-domain engineering (hydraulics, electrical, mechanical, communication) methods and tools, including reference platforms and tool chains for complex, multi-critical, multi-manufacturer Systems/CPS; Cost reduction of system design, increased quality of services and cross-sectors usability; New standards for global cost reduction				4.1; 4.2; 4.3
B.3 Verification and validation methodology and tools for Complex CPS	Methods to select relevant test scenarios and define test coverage, stochastic testing, models of environment (e.g. traffic simulation), creation of test scenarios, formal verification.				
B.4 Integration of environment modeling and simulation into the HW and SW design flow	Efficient modeling and simulation of environmental effects on embedded systems in large complex systems; Reduction of the product development cycle while increasing product and service quality				6.1; 6.2
B.5 Provide complete tool-chains for Model-Based Design	Efficient modeling and simulation of human being and their interaction in the CPS				
B.6 Provide complete tool-chains for Model-Based Design	Practical architectural exploration and development tools based on common meta models; Provide tool facilities to detect problems earlier in the development life cycle; multi-disciplinary modeling tools; Improve Quality of Service; reduce effort and time for re-validation and re-certification after change;				6.3; 6.4; 6.5

Research Challenge	Expected Impact (Sub-Challenges)	Ph1 2014 - 2015	Ph2 2016 - 2017	Ph3 2018 - 2020	Cross reference to Annex1
B.7 Engineering for complex systems and environment	Managing the complexity and reducing design costs. Complexity management of embedded systems interactions Intelligent interfaces and artifacts Reuse of low level software elements, sub-systems, and design and validation tasks Enable development of systems which are several times more complex than the current ones and that are needed to solve societal problems without increasing development cost; Enable navigation through the development cycle; Standardization of meta-model to achieve interoperability between tools; provide capabilities to easily integrate specific process, meta-model, profile or architecture in development tools; Achieve cross-sectoral reusability of designs and models.				4.4; 4.5; 4.3; 6.6; 6.7; 6.8; 6.9
C - Autonomous adaptive and cooperative of Cyber-Physical Systems					
C.1 Optimal control using autonomous CPS	Efficient use of resources (computing, power, development effort …) and optimize global application performance and life-cycle costs.				1.1
C.2 Development of mechanisms of autonomous CPS	Design, planning, control and operation for autonomy and runtime adaptation (configuration, behavior), including monitoring and on-line diagnosis.				1.3
C.3 Development and control of cooperative and autonomous SoS (e.g car networks, smart grids, adaptive swarms)	Cost efficient cooperative systems with cooperative, distributed situation awareness and solution finding, decision making, planning and execution, including self-healing (e.g., Adaptive swarms				1.3
C.4 Seamless Interaction	Deliver Interoperability standards, middleware. Enable new functionalities trough interconnection (e.g systems for reduction of fatalities or protection of the environment) while protecting the privacy of the users.				5.1

Research Challenge	Expected Impact (Sub-Challenges)	Ph1 2014 - 2015	Ph2 2016 - 2017	Ph3 2018 - 2020	Cross reference to Annex1
C.5 Real-time sensing and networking in Challenging environments	*New sensors operating in harsh environments for process industries and manufacturing plants*; Reliable real-time sensor data fusion and situation awareness				5.2; 5.4
C.6 Reliable and trustable decision making and planning for safety-related autonomous CPS/SoS	Extension to distributed CPS/SoS Better (distributed) reliable decision making and planning with autonomous CPS/SoS				5.3
C.7 HMI and WMI CPS (common to B System design)	Attractive, intuitive and enhanced accessibility for users – e.g. drivers assistance				5.4
D - Computing Architecture and energy management					
D.1 Low power computing systems: > Heterogeneous and specialized > From energy management at system level to energy harvesting devices	Global system view for energy management (Ph1) Dynamic adaptation/selection of heterogeneous multi/many core computing resources to application needs (Ph2) Environment modeling in the loop (for predictive and adaptive computations) (Ph3)				
D.2 Collaborating computational elements – managing complexity > Distributed computations -> computation AND communications together > Processing according to the data/ data reduction (for taming the data deluge) > Decoupling hw/sw: portability, task migration, dynamic adaptation at system level	- Standard interfaces and synergies between computing segments, reuse, TTM (Time to Market), including link with existing OSes and new OSes. (Ph1) - Data driven processing, extracting the relevant data at each level, data fusion (Ph1) - Full system debugging and validation (Ph1) - "System level programming", AaaS (Application as a Service), portability, virtualization (Ph2) - Global cooperative and distributed system debugging and validation(Ph2) - Platform implementing Global Model of Computation and Communication (-> from FET) (Ph3) - "Declarative", rule based system behavior construction and "programming" (Ph3)				
D.3 Interfacing with sensors and actuators- including Human Interfaces) > Various real-time requirements > Time and latency as first class citizen	- Data driven processing, extracting the relevant data at each level(Ph2) - Mixed criticality systems (Ph2) - Environment modeling in the loop (for predictive and adaptive computations) (Ph3)				

Research Challenge	Expected Impact (Sub-Challenges)	Ph1 2014 - 2015	Ph2 2016 - 2017	Ph3 2018 - 2020	Cross reference to Annex1
D.4 Reliable trustable computing platforms > At hardware, system, programming levels > Qualification and certification o For multi/many cores o For distributed systems o For virtualized systems	- QoS management at all level (from HW to algorithms) - Online bug detection and correction, isolation of faults, resilient and self-healing systems - Affordable qualification and certification (lobbying, regulation) - Scalable and modular approach (Ph1) - Reduction of effort for revalidation/ recertification (Ph2) - Virtual hardware to increase time in market (Ph3)				
D.5 Securing and tamper proofing at platform level	- Securing and tamper proofing at platform level (Ph1)				

6 Innovation environment context – Make it Happen

6.1 ARTEMIS Innovation

ARTEMIS is an Innovation Program around Embedded Systems. As the term "innovation" is broadly used, in the ARTEMIS program "innovation" will be mainly connected to innovative technologies, will range from fundamental and industrial research to experimental development of new products, processes and services. Process and organization innovation of services are within the scope of the ARTEMIS program.

Maintaining the ARTEMIS differentiators
ARTEMIS should maintain its differentiators, as:

- An 'Industry driven' initiative,
- A unique example of tri-partite cooperation between the EU member-states, the European Commission and the Industry,
- Sustaining its focus on both business competitiveness and technical excellence,
- A descriptive 'Top-down' approach based on a Strategic Agenda, supported by a bottom-up expression of needs through Centres of Innovation Excellence,
- Keeping the focus on large impact and market-oriented projects (the AIPPs);
- Having large footprint projects with support from smaller focussed projects, while ensuring the balance between different research's actors (large, mid and small industry as well as RTOs and Academic) to drive innovation,
- Actively supporting the creation of innovation eco-systems,
- Openness and complementarities with EU framework programmes and ITEA.

These differentiators are Innovation Accelerators essential to allow technology developments to become strong market influencers, through business-driven engineering, as among ARTEMIS accelerators:

- **Standards** ensure interoperability in its many forms, through active participation in their definition and promotion.
- **Tools,** developed from a rigorous scientific basis, allow timely and "right first time" product/system definition, analysis and development.
- Rugged, **science-based engineering processes**:
  - o embrace fast-changing requirements as a fact,
  - o integrate multiple and diverse technologies and non-functional aspects,
  - o provably guarantee correct functionality,
  - o provably guarantee immediate conformance to safety/security/privacy certification needs,

  These accelerators facilitate Innovation by:
  - Reducing development costs and time
  - Allowing the pace of product-family roll-out to be governed by business needs (rather than engineering limitations)
  - Lowering the threshold of product introduction in face of rapidly changing market needs
  - Increasing customer confidence, trust and acceptance

6.2 The Programmes

In addition, to the Matrix Approach, the ARTEMIS strategy aimed to: *"Build self-sustaining innovation ecosystems for European leadership in Embedded Systems"*, by stimulating the emergence of innovation ecosystems within the field of embedded systems in **a number of business sectors**, facilitating their integration into larger ecosystems, **mainly through support of R&D projects**.
Such R&D projects are generated through the responses to work-progammes that could be launched by the EC, the new JU, or National programmes.

6.2.1 The ARTEMIS Sub-Programmes

To achieve this, an essential element of the ARTEMIS-JU strategy is to establish a suite of ARTEMIS Sub-Programmes (ASP) that embrace both technological and application-oriented development in a way that integrates the participants so as to facilitate the emergence of innovation ecosystems of pan-European scale. These ecosystems are expected to grow around existing or new Centres of Innovation Excellence, feeding on the innovations created within the sub-programmes' R&D activities

6.2.2 The ARTEMIS Innovation Pilot Programme

The "ARTEMIS Innovation Pilot Programmes" were set after the ARTEMIS-IA 2011 Summer Camp, as anticipation to the H2020 KET initiative, while adapting this concept to the Embedded Systems field.
The AIPPS *are targeting large scale integration projects and set-up to respond to the following targets:*

- Seamless technology, interoperability within and between ambient environment to achieve cross-domain connectivity and communication capabilities to realise the seamless interoperability between the 'Ambient Intelligent Environments'.
- Successful Tool strategy to establish integrated chains and interoperable of Tool Platforms, based on ARTEMIS-JU results, to support development of Embedded Systems from user requirements, through system design, to system-on-chip production.
- Cross- sectorial technology development, multiple use and reuse: to cross-sectorial usability of Embedded System technology and devices such as interoperable components (hardware and software) in, for example, the automotive, aerospace and manufacturing sectors, which will be developed using the ARTEMIS-JU results.
- Addressing main societal concerns: to address issues of significant societal impact, offering solutions to the main concerns encountered by people in their everyday life. Topics such as efficient energy use, safety and privacy, meaningful employment, health-care cost and urbanisation (its benefits and disadvantages) will help assure high market acceptance of the ARTEMIS-JU work

The ARTEMIS Innovation Pilot Projects are expected to foster and sustain the ARTEMIS innovation environment through:

- Creating new business innovating eco-systems,
- Efficiently using of Public, Private Partnership in the Embedded Systems arena to overcome the resource deficit for R&D and to foster innovation & collaboration in Europe,
- Aligning implementation of R&D&I (Research and Development and Innovation) priorities for Embedded Systems in Europe to turn European "diversity" into a strength,
- Achieving a "European Dimension" by combining the R&D efforts across Europe for future proven application domains and technologies, while pulling resources in key areas, and involving relevant players having the ability to insure successful valorisation and take-up of the results.
- Establishing and sustaining a holistic approach to R&D&I, by undertaking projects of critical mass, reconciling the market silos/ business efficient approach with the cross-domain synergies.
- Risk sharing by allowing projects that otherwise would not be undertaken,
- Building upon results from existing and previous projects for providing market driven solutions based on

prototypes and demonstrations,
- Pooling industrial resources and "sharing" (e.g. standards and methods) to foster interoperability and synergies between various environments, in order to keep leadership position in traditional markets, and gain worldwide positions and more market in new areas.
- Setting and sharing of R&D&I infrastructures.

6.2.3 KETs/ multiKETS

The European Commission has identified 6 Key Enabling Technologies (KETs) that are crucial to the development of the European economy:
- Micro-Nano electronics
- Advanced Materials
- Nanotechnology
- Biotechnology
- Photonics
- Advanced Manufacturing

These Key Enabling Technologies are considered as playing a crucial role for insuring the competitiveness of European industries and as main driving force (enablers) for European R&D and innovation. They promote enhancing technology research to facilitate the delivery of product demonstrators as well as the implementation of pilot lines to stimulate large-scale production in Europe. Mastering these technologies and production means is at the forefront for managing the shift to a low carbon, knowledge-based economy.

Although Embedded Systems are not retained as such in the KET initiative, Embedded Systems are key enabler for efficient use and exploitation of these KETs in the ICT environment and for generating intelligent applications, as Embedded Systems pervade in all artefacts of life providing intelligence and capabilities to cleverly connect to the abundance of systems in their environment, either physically or at cyber-space level, and in real time. Joining and contributing to these KETs is part of ARTEMIS Strategy to be developed and sustained during the H2020 implementation.

Beside the KET initiative, the EC has also opened the possibility to set two Multi-KET pilot lines, for topics that could be driven by a combination of technologies. **This mKET will be considered in ARTEMIS Strategy implementation as an opportunity to develop, jointly or separately with the AIPPs concept described above.** Adapting the concept of "pilot lines" to Embedded Systems, as the *ARTEMIS Innovation Pilot Project* approach, has already paved the way to these initiatives and triggered this concept in a number of meaningful areas for Europe industries based on selected /focused domains aims to contribute in achieving ARTEMIS high level targets (such as CRYSTAL and ARROWHEAD projects).

6.3 Real-Life experiments in Living Labs

ARTEMIS supports the creation of Living Labs as part of or besides the typical R&D projects. The concept of Living Labs 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 end users.

The Living Labs concurrently involves the following multidisciplinary activities: co-creation, exploration, experimentation and evaluation. The living labs should provide the practical links between the research activities in clusters A, B, C, D and application domains. The phases of the research roadmap should, in each cluster, meet the adoption pace of application domains. For example, autonomous adaptive and cooperative CPS technology

results from cluster C would meet different application contexts (e.g., home context, aiming at assisted care, or road traffic context, aiming at autonomous cars) in different living labs.
ARTEMIS recognizes that large experimentation platforms exist at national or European levels, which could provide for some applications domains targeted by ARTEMIS a suitable "real-life" experimentation environment, and which could benefit from the innovative ideas, concepts and artefacts developed by ARTEMIS. Supporting the participation to such established Living Labs is part of the real-life experiments priority.
As example:

> Digital lighting is far more suited for manipulation of the lighting conditions in terms of intensity, spatial, temporal and spectral distribution. Information is available on the effect of incumbent lighting technologies on the health and well-being of people. How dynamical effects of lighting affect people however is unexplored territory. In order to surface the beneficial effect of dynamic lighting there is a need for living lab involving thousands of people.

6.4 Centres of Innovation Excellence

In order to meet the medium to long-term research needs of European industry, ARTEMIS developed the of Centres of Innovation Excellence (CoIEs) concept and focused 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.

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.

Their mission is to pursue the implementation of industrial research visions, as expressed in the ARTEMIS Strategic Research Agendas. They create new Innovation Eco-systems, taking advantage of the critical mass of competences and resources that have already been organised in its supporting regional clusters. They focus on European research efforts, mobilise research actors for tackling the SRA challenges.

Several initiatives have already been launched 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 ARTEMIS success that these regional innovation initiatives in Europe can participate to and be integrated into the ARTEMIS Innovation Environment.

Centres 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.

6.5 SME Integration

Support integration of the SME environment in ecosystems
This involves facilitating such services as identification of high-potential SMEs, promoting business development beyond the projects, enabling that the point of view of SMEs is brought to the different events such as summer camps, conferences, working groups, etc.
Facilitate the participation of SMEs in projects.
A basic requirement in assuring heightened SME enrolment is the creation of an environment that will allow high-potential SMEs to be identified and communicated with, that encourages their participation in technically relevant collaborative R&D projects, and carries this through with support in valorising these developments as market-viable innovations.

6.6 Collaborative Innovation

The key actions to push open innovation within ARTEMIS-JU projects will be to:
- use Centres of Innovation Excellence to collect, attract and retain skills and resources, which will form critical mass for sustainable innovation;
- support actions towards SMEs and for SME networking;
- develop open- or community-source organizations for embedded software technologies, where appropriate;
- facilitate access to funding instruments to support development and commercialization of new innovations (Interface with European Investment Bank and with other financial institutions providing guarantees to SMEs, EC instruments, Venture Capital firms);
- support standardization activities, combating today’s fragmentation;
- encourage sharing of research infrastructures, or other platforms,
- encourage sharing of and contributing to tool platforms;
- support projects to sustainably exploit their results and bringing them to market, particularly for building sound business models when delivering reference platforms.

6.7 Standards

All projects to be supported by the ARTEMIS-JU are required to agree a strategy for standardisation, whenever applicable. This will include a rationale for that strategy that takes into account the ARTEMIS Strategic Standardisation Agenda (available from the ARTEMIS-IA web-site, see section 7). Projects will be expected to communicate with relevant ARTEMIS standardisation initiatives concerning their standardisation needs and opportunities, including those that may emerge during project execution.

6.8 Education

Effective education and training is crucial to maintaining competitive leadership. ARTEMIS-JU projects will make recommendations to instigate improvements to the following:
- creation of a highly skilled, multi-disciplinary work force, and maintenance and upgrading of existing skills of a professional workforce (life-long continuous learning);

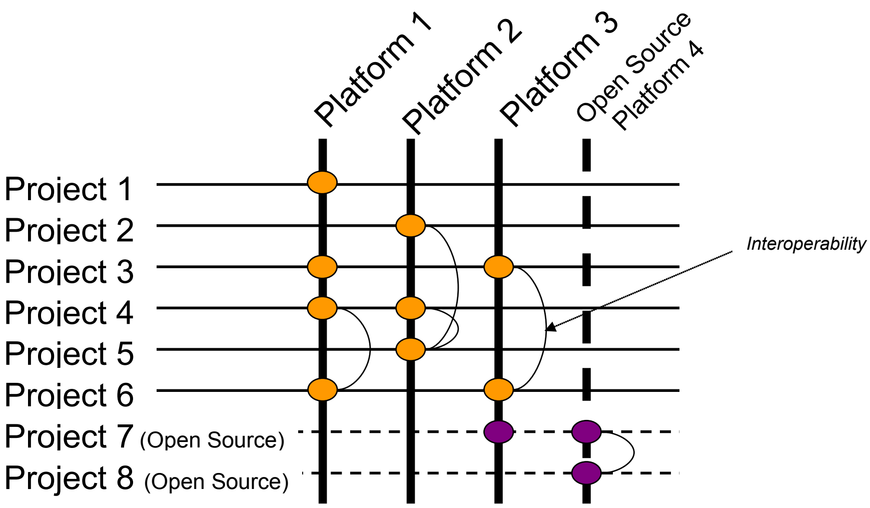
> joining of forces and inclusion of interests of both industry and academia, in initiatives, support actions etc., designed to overcome the gap between theory and practice of (industrial) application;
> establishment of new types of people mobility programmes with an industrial focus, additional to those with a rather academic focus;
> support of high-tech spin-off and start-up companies by facilitating non-technical training in entrepreneurship, finance and business practice, etc…;
> pan-European Policies for long-term effort in Embedded Systems Education and Training,
  o providing adequate university and applied university curricula in embedded and smart systems domains, and
  o providing a platform of excellence with special curricula and educational and training institutions (separately or on top of existing organizations).

For the realisation of the above targets, cooperation with EIT-ICT-Labs should be pursued in order to foster the link between R&D projects.

6.9 Tool platforms

The need for integrated, trustable, interoperable tools and tool-chains from reliable sources with assured long-term support is identified in the ARTEMIS-ETP SRA on Design Methods and Tools. The innovative element is the concept of the "ARTEMIS Tool Platform"[19], of which there may be several – each adapted to particular sector or part of the complete design flow.

Unlike a complete design flow tool-chain, an ARTEMIS Tool Platform may 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 refined over time, that allow specific tools addressing 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. In its simplest expression, it is a specification for interfaces and operating methods. 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, as shown schematically below.



Here it can be seen how tools developed in various research projects can be linked via the platforms into viable solutions as part of a complete chain. This also includes the possible inclusion of existing (commercial or open-

19 Tool platforms description on ARTEMIS-IA website: http://www.artemis-ia.eu/tool_platforms

source) tools. Note that a development project can yield a tool or tools which is/are compatible with more than one Platform. Also, the Platform concept does not impose a specific business model: these can be aimed towards a specific commercial implementation (a future ambition), can expressly address the Open Source paradigm, or even a mixture of these. A Tool Platform can also form the core of an ARTEMIS ecosystem.

6.10 ARTEMIS Repository

The ARTEMIS Repository[20] collects various public technical results into place of single access and description form to be shared for the developing community. The level of openness and availability is defined by the provider of the results. The ARTEMIS Repository is complementing the ARTEMIS Tool Platforms. In short, the purpose of the ARTEMIS Repository is to:

> Make public project's results available to the Embedded Systems R&D community in Europe.
> Enable new ARTEMIS-JU projects to build on results of previous ARTEMIS-JU projects.
> Provide information to proposers of new projects on results achieved and the state-of-the art.
> Promote ARTEMIS-JU project results. The Repository is a window showing the impact of results accompanied with information on the actual use and proliferation of results.
> Provide a snap-shot of the coverage of the ARTEMIS industrial priorities.
> Support the building of networks, especially the Center of Innovation Excellence networks.

ARTEMIS asks future project proposers to voluntarily indicate, for information, what potential project results they foresee to contribute to this repository.

6.11 KIC EIT ICT LABs

EIT ICT Labs vision is *to 'reach its mission by exploiting Europe's strengths in deploying ICT in key domains with societal impact, increasing the pace of innovation of core ICT players in Europe, creating fast growing new ventures through entrepreneurship and new talents, and intensifying the interaction between the knowledge triangle actors.'*

In that, the KIC EIT ICT Labs is complementary to ARTEMIS, and a joint action should allow both initiatives to reach their objectives, and be more efficient in boosting the innovation potential and act in the triangle of knowledge. The areas of cooperation should include complementary actions executed on top of existing programmes and instruments for added value and high leverage.

6.12 Relationship with relevant PPPs

Interaction and synergies must be undertaken between ARTEMIS and the following PPPs/ETPs:

> The ETPs : ERTRAC
> European Factories of the Future Research Association (EFFRA)
> The PPP "Horizon 2020 Advanced 5G Network Infrastructure for Future Internet PPP" on the 5G Infrastructure
> The PPP related to manufacturing: for FoF and Spire ARTEMIS will provide horizontal technology enabling further automation for both manufacturing and process industries. Through the CoIE ProcessIT.EU, ARTEMIS has established a strong link to Spire and an emerging link to both the ETP Manufuture and the Association EFFRA.
> The future Robotics ETP: The Association euRobotics (aisbl), ARTEMIS to establish links with.

[20] ARTEMIS Repository description on ARTEMIS-IA website: https://community.artemis-ia.eu/roadmap/repository

6.13 International Dimension

More and more research and innovation are performed in the third countries and more specifically in the BRICS in order to open dialogue and exchange with the 'best in the world'.

As described in the ARTEMIS SRA 2011, such "International Collaboration can encompass a wide range of activities, from the organisation of technical meetings, high-level meetings, conferences, schools, and joint international projects".

"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."

7 ANNEX 1: Research Topics Table

Research challenge		Technical objectives
1 Cyber-Physical enabled Embedded Systems		
1.1	Optimal control using cyber-physical enabled embedded system	Enable the development of intelligent, autonomous agents. Despite of: - Limited accuracy/reliability in sensing and actuation, - Limited computational resources, and - Limited reaction time, these agents should be able to choose actions that optimize, for: - The given constraints, - Percept history, and - Whatever built-in knowledge they posses, a measure of their performance within an uncertain environment. ▪ As a consequence of this intelligence, such agents should be able to: - Self-diagnose and self-maintain. In particular, by taking advantage of the redundancy within their sensor-actuator chains, they should be able to: - Self reconfigure and self-repair them. ▪ In order to support the development of autonomous agents it will be also necessary to: - compute trajectories within the virtual world e.g., energy optimal vehicle strategy based on actual and estimated traffic and road information - Decrease development effort for highly increasing number of variants by model-based calibration - Introduce of model predictive control - Enable holistic modeling of the computational and physical aspects of a CPS - Provide advanced simulation techniques for CPS - Enable model-based development environment for CPS - Enable modular certification and efficient integration of sub-systems with mixed-criticality levels - Enable modular certification and efficient integration of sub-systems with mixed-criticality levels ▪ Enable the development of distributed intelligent agents, capable to optimize a global performance measure: - within a spatially –extended environment, - despite of uncertainty, dynamic evolution and - unwanted emergent behavior caused by the: - the possibly cooperative/competitive interaction among the autonomous agents. ▪ Achieving global optimality will require the development of: - wireless techniques and protocols for real-time traffic control, - Optimal partitioning of real-time workload between field devices and the cloud - and online system evolution. In particular the availability fast (deterministic) Internet communication will allow the exploitation of - huge cloud knowledge bases - huge cloud computational power. ▪ It will also require: - the provision of reliable and deterministic system architectures - methodologies supporting an evolutionary, adaptive and iterative SoS life-cycle, - open, safe and secure smart environments, - assisted, autonomous and safe mobility.
1.2	Architecture Principles for Cyber Physical Systems / Systems of Systems	▪ Requirements management (system of systems aspect, Elicitation of requirements), ▪ Architecture and Protocols for Seamless Interaction of multi-domain, multi-manufacturer Cyber-Physical Systems, building ontologies / domain analysis, Methods & Tools, Automated design exploration and synthesis, Property prediction / identification, Security, Design for non-functional requirements, Soundness and Completeness of requirements, Change Management, Multi-manufacturer / Multi-OEM systems, Traceability, Predictability, scalability/ extensability, composability, re-usability, reference architecture (modular), architecture complexity, interoperability; ▪ Design for diagnosis (predictive maintenance, online/offline, supported by data-driven analysis), Software and Hardware development of Human Machine Interaction (Cognitive User Models, prototyping, interface protocols, interface modeling and analysis, integration of HMI models and functional SW models, generating and integrating new knowledge on human performance, modelling cooperation between agents and match of mental models to system behavior, coherent world views); Distributed Situation Awareness and Solution Finding

	Contribution to ARTEMIS technology opportunities research domains								Contribution to ARTEMIS research domains			Proposed project time and budget		
Impact	safety critcal systems	virtual world	Big Data	System of Systems	Cloud Service	Internet of things	Autonomous, adaptive, dynamic control	Multicore	Reference design & architecture	Seamless connectivity and interoperability	System design methods and tools	from year	to year	Estimated Budget
Reduce usage of resource and optimize efficiency of embedded safety critical systems by utilizing CPS technologies	x	x	x	x			x		x	x	x	2014	2017	100 M€
Seamless Interaction of interoperable multi-domain, multi manufacturer Systems of Systems / Cyber-Physical Systems / Socio-technical Systems, Cost efficient Development of these Systems Re-Usability, Composability, scalability and predictability of Architectures/Components/Systems: reference architecture, modular architecture, interoperability:	x	x				x	x		x		x	2014 2016	2016 2020	700 M€

Research challenge		Technical objectives
1.3	Development of autonomous (cooperative) systems (with cooperative, distributed situation awareness and solution finding)	▪ Distributed Situation awareness, coherent world views, distributed, cooperative solution finding, Coping with evolvability, resilience (vs. strict predictability and dependability), autonomous, adaptive, self-organizing, self-healing and self-diagnosing systems, security; ▪ Design languages for autonomous CPS; Automated Design for multi-domain, multi-criticality, multi-manufacturer, adaptive, autonomous, human-centric Systems of Systems / Cyber-Physical-Systems, ▪ Emergence of complex behaviour out of an assembly of simple components that are context aware and act autonomously within their limited context, runtime system monitoring for property prediction; ▪ <u>Human Centred Design:</u> paradigms/techniques/technologies for "interligent" interactive systems (techniques to infer user intention and preferences from interaction data, recognize the operator's mental and physical state (incl. data fusion from multiple sensors and/or different subsystems), interaction patterns, user interface patterns, adaptive systems, self validating interfaces, goal oriented interaction)
1.4	Safety and security for Cyber-Physical Systems	▪ Safe control architectures for large scale networked industrial automation ▪ Validation and Verification (V&V) Technologies (Component based V&V, Incremental V&V, Composable V&V, Coping with emergent behavior, Multi-critical, multi-manufacture, multi-domain systems of systems / CPS, V&V for product lines, Co-simulation and testability, Simulation platform, ▪ Architectural verification, run-time system monitoring, Verification of non-functional properties, verification of large models with large parameter sets); Integration of human models in V&V and simulation; Cost-efficient Certification; ▪ Qualification/Certification of Human Machine Interaction (including cognitive systems), V&V for product lines, Dependability Analysis (Similarity analysis, Maintaining Safety and Availability in the case of failures both autonomously and by operator interaction, Evaluation and verification of dependability, Design for dependability) Safety:, Proof of Segregation between critical and non-critical functions; Security impact on Safety (on all levels) ▪ Safe and certified operation for highly autonomous systems
2 Safe and Secure Systems		
2.1	Providing safety and enabling certification (ISO 26262) in highly complex and non-deterministic environments	▪ Cope with decreasing reliability of computational components (e.g. due to decreasing feature sizes) ▪ Cope with highly complex and heterogeneous processor architectures (multicore) ▪ Cope with new unreliable sensors (weather dependent video cameras, radars) Non-deterministic algorithms (e.g., pattern recognition for driver assistance systems (ADAS)) ▪ Handle unreliable communication (wireless)
		▪ new methodology to asses impact of aging on processors' performances (Homogenous & heterogeneous multicores) ▪ Impact of aging on EMC of complex ICs
2.2	Convergence of safety-critical systems and consumer IT	▪ Handle technology cycles with different periods (life time of a car is greater than life time of consumer devices like phones and tablets; which is greater than life time of software; which is greater than life time of APPs) ▪ Support mixed-criticality levels and certification requirements (link to AIPP5) ▪ Enable interoperation of existing industrial (e.g. AutoSAR) and consumer standards (e.g., Android or iOS-Devices) ▪ Support new user concepts (e.g. augmented reality, …)

	Contribution to ARTEMIS technology opportunities research domains								Contribution to ARTEMIS research domains			Proposed project time and budget		
Impact	safety critical systems	virtual world	Big Data	System of Systems	Cloud Service	Internet of things	Autonomous, adaptive, dynamic control	Multicore	Reference design & architecture	Seamless connectivity and interoperability	System design methods and tools	from year	to year	Estimated Budget
Cost efficient development of autonomous systems, where subsystems share a coherent view of the situation and are able to cooperatively build strategies to reach solutions	x	x	x	x	x	x	x		x	x				630 M€
Systems in simple structured environments and/or hard-wired tasks: 2014-2017;														
in complex environments and for adaptive tasks: swarms: beyond														
												2014	2017	
												2017	2020	
Safe and Secure Systems of Systems / Cyber-Physical Systems with Validation/Verification/Certification at affordable costs	x	x	x	x	x	x	x		x		x			490 M€
modular (re-)certification; multi-criteria applications;												2014	2016	
Safety and security in open systems, eg. through reconfiguration												2015	2020	
safety and security in dynamic systems												beyond		
Advanced control system structures for crash free driving, better usage of space in cities (automatic driving, V2V,..), application to healthcare systems	X	X							X	X		2015	2018	100 M€
												2015	2018	20 M€
Enhanced safety and security for a larger number of application areas Increased efficiency in respect to energy, CO_2-pollution, usage of city space Enhanced user experience and safety in mobility	x				x	x			x	x		2014	2017	30 M€

Research challenge		**Technical objectives**
2.3		
2.3	Software methods for real time data plausibility checks of generic inputs	▪ New software algorithms for the calculation of real time measurement reference values. ▪ Different data inputs (regarding acquisition rate and physical measurement principle e.g. electrical signals, indicating values, temperatures, ADC values...) have to be fused and compared with the individual measurement values in real time. ▪ Plug and play software interfaces for implementing different data inputs and the infrastructure regarding data storage and data handling are required
2.4	Safety and security	▪ Security (as a safety issue); Security services, control effect on timing through security mechanisms, protect temporal properties of hard real-time systems (e.g. latencies, jitter); ▪ Methodology for verification/ qualification of complex components including COTS. ▪ Simulation platform: design and implement a new kind of distributed, heterogeneous, interoperable, ▪ COTS and IP sensitive simulation platform to provide the high integration required for the V&V of safety critical real time systems through virtual engineer; architecture, standard infrastructure and internal interfaces for multi-modal interaction)
2.5	digital identities for Things	
2.6	On board operating diagnostics systems for detecting malfunction of propulsion systems during operation	▪ Compact and robust cost effective sensors and data acquisition systems for measuring parameters (e.g. combustion pressure, voltage/current and additional ADC inputs) direct onboard the propulsion system. ▪ Development of highly integrated indicating hardware with integrated charge amplifiers for harsh environments (high IP protection class). ▪ Delivering of values via standard network interfaces and automatic calculation of failure modes.
2.7	Modular data acquisition for generic inputs	▪ Versatile data acquisition system for measuring different input signals (ADC, high voltage high current and other physical values) and supporting plug &play interfaces for transferring results to other systems (e.g. automation systems, application systems). ▪ Synchronization of input handshake mechanism for safe data transfer in real time channels and intelligent
3 Architectural Principles		
3.1	Reference Architectures	Design Patterns to support composability and evolvability: - Hardware Software Co-Design; - Methodology and tools, - chip level virtualisation mechanisms allowing reliable support of heterogeneous operating systems on the same processor; - chip level static configuration and dynamic reconfiguration capabilities, with associated firmware and operating system support; - support for multi-core architectures, embedded multi-process architecture platforms for multi sensor applications, Component product line, Reducing energy consumption (HW+SW), HW+SW integration and validation

	Contribution to ARTEMIS technology opportunities research domains								Contribution to ARTEMIS research domains			Proposed project time and budget		
Impact	safety critical systems	virtual world	Big Data	System of Systems	Cloud Service	Internet of things	Autonomous, adaptive, dynamic control	Multicore	Reference design & architecture	Seamless connectivity and interoperability	System design methods and tools	from year	to year	Estimated Budget
Increased robustness, and safety Reduction of the possibility of wrong measurements and avoidance of creation of bad data.	x	x					x		x		x	2014	2017	60M€
Safe and Secure Architectures/Middleware Operating Systems for Systems of Systems / Cyber-Physical Systems; Impact of Security Issues on Safety	x	x		x						x		2014	2020	510 M€
Improve systems security and traceability of data, as in the health care and care processes						x			x	x	x	2017	2020	
In combination with other measurement values the overall operating strategy can be influenced significantly. This helps to reduce operating costs significantly and to protect our environment.	x			x			x		x	x		2017	2020	60 M€
Reduction of the possibility of wrong measurements and avoidance of creation of bad data.	x			x	x		x		x	x		2014	2017	60 M€
Reference Architectures, Design Patterns, Hardware-Software Co-Design, Virtualization Reference Architectures for Systems of Systems /Cyber-Physical Systems	x							x	x		x	2014	2017	280 Mio Euro (*)

Research challenge		Technical objectives
3.2	Architecture Principles for Seamless Connectivity and Interaction	▪ Architectures and Middleware supporting Multiple levels of safety, deterministic behavior, fault isolation/containment, reconfiguration (static, dynamic, incl. multi process or multi core, redundancy management), diagnosis (Diagnostic Services, Detection of transient and permanent faults, avoidance of probe effects, maintenance-oriented diagnosis, Active diagnosis (i.e. for controlling fault recovery mechanisms)), ▪ New communication concepts wrt. reconfigurability, robustness, security; resilient computing (Robustness services, design for robustness); ▪ Resource Management and virtualisation (WCET prediction, exploration of execution environments and algorithms that reliably predict the WCET of time-critical tasks; predictable and efficient shared resource management mechanisms and arbitration rules); ▪ Methodology and tools, chip level virtualisation mechanisms allowing reliable support of heterogeneous operating systems on the same processor; ▪ chip level static configuration and dynamic reconfiguration capabilities, with associated firmware and operating system support; support for multi-core architectures, embedded multi-process architecture platforms for multi sensor applications, ▪ Component product line, ▪ Reducing energy consumption (HW+SW), HW+SW integration and validation
3.3	Architectural framework for combined safety-related and security-related domains	▪ Design of multi-functional complex integrated systems ▪ Central computing platforms for safety/ cloud-based architectures ▪ Methods and tools to improve quality offered by cloud-based heterogeneous service infrastructures. ▪ Enable solutions for safety and security threats to society, ▪ Prevent malicious attackers and intruders to large systems such as energy grids (compare threats in smart grid activities), ▪ Avoid improbable corner cases, or environmental variations can exploit weaknesses in the interactions that lead to system failure
3.4	Architectures and frameworks new use cases	New cases : novel frameworks of design principles and reference architectures allowing and supporting the quick and efficient realization
4 System Design and Virtual engineering		
4.1	Virtual Engineering for Systems of Systems	▪ Component based design (Design for non-functional requirements (safety, but also others: security, power, …), V&V, contract based engineering and reasoning, component based certification, Systems interfaces management); ▪ Product Line Engineering (Consistent integration of methods and tools to support product line maintenance and evolution – with focus on: Multi-critical architecture design, Multi-objective optimization, pre-certification and qualification, product-line evolvement over time); ▪ Large Scale Deployment of Model based design (Interoperability of heterogeneous system models, Modelling and control of multi-systems / SoS / distributed systems, HMI design, Design Patterns for component based design); ▪ Simulation platform for Validation and Verification; ▪ New methodologies for agile HMI (Human Machine Interaction) prototyping (Human factor analysis of HMI, methodologies for agile prototyping, physical simulation environments, cognitive task analysis, model based analysis, human hazard and risk assessment, models of human behaviour (adapted to different target groups), usable security mechanisms, usability analysis, rules and metrics for user acceptance, adaptable HMI, long term effects analysis, analysis of consequences of non-conforming behaviour); ▪ Large scale cross domain tool interoperability and standards; ▪ Legacy integration (Data migration, long term data retention, reverse engineering); ▪ Verification of synthesis tools (including automatic code generation and test generation); ▪ Methods and tools for verifying business constraints
4.2	'Low-level' semantics:	▪ methodological, mathematical and software tools taking into account the 'low-level' semantics to model and validate low-level software aspects (buffers, interrupts, memory addressing …) and the SW/HW dependencies. ▪ New automated proof techniques. ▪ Formalism for 'low level' property specification and abstraction. ▪ Derive new analysis and debug tools.
4.3	Re-use of: low-level software elements; of whole sub-systems; of design and validation tasks.	▪ New standards for software-software and hardware-software interfaces. ▪ New standards to formalize the "physical" properties of software (power consumption, bus bandwidth, memory use…) New standards to formalize hardware-software integration (meta-models for HW-SW systems needed). ▪ Factor out the design and validation tasks for families of similar low-level components (e.g. drivers for similar hardware) and families of different implementations (e.g. targeted to different OSes) of the same component ▪ Factor out the design and validation tasks for families of similar low-level components (e.g. drivers for similar hardware) and families of different implementations (e.g. targeted to different OSes) of the same component. ▪ Develop meta model and generic simulation model for operating system including standardized interfaces between the OS and Middleware on one side and OS and Application on the other side. Synthesis of functional HW/SW Interface (HW side and SW side) from a single description. ▪ Synthesis of functional HW/SW Interface (HW side and SW side) from a single description. ▪ Making formal methods for HW/SW Verification usable, i.e. develop and train methods as well as fully automate verification. ▪ Seamless reuse of models and integration of results obtained by different tools.

	Contribution to ARTEMIS technology opportunities research domains								Contribution to ARTEMIS research domains			Proposed project time and budget		
Impact	safety critical systems	virtual world	Big Data	System of Systems	Cloud Service	Internet of things	Autonomous, adaptive, dynamic control	Multicore	Reference design & architecture	Seamless connectivity and interoperability	System design methods and tools	from year	to year	Estimated Budget
Architectures, Middleware, Operating Systems, Safety, Security, Resilience, Robustness, Multi-Core Architectures, Middleware and Operating Systems for safe, secure, robust, reconfigurable, dynamic Systems of Systems / Cyber Physical Systems Composability, scalability, virtualization, predictability of Architectures/Components/Systems modular reference architecture, modular architecture, reconfiguration, interoperability												2014 2016	2016 2020	300M€ 250M€
	x	x	x	x	x				x	x	x	2015	2017	60M€
	X	x	x	x	x	x	x	x	x	X	X	2017	2020	100 M€
Virtual Engineering for complex, distributed, multi-critical, multi-manufacturer Systems of Systems / Cyber-Physical Systems, incorporating multiple domains and the whole supplier chain Process integration across supplier chain, platform and variant management; virtual concept finding and feature planning interacting models(across several levels), virtual system integration, reference technology platform, consistent tool-chains, process development/automation multi-domain engineering, life-cycle management: beyond	x	x		x	x	x	x		x	x	x	2014 2017	2016 2020	700 M€
Reduce the cost of system design, Achieve cross-sector reusability, increase Quality of services.												2015	2017	200 M€
New Standards for global cost reduction – Models and Meta models – OSes												2014 2017 2018	2016 2019 2020	600 M€

Research challenge		Technical objectives
4.4	Complexity management of the embedded systems interactions	▪ Model-based design methodologies to cover developments in cyber-physical systems ▪ Increase adaptability, autonomy, efficiency, dependability, safety, and security. ▪ Intelligent interfaces and artefacts with cognitive and bio inspired capabilities ▪ Augmented reality ▪ Adaptive ' morphing' embedded systems
4.5	Complex systems and environments	▪ Design methodologies must support heterogeneous systems with a unified design flow (per application domain), ▪ Modeling and Design approaches to cope with incomplete specifications / unknown environments, ensuring that the system still behaves correctly. ▪ Approach to design systems based on unreliable components.
4.6	Life Cycle Management:	▪ Cycle Management is important and can not be reduced to the design and development process. ▪ Develop the life cycle of the Product, the system ageing, and configuration management problematics
5 Seamless Interaction (Networking and Connectivity)		
5.1	Seamless Interaction	Seamless data acquisition, seamless authentication, seamless user interaction; Methods and tools for ensuring that middleware services support extra-functional requirements and notably safety, end-to-end latencies by middleware services, diagnosability, data integrity, authentication,…; Integration of services, developing / supporting / influencing de-facto standards, systems of systems / cross-domain, architecture and tools for distributed systems, security, multiple criticality; Sensors and Sensor Networks (Access layers (wireless, optical, etc ...), Energy harvesting in the sensor network); Changing topology, network management, service discovery, Dependability, security, Semantic services
5.2	Real-time Sensing & Networking in Challenging Environments	▪ Equipping disposable sensors with wireless communication capabilities to enable new measurement possibilities and support improved process monitoring and control, as measurements from the process core available in real time: ▪ Non-disposable wireless sensors requiring long-term energy supply to measure and report relevant information. ▪ Envisioned technological challenges includes: extremely low powered electronics, robust, rugged encapsulation, autonomous energy management, wireless communication in harsh environment.
5.3	Increasing openness and interconnection (e.g., traffic control) while retaining security and safety properties (link to ASP3)	▪ Provide stability, safety, security in dynamically evolving system-of-systems ▪ Enable Testing, and V&V in reasonable time and cost ▪ Support interconnection of deterministic systems to highly non-deterministic and dynamically changing environments ▪ Detect and tolerate unreliable constituting subsystems in an open SoS (e.g., malicious subsystems) ▪ User centric traffic management on key European road links strategic, tactical and operational level ▪ Optimal balance between collective measure and individualized services ▪ Runtime configuration based on infrastructure (energy, efficiency, safety, ..) ▪ Automation to mitigate and avoid accident (minimize human errors) , optimize driving (improved energy efficiency and reduced emissions) ▪ Digital and physical security convergence for the integration of real and virtual systems through sensors, … ▪ Develop cyber- security mechanisms for the detection of abnormal events (behavior analysis, analysis of heterogeneous information from multiple sources), ▪ Observation of attack patterns and creation of counter measures stopping attack proliferation. ▪ Context based security in order to enable (big) data flows and scalable trusted identities federation.

	Contribution to ARTEMIS technology opportunities research domains								Contribution to ARTEMIS research domains			Proposed project time and budget		
Impact	safety critical systems	virtual world	Big Data	System of Systems	Cloud Service	Internet of things	Autonomous, adaptive, dynamic control	Multicore	Reference design & architecture	Seamless connectivity and interoperability	System design methods and tools	from year	to year	Estimated Budget
	x	x	x	x	x	x	x	x			x	2017	2020	50 M€
Contributes to managing complexity increase and reducing design cost Tool support for the extension of modeling framework to support heterogeneous and dynamic systems	x	x	x	x	x	x	x	x			x	2015	2018	250 M€
												2014	2016	
Middleware, Operating Systems, Interoperability, Standards, Sensor Networks, Dependability, Semantic Services Seamless Interaction of Components to dynamically form Systems of Systems / Cyber-Physical Systems for known configurations, not proprietary systems, hard-wired applications dynamic heterogeneous systems, role adaptive, anticipating:												2014 2017	2016 2020	700 M€
New sensors operating in harsh environments for process industries, manufacturing and medical applications.	x	x		x	x		x		x	x		2015	2016	100 M€
Reduce fatalities and increase environmental consciousness in mobility	x	x	x						x	x	x	2016	2019	120 M€

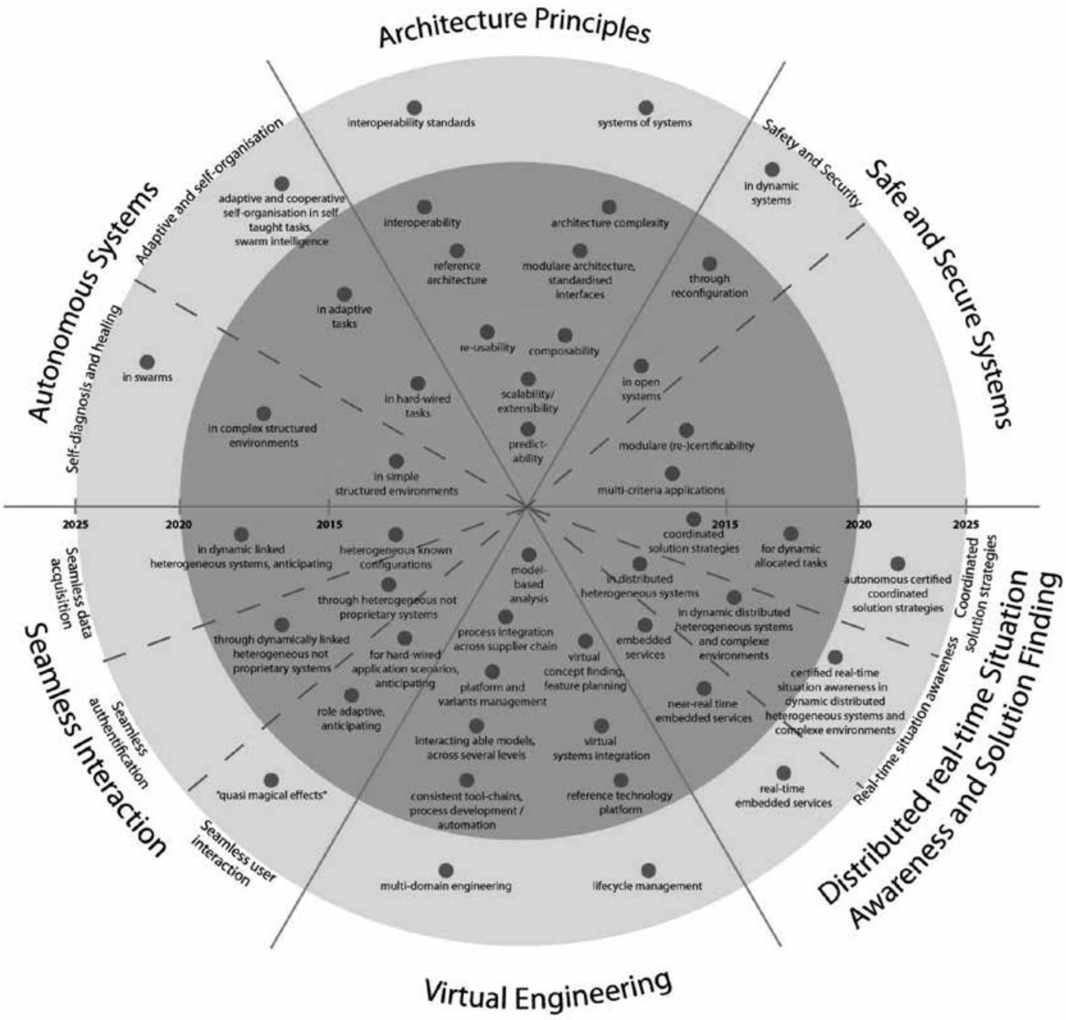
Research challenge		Technical objectives
5.4	HMI/WMI : Reliably construct an accurate real-time image inside an embedded system and of its environment.	▪ Develop new approaches, solutions, technologies using networked environment to enhance the human-in the Loop' approach, and propose new paradigms for improved cooperation between humans and computing units. ▪ Exploit emerging computing infrastructures such as cloud computing, or others), wireless networking, with the goal to provide seamless interactions (voice, gestural, retina- integrated displays, and brain-machine interfaces, etc ,). Multimodal integration is required to reduce user workload. Cross sectoral applications: home, automotive, education, factories, etc..
6 Modeling and simulation techniques for efficient Design methods and tools		
6.1	Integration of environment modeling and simulation into the HW and SW design flow	▪ Obtain integration of environmental modeling tools in to the HW and SW design flow and their suite of tools like Spice, VHDL, UML etc., ▪ Enable environmental modeling supported HW-SW co-design, Provide integrated design environments enabling efficient design and verification methodologies ▪ Real-time HW/SW co-simulation
6.2	Efficient modeling and simulation of environmental effects on embedded systems in large complex systems,	▪ Efficient and accurate tools for modeling and simulation of environmental effects like electromagnetics, temperature, vibration, stress etc.,
6.3	Practical architectural exploration and development tools based on common meta-models	▪ Automatic tuning of architectural parameters for targeted application workloads (e.g. cache size, bus-width…),., ▪ Design space exploration with multiple objective functions (e.g. power performance trade-off curve exploration), including sensitivity analysis, ▪ Means to guarantee consistency of functional and non-functional properties across models at different levels (requirements, specifications, designs), ▪ Support for solution emergence from functional need: design rationalisation, auto-organisation, factorising, architectural patterns, design rules, know-how to be capitalised.
6.4	Implement complete Model-Based Design tool-chain (software "factories")	▪ further develop tools around model-based design approach (MBD) from a common basis low cost, ▪ develop model transformation facilities such as the MDA approach ▪ Enable verification activities previously performed at code-level to be performed at Model-level, Integrate MBD tools into complete "Software Factories"
6.5	Provide tool facilities to detect problems earlier in the development lifecycle	▪ Improve Software Quality by developing: Tool-aided process and product control ▪ Simulation, model assembling and formal model checking & verification facilities. ▪ Multi-disciplinary modeling tools (Functional modeling, , ..) ▪ Quality of Service, Interfaces modeling, Operational modeling…), ▪ System/ software integrated development environments to avoid design flow gaps
6.6	Provide capabilities to integrate easily specific process, meta-model, profile or architecture in development tools	Enhance Tools adaptability : ▪ Develop multi-platform transformation, ▪ develop heterogeneous integration & validation infrastructure, ▪ Develop certification, safety, and RTE profile implementation, ▪ develop certification, safety, and RTE profile implementation, develop meta-model plug-in facilities in development and integrated validation &verification tools
6.7	Meta-model standardization	▪ Common meta-model standardization among tools, based on user inputs ensuring standardised repositories for multi-organisation/tools access:, ▪ tools to support Product Line Policy (functional and technical, architecture + middleware…), ▪ component-oriented designs, ▪ common meta-model standardization among tools,

	Contribution to ARTEMIS technology opportunities research domains								Contribution to ARTEMIS research domains			Proposed project time and budget		
Impact	safety critical systems	virtual world	Big Data	System of Systems	Cloud Service	Internet of things	Autonomous, adaptive, dynamic control	Multicore	Reference design & architecture	Seamless connectivity and interoperability	System design methods and tools	from year	to year	Estimated Budget
Attractive, intuitive and enhanced accessibility for users- e.g drivers assistance		x							x	x	x	2016	2018	100 M€
Will shorten product development cycle., Will improve product quality, safety, security and dependability., results in commercial tools		x						x			x	2014	2017	
Will shorten product development cycle. Will improve product quality, safety, security and dependability. , Will provide directions for sustainable competence development in the field --▪ Accurate full 3D modeling and simulation for most major problems are possible to reasonable computational cost.		x					x		x			2014	2017	
Reduce the cost of the system design by 50%., Achieve 50% reduction in development cycles, Manage a complexity increase of 100% with 20% effort reduction --▪ Modelling techniques, tool prototypes capable of (partially) automatic design space exploration, and providing a high level of support for rapid and correct-by-construction design instantiation								x			x	2015	2018	
Reduce by 50% the effort and time required for re-validation and re-certification after change	x	x	x	x	x	x	x	x			x	2014	2017	
Reduce by 50% the effort and time required for re-validation and re-certification after change	x	x		x							x	2014	2017	50 M€
Achieve cross-sectoral reusability of designs	x	x					x				x	2015	2017	
Interoperability between Tools, Achieve cross-sectoral reusability, Horizontal contribution to all Design Methods & Tools research priorities	x	x	x	x	x	x	x	x			x	2015	2018	

Research challenge		Technical objectives
6.8	Development cycle navigation	Ease navigation on the whole development cycle by: - ensuring traceability/navigation between all development artefacts, - supporting workflow of information throughout organisation & development cycle.
6.9	Cooperation in the entire development process (link to AIPP1)	▪ Enable efficient collaboration among all stake holders across the entire application lifecycle ▪ Reduce the development time and cost by employing frontloading (e.g., building direct bridges in the V-model) ▪ Enable efficient variants management by increasing traceability, and enabling modular certification (Product Line Engineering PLE) ▪ Reduce software development lifetime costs (maintenance and evolution, adaptation of existing architecture, processes and tools)
7 Computing Architecture and Energy Management		
7.1	strengthened use of multi/many core systems, System-on-a-Chip (SoC) and Network-on-a-Chip (NoC) technology	Better multi-core integration – using full potential of multi-core systems and integrating new functionalities, new services
7.2	innovative collaboration platforms that are based on loosely coupled systems with standardized flexible interfaces	
7.3	enabling cost-effective, portable and efficient Many core/ multi-core programming	▪ Scaling to high core counts. Use of many core processors for integrated mixed criticality systems Certification aspects of many core processors systems (reliability, structured design, , ..) ▪ Non-intrusive diagnostic ability of many core systems ▪ Heterogeneous multicore systems (many cores but different functionalities and capabilities) cores to be built around a few generic CPU cores
7.4	Efficient Energy Management	Including degraded mode; energy efficient OS, low power compilers, design of energy constraint architectures, power modeling and estimation, management of energy sources (battery, harvesting, . . .), distributed energy management (wireless connectivity), user centric power management, power aware algorithm design, any-time algorithms, improvements in battery management
7.5	Observability and debugging	Tool facilities to observe and analyse the behaviour of the low-level system components at run-time
7.6	Joint Hw-Sw diagnostics	Develop methods for jointly debugging of HW and SW with focus on massively parallelism, real time analysis capability (as one representative of physical feature debugging)

	Contribution to ARTEMIS technology opportunities research domains								Contribution to ARTEMIS research domains			Proposed project time and budget		
Impact	safety critical systems	virtual world	Big Data	System of Systems	Cloud Service	Internet of things	Autonomous, adaptive, dynamic control	Multicore	Reference design & architecture	Seamless connectivity and interoperability	System design methods and tools	from year	to year	Estimated Budget
Mastering development complexity	x	x	x	x	x	x	x	x			x	2015	2018	
Enable the development of systems which are several times more complex as current systems needed to solve societal problems without exponentially increasing development costs	x	x	x	x	x	x	x	x			x	2017	2020	60 M€
	x							x	x	x	x	2016	2019	100 M€
	x	x	x	x	x	x	x	x		x				
Performance optimization Cost reduction. Reduce development cycle. Quick to market.	x							x	x		x	2015	2018	50 M€
Energy Management for distributed Systems of Systems / Cyber-Physical System	x	x	x	x	x	x	x	x	x			2014	2020	280M€
Reduction of the cost of system design Reduction of the effort for re-validation or re-certification.														
Reduction of effort for Reuse of "full IP" incl. low-level SW														

8 Annex 2: SafeTrans Research Areas Roadmap[21]



[21] Courtesy from SafeTrans