Presenting
ARTEMIS-IA
Strategic Research Agenda 2016

Brussels November 15th 2016

Ad ten Berg
ARTEMIS-IA
The Pathway to the Digital Transformation
An Opportunity for Europe
Acknowledgement

• ARTEMIS-IA gratefully acknowledges the contributions made by the following persons of the WG SRA Group of experts producing this SRA 2016:

  » Ronald Begeer
  » Ad ten Berg
  » Albert Cohen
  » Armando Colombo
  » Gerard Cristau
  » Werner Damm
  » Jerker Delsing
  » Marc Duranton
  » Christian EL Salloum
  » Sebastian Engell
  » Laila Gide
  » Radu Grosu
  » Matthijs Leeuw
  » Jürgen Niehaus
  » Stefano Pasquariello
  » Michael Paulweber
  » Erwin Schoitsch
  » Daniel Watzenig
The SRA content

1. Introduction
2. The new rationale: digital transformation
3. The ARTEMIS Vision, Ambition, and Main Objectives
4. The Digital Transformation in economic and societal challenges

5. ARTEMIS Innovation Strategy and Research Priorities
   – 5.1 ARTEMIS Priority Targets
   – 5.2 Innovation Strategy
   – 5.3 Strategy Implementation
       – 5.3.1 Cross domain Approach
       – 5.3.2 Strategic Research Challenges

6. Innovation environment context – Make it Happen
The digital evolution, or digitisation, is a silent revolution that is transforming our way of living and of doing business.

“Europe Future is Digital”*

* an excerpt from Commissioner Oettinger speech at the Hannover Messe 2015.
The SRA 2016: a new rationale
Digital Transformation

The world is changing fast

The example of the evolution of photography

Cyber-Physical Systems are key driver in the Digital Transformation

The main trends that will define the new era of Cyber-Physical Systems are:

The integration of functions across application contexts on large and open platforms, and

The combination with the Internet, its information and data, and its computing resources.
The post-Moore's law semiconductor technologies open unique opportunities for the industry to embed more software capabilities in a growing number of devices, sensors and actuators, themselves embedded in a variety of smart products/systems that interacts with the physical world.

Most industrial sectors benefiting from affordable hardware components should not miss this opportunity for software-enhanced applications and the potential of the Internet Economy to deploy new smarter products and new services enabling economical growth along the whole value chain and products life cycle.

Companies and ecosystems providing consistent and fast answers to these challenges are dominating the markets.
The Digital Transformation Drivers

- **Leadership of vertically integrated companies**
  - GAFA and others tend to extend their range from smart products to devices and even from silicon design to retail or Internet shops, while Samsung, Apple and IBM are moving into services.

- **The “Always Connected Society”**
  - The virtualisation of communities has changed our society and the way information and knowledge are exchanged, made available or shared.

- **The Platform concept and new hyper-scalability business models**
  - Platform concept is cost efficient, provides new innovative products & services and businesses.

- **Data value**
  - Data deluge generated by the increasingly connected smart ‘Things’ and exchanged in an open-ended relationship – transformed into information.

- **Security**
  - Security considerations are essential as CPS are open and used in a networked environment.

- **The software value**
  - A stronger software ecosystem is needed to nurture sustainable, interoperable CPS software development.

- **Vulnerability, trust and privacy**
  - By reaching the right level of safety and security while protecting the user’s privacy, CPS contribute in providing benefit to society in various application areas.
ARTEMIS subscribes to the ‘Digital Single Market for Europe’ by providing strong technological capability over the total value chain.

Therefore ARTEMIS main objectives are to:

- Consolidate the **pathway of the digital revolution**
- Enable a more agile and shorter development cycle through the adoption of **design by composition and correct-by construction principles**.
- **Overcome fragmentation** in the European supply base for the components and tools of design and engineering.
- **Remove barriers between application contexts** to yield multi-domain, reusable components and systems.
- Extend the use of **digital platforms** to build the eco-systems needed for accelerating the innovation and the creation of new business models.
ARTEMIS Priority Targets

With the purpose of having greater impact and quick-to-markets results and to guide the R&D programmes the following priority targets are selected:

- **product-family roll-out governed by business needs** (rather than engineering limitations)
- **faster to market**: reduce the development cycle, and development costs by: *Shorten the time to market and Mastering the complexity*
- **Increased efficiency**: easy adoption by the users and lowering the threshold of product introduction in face of rapidly changing market needs *better pervasive/ adoption*
- **Improved sustainability**: by enhancing product and system ease of use, adopting multi-view system design (from *conception to operation and services*) as well as a reuse policy.
Innovation strategy: The concept

There is a change from static networked Cyber-Physical Systems to Systems-of-Systems and Cyber-Physical Systems technology should no longer be considered in isolated application contexts

- ARTEMIS innovation strategy developed in the previous SRA is two-pronged:
  - one is to ‘Build on the leading positions where Europe is strong’
  - And the other to ‘Create new opportunities’ for Europe to be positioned at the forefront of new or emerging markets with high potential growth rates

The new strategy is more user-centric
- To take into account the user’s benefit and experience, over the whole value chain
- By building better and more efficient technological solutions
Embedded Intelligence needs
Global integration of communication, computation and reaction

- Smart products & sensors
- Cyber-Physical Systems
- Cloud / HPC
- AI, Cognitive computing / Data Analytics
- Networks e.g. Internet
- Big Data
- Fog computing
- Edge computing
- Stream analytics...
In order to break domain barriers and boost innovation, research activities should continue to foster the cross-domain approach and seek greater synergies to develop common building blocks.
Strategy implementation: The Cross-domain approach

To share communalities and synergies to overcome the fragmentation and create critical mass for the investments and to embrace the technology challenges.
Building such predictable CPS components is needed to maximise the reuse, accelerate the development cycle and, consequently, time to market.

New core elements and development and validation technologies are needed for the development of smart, connected and highly automated smart products.
Research Funding Programmes

To ‘Make it Happen’ ARTEMIS Industry Association’s ambition is to inspire a wide range of the research policymakers in Europe and their work programmes, mainly:

- the **EC Research Framework Programmes** (such as H2020 2014-2020),
- the **ECSEL JU work programmes**
- the multi-national **Eureka clusters ITEA3 and PENTA** programmes,
- **National and Regional** research programmes

*Efficient use of Public available funding in the Cyber-Physical Systems arena will help overcome the resource deficit for R&D and to foster innovation & collaboration in Europe,*
Standardisation is important for exploiting the results of research projects

- New topics, like IoT, Cloud Computing, Automated Vehicles (Driving), Autonomous Systems, Robotics etc. have taken up standardisation as a mandatory need in their context.
- Without stringent standardisation it will not be possible to make things happen such as the interoperability of components and systems, and of tools and data, and communication in a connected world of “things”, complex systems-of-systems, like IoT or “connected autonomous vehicles”,
- Cyber-Physical Systems-of-Systems (CPSoS) require multi-concern assurance for qualification or certification. The dependability properties have to be assured via co-analysis and developed via co-engineering methodologies, which again requires research results to be brought to standards or integrated into standards

ARTEMIS require that RD&I projects communicate with relevant ARTEMIS-IA standardisation initiatives concerning their standardisation needs and opportunities, including those that may emerge during project execution.
The new global Digital Economy needs and its high growth rate faces the “largest human capital shortage in the world”

**Effective education and training is crucial** to maintain competitive leadership as a pre-condition for “sustainable innovation ecosystem”.

The Strategic Research Agenda recommends:

- Make “education and training” output part of projects’ deliverables
- Foster life-long continuous learning to create a highly skilled, multi-disciplinary workforce, and maintain and upgrade the existing skills designed to overcome the gap between theory and practice of (industrial) application;
- Establish new types of people mobility programmes with an industrial focus,
- Support high-tech spin-offs and start-up companies by facilitating non-technical training in entrepreneurship, finance and business practice, etc…;
- Influence pan-European policies to achieve long-term effects in Embedded Systems education and training,
- Provide adequate university and applied university curricula in Embedded Intelligent Systems domains,
- Foster the cooperation with the EIT KIC Digital in this topic.
ARTEMIS SRA focus area is cross-cutting to all as the embedded software development, software-based services and the Cyber-Physical Systems technologies, constitutes an indispensable enabler.
• ARTEMIS has proven to be a unique ‘initiative’ that in just a few years succeeded in establishing the largest R&D&I projects ever in the area of Embedded Intelligent Systems.

• The renewed vision and strategy aims to pursue this strategy in order to accomplish the ARTEMIS ambition and position it as a world-class initiative in the area of Cyber-Physical Systems.

• The emerging Digital evolution relies heavily on Embedded Intelligent Systems technologies in domains where it is paramount that Europe takes a leadership role. Our renewed Vision and Strategy aims to follow this path in order to accomplish the ARTEMIS ambition and become a world-class initiative in the Embedded Intelligence and Cyber-Physical Systems.

• We need increased investments to support our Research Agenda and to sustain our proposition of an ‘Innovation Environment’ allowing high value creation in the new generations of smart products and services.

• Giving the right economic visibility of Embedded Intelligence is of utmost importance to the European Industry for the Digital Future of Europe.
Thank you
Some insight into ARTEMIS-IA SRA Matrix Approach
• is up-dated to cope with the Digital Transformation
Overview of the Strategic Research Challenges

Computing /Multicore
Overview of the Strategic Research Challenges

Computing /Multicore

More than Moore – More Opportunities!

Transistors bought per $, m

Who will fuel the race for smarter devices?

Intel
Overview of the Strategic Research Challenges

Computing / Multicore

More than Moore – More Opportunities!

Transistors bought per $, m

.performance

Performance/Cost (log)

CMOS Technology

New Technology

Our Challenge

[2022, 2004]

[80s, 90s, 00s, 10s, 20s, 30s, 40s]

[Hill & Kozyrakis’12]
Overview of the Strategic Research Challenges

Computing / multicore

Software Crisis

(Fog computing
Edge computing
Stream analytics
Fast data by real-time
micro-servers
and even Nano-servers (concentrator, fusion of several sensors) in different layers (Onionskin))

NEW SERVICES

TRANSFORMING DATA INTO INFORMATION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

CLOUDP/IT

(CYBER) PHYSICAL SYSTEMS

SMART SENSORS

INTERNET OF THINGS

COGNITIVE COMPUTING / DATA ANALYSIS

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION

GLOBAL INTEGRATION OF COMMUNICATION, COMPUTATION AND REACTION
Software Crisis

The major cause of the software crisis is that the machines have become several orders of magnitude more powerful! To put it quite bluntly: as long as there were no machines, programming was no problem at all; when we had a few weak computers, programming became a mild problem, and now that we have gigantic computers, programming has become an equally gigantic problem.
The major cause of the software crisis is that the machines have become several orders of magnitude more powerful!

To put it quite bluntly: as long as there were no machines, programming was no problem at all; when we had a few weak computers, programming became a mild problem, and now that we have gigantic computers, programming has become an equally gigantic problem (1).

(1) Edsger Dijkstra, The Humble Programmer [Dijkstra 72],

Correctness challenge
Performance challenge
Data challenge
Holistic and interoperability challenge
Software Crisis – Opportunities

Focus on high-productivity, high value software

- Higher level, reactive programming languages
- Correct-by-construction approaches
- Ubiquitous parallelism
- Ubiquitous distribution: elasticity, heterogeneity (edge/fog)
- ‘Non-functional programming’: time, resources, faults...

- **Invest in tools and reference platforms:**
  - larger businesses, virtually vertical organizations, and funding agencies need to understand the urge and value in supporting a sound ecosystem of tools and platforms

- **Develop new computing modalities in HW and SW:**
  - dynamicty, adaption, learning and reasoning, accuracy, trust, predictability, agile development… without throwing validation, verification, certification, quality away

- And… engage into standards committees
Overview of the Strategic Research Challenges

CPS Architectures (System design, dependable technology bricks)
Complexity as one of the major drivers

- Increasing openness and interconnection while retaining security and safety properties (e.g., connected car)
- Enabling certification in highly complex and non-deterministic environments
- Heterogeneous communication infrastructures and requirements
- On-line evolution of large real-time systems
- Cooperation in the entire product life-cycle
- ...

- It would be futile to tackle the complexity challenge with a pure bottom-up approach!
System and System-of-Systems (SoS) Level

- Architectures and platforms to provide **holistic solutions** to satisfy the (sometimes contradicting) requirements for **fault tolerance**, **real-time emergent behavior**, **security** and **openness**
- **Wireless** techniques and protocols for **real-time control**
- Enable **interaction** of **hard real-time CPS** with services in the **Cloud**
- Enable **Self-Maintenance**
- Enable **independent validation and certification** of individual CPS that are part of a larger System-of-Systems
- ...
Overview of the Strategic Research Challenges

CPS Architectures (System design, dependable technology bricks)

Reference Architecture(s): pursue the SRA 2006 road-map, and address new issues

- **Separation of concerns**
  - Generic and common topics are handled by the architecture/platform
  - Engineers to concentrate on solving their truly application-related problem

- **Provision of common services** required by most of the applications
  - Security and access rights management
  - Communication and storage
  - Registration and discovery
  - Monitoring and maintenance
  - Deployment (e.g., update-over-the-air)

- **Support efficient reuse and composability**
  - Enable product creation by composing pre-validated building blocks from a library
  - Specific challenges: real-time behavior, fault tolerance and security

- **Dependability by design**
  - Enforce architectural principles that lead to dependable products and fault tolerance

- **Establish a (de-facto) standard and provide open interfaces**
Overview of the Strategic Research Challenges

CPS Architectures (System design, dependable technology bricks)

• Multi/many-core systems / System-on-a-chip/ Network-on-a-chip
• Multi-core and SoC architectures have been extremely successful in the consumer, desktop and high-performance market
• For safety-critical, real-time CPS important challenges have to be solved:
  – Enable devices with low energy footprints
  – Support guaranteed real-time behavior in a multi-core context
  – Enable certification of highly complex and performant multi-core SoCs
  – ...

Closely related topic in SRA: Cyber-Physical Systems of Systems

- **Key features**
  - Size and distribution
  - Distributed Control and Management
  - (Partial) autonomy of the constituent systems
  - Continuous evolution and dynamic reconfiguration
  - Emergent Behaviours

- **Research Challenges**
  - Decision structures and system architectures
  - Self-organisation, structure formation, and emerging behaviour in technical systems of systems
  - Real-time monitoring, exception handling, fault detection and mitigation of faults and degradation
  - Adaptation and integration of new components
  - Humans in the loop and collaborative decision making
  - Trust in large distributed systems.
Overview of the Strategic Research Challenges

Methods and Tools for Virtual Engineering
As always....

• Embedded Systems and Cyber-Physical Systems
  – are becoming more and more complex
    • New functionalities

Therefore we need more/better/more cost-efficient Design Methods and Tools
Overview of the Strategic Research Challenges

Methods and Tools for Virtual Engineering

But with CPS, it get’s worse ....

• As CPS are Networked Systems
  – Security (resp. Security impact on Safety)
  – Cooperation, Coordination
    • of systems from different manufacturers
  – Handling uncertainty
    • Wrt. trustworthyness of ‘external information’

• Increasing Level of Automation (up to Autonomy)
  – Explosive increase in possible system ‘behaviour’
    • The amount of testing needed to be even only ‘reasonable sure’ of system’s correctness is prohibitive
  – Complex decision making
    • Self Learning?
      – How to analyze such systems at all?
    • Ethics?
  – Handling uncertainty
    • Observation of environment is often incomplete
Humans are integral part of the overall system
- Human Machine Interaction
- Human Machine Cooperation
- Machine Adaptation to Human needs

Long lifetime of systems
- Need to cope with
  - New situations
  - new cooperations partners (with new capabilities)
  - new requirements
- which were not even envisioned during design time...
- Also the other way around: Need to cope with legacy systems
Another set of challenges: Changes in development processes
• Multi-disciplinary and Physically and organizationally distributed design teams
  – ... spanning more than one company
• Changes in OEM – Supplier relationships: From supplier chains to supplier nets and OEM not necessarily the (sole) integrator any more

Yet another set of Challenges: Where worlds collide...
• Need to adapt/enrich Design Methodology and have tool support for Consumer Electronics and Assistance Systems
  – Part of the same system, but different lifecycles / lifetimes
    • Feature interaction? Impact on Safety (and Security)?
    • Different possibilities for Upgrades/Changes/Evolutions
      – Apps for Assistance Systems?
• Embedded Systems and Internet/Cloud
  – Reliability / Trustworthyness (of information)
  – Quality of Service (latency, accuracy,...)
  – Security (who gets in and who stays out...)
Examples of High level topics

• Model based design, including
  – multi-domain, multi-dimensional, and multi-objective specification and modelling
    • across application domains
    • across engineering domains
    • across supply chain
  – support for heterogeneous models
  – support for re-use of models
  – models for certification
  – support for an integrated safety and security development process

• Multi-Objective Optimization
  – For heterogeneous models
  – multiple objectives from different application and engineering domains
  – across the supply chain

• V&V - Verification and validation methodology and tools
  – formal verification, simulation, testing for complex, extendable, upgradable and evolvable Cyber-Physical Systems, including on-line validation/verification
  – Support to Incremental analysis, certification and Integration of heterogeneous models
    • Model-/software-/Hardware/system-in-the-loop simulation and testing
  – ability to handle new functionalities
    • uncertainty stemming from incomplete environment observations and different levels of trust placed in external information
    • The dynamic behaviour of CPS to establish properties like Safety, Security
    • Real-time behaviour and quality of service

• Monitoring and Diagnosis in the field
  – Failure detection, Adaptation, fail-safe degradation, Self-Healing, Life-long learning
Methods and Tools for Virtual Engineering

Additional High level topics

• Human Aspects
  – Human Machine Interaction
  – Human Machine Cooperation
  – Machine Adaptation to Human needs

• Pushing Open, horizontal Standards
  – Interoperability
  – Communication, Cooperation, Coordination
  – Test- resp. V&V Szenarios

• Build Eco-System for processes, methods and tools for the cost efficient design, analysis and test of safe and secure CPS based on standards, including the whole value chain
Thank you