STRATEGIC AGENDA ON STANDARDIZATION FOR CYBER-PHYSICAL SYSTEMS

CP-SETIS
Towards Cyber-Physical Systems
Engineering Tools
Interoperability Standardisation

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A Proposal for an Update of the
ARTEMIS Strategic Agenda for Standardization

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Summary

This document is the final deliverable of the CP-SETIS project with respect to the Strategic Agenda for CPS Standardization. It includes and summarizes the first ARTEMIS-IA Strategic Agenda for Embedded Systems Standardization, and the work done in the support actions ProSE ("Promoting Standardization for Embedded Systems", FP7, contract no. 224213) and CP-SETIS (Towards Cyber-Physical Systems Engineering Tools Interoperability Standardization, grant agreement no. 645149).

ARTEMIS-IA (Industrial Association for Advanced Research and Technology for Embedded Intelligent Systems) considered Standardization from the very beginning as one of the key pillars to create a sustainable innovation ecosystem. CP-SETIS is a support-action type IA (Innovation Action) in Horizon 2020, driven by key players from the ARTEMIS Standardization community and key ARTEMIS/ECSEL projects focusing on the particular aspect of tool interoperability. As opposed to the efforts in the past, the goal is no longer to initiate, enhance or update one or the other particular standard, but to cover the whole area of tool interoperability. This cannot be done by just one interoperability standard, specification or guideline, but needs adoption and adaptation of a whole set of standards, specifications and guidelines from different areas and organizations. How this is planned to be achieved and how the approach has to deviate from the ProSE approach will be explained in this document and related deliverables of CP-SETIS.

The aspect of sustainability differs as well: if you want to address just a particular standard to be initiated or adapted, this is done in context of existing standardization organizations (international standards organizations with their national mirror groups, European or US standards organizations, industrial associations being active in special areas, etc.). They have existed for a long time and already have a sustainable structure. The IOS, as a set of standards from different organizations, needs a particular sustainable hosting structure which allows an umbrella-like mode of work, raising awareness and providing information and some basic support for users and clients beyond the lifetime of CP-SETIS and the ARTEMIS/ECSEL projects that have provided contributions and developments.

These considerations led to the concept of a "Multi-Standard", which, in principle, is not only applicable in the case of the IOS, the Interoperability Specification(s), but should be considered in other standardization areas as well, particularly if you look at areas where a large set of standards is required to fulfil a task or service specification, or when a group of related standards has been (or are) developed to fulfil the same or similar requirements in different domains. In a solution-oriented approach, these standards should be coherent and complement each other in an appropriate manner. This approach to standardization, as a CP-SETIS result, serves as new input to the Strategic Agenda for Standardization for CPS in the process-oriented part of the Standardization Agenda on how to transfer the results of research projects to standardization as a new subchapter. The concrete IOS solution concerning tool interoperability is added to the general overview section on stakeholders, standardization organizations and standards, where several other updates on organizations and standards are provided, with a perspective of new emerging, evolving areas and paradigms, which have to be considered due to the technological and encompassing methodological progress and changes that have taken place in recent years. An outlook is provided for the potential influence on tool qualification requirements in functional safety standards and future IoT standardization.
This document is the update and enhancement of the general Strategic Agenda for CPS Standardization of ARTEMIS by the results and findings of CP-SETIS and other developments in the standardization scenarios.

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INTRODUCTION

1.1 Role of Deliverables

CP-SETIS WP 5 ('Update of the ARTEMIS Strategic Agenda for CPS Standardization') submitted two deliverables. The first deliverable provides an overview of the strategic work done in the past by ARTEMIS-IA, the ARTEMIS Strategic Agenda for Standardization for Embedded Systems and the results of ProSE, a previous guideline on how to effectively get research results into standardization. It also considers how the approach of CP-SETIS follows this guideline and why there had to be certain deviations since the IOS (Interoperability Specifications) cannot be just one standard, specification or guideline. It has to include the adoption and adaptation of a full set of such standards, specifications and guidelines, of extensions and bridges detailing the relationships and interactions between existing standards/guidelines that requires a particular adaptation of the strategy.

This first document was the basis for the final document of the updated CP-SETIS Strategic Agenda for CPS Standardization, to be submitted at the end of the project, which includes the essence of the first document. It represents an updated strategic agenda for CPS (Embedded Systems) including the new aspects of Interoperability Specifications and the planned sustainable IOS Platform (Forum) structure, which were not considered in the ARTEMIS/ProSE Strategic Standardization Agenda. Of course, a general update with respect to the other standards and standardization organizations somehow relevant to CPS is provided as well to demonstrate progress and achievements in the standardization landscape since the previous issues 2007 and 2010/11.

1.2 Structure of this Document

Chapter 1 describes the role of the document. Chapter 2 describes the contents of the existing ARTEMIS Strategic Agenda for Embedded Systems (now "Cyber-physical Systems", CPS, is used) and the ProSE Agenda. In chapter 3 the CP-SETIS IOS approach is summarized and where the approach is similar or had to deviate from the ProSE model is discussed. Chapter 4, as process oriented guideline, summarizes a few ideas where other standards, particular functional safety standards and IoT standardization, could be influenced by the IOS approach with respect to tool qualification and tool chains. Chapter 5 contains references and a table of abbreviations.

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2

THE ARTEMIS STRATEGIC AGENDA

2.1 Background: History and Motivation

From the very beginning ARTEMIS (Advanced Research and Technology for Embedded Intelligent Systems) was aware of the importance of standardization, particularly from the safety-critical systems engineering perspective. This was complemented by the rising awareness of the European Commission of the importance of standardization for competitive markets; standardization is considered one of the major means to exploit research results.

The first ARTEMIS SRA (Strategic Research Agenda) had already identified standardization as one of the seven pillars to create a sustainable innovation eco-system (see Figure 1).

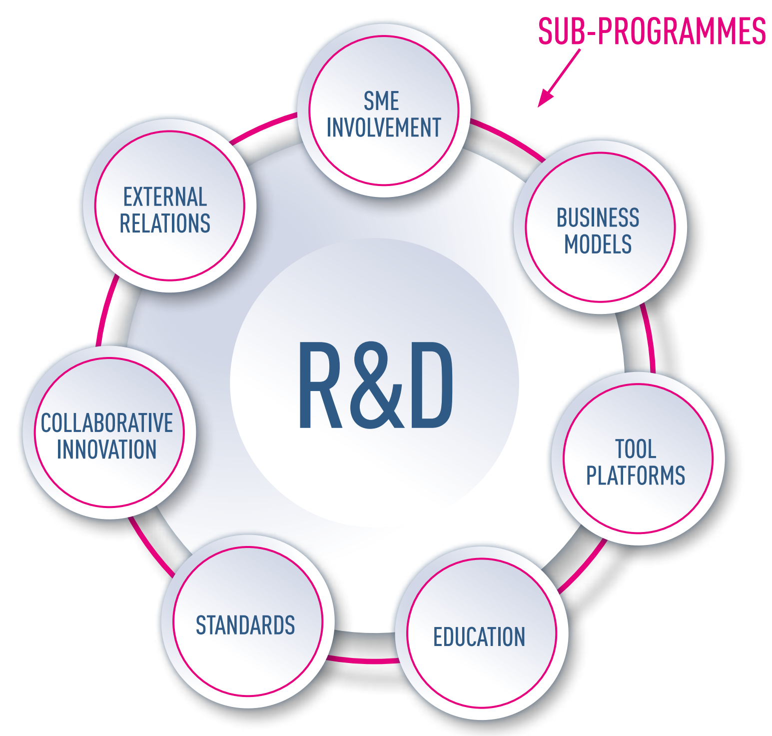

Figure 1 *Conceptual model of an ARTEMIS eco-system for (open) innovation*

One of the first working groups created was the ARTEMIS Standardization Working Group. The author of this document has been a member of the working group since 2007 and was involved in the first ARTEMIS Strategic Agenda for Standardization (in support of the general ARTEMIS SRA), for which the first (final) draft was submitted in December 2007 and printed in 2008 when standardization was included as a working item in all ARTEMIS JTI/JU projects.

To be able to invest more effort and get funding, the ProSE ("Promoting Standardization for Embedded Systems") proposal was submitted in October 2007 and started in 2008, ending in December 2010 (8 months extension). The goal of ProSE was to provide an overview of all relevant standardization groups and standards in the area of (connected) embedded systems and to provide some guidance to research projects on how to address the standardization of their research results in an effective manner, and to report on some success stories of the successful integration of research results into standardization. One of the examples was that in the new edition 2010 of IEC 61508, the basic functional safety standard of ISO and IEC, results from the FP6 projects DECOS (Time Triggered Architectures, first security consideration in a functional safety standard) and MOGENTES (Model-based Testing and Automatic Test Case Generation) became part of the methods and techniques for higher SILs (Safety Integrity Levels). The goal of ProSE was NOT to do standardization, but to pave the way. Since then, many ARTEMIS and now ECSEL projects have contributed considerably to standardization – examples are ARROWHEAD, EMC², MBAT, SafeCer in the area of safety & security co-assessment and co-engineering, contract-based design, run-time certification, multi-core systems and service interoperability for collaborative automation (in the cloud), to name just a few, and particularly CRYSTAL in the area of tool interoperability (IOS). CP-SETIS took over the task to create a process and a sustainable structure as a forum (platform) for all stakeholders for maintaining and enhancing the IOS scene, and, like ProSE, NOT standardization as such, which would be far beyond the time schedules of a two-years support action or even projects of three to four years!

2.2 Model and contents of the original ARTEMIS/ProSE Agenda

The ARTEMIS Standardization Working Group was aware of the extremely large number of relevant standards for Embedded Systems (CPS), of the wide variety in scope, nature and processes of maintaining/developing them. The Strategic Agenda recommended a prioritization, with a focus on cross-domain/sector standards (which was always one of the goals in ARTEMIS projects and is now in ECSEL CPS projects). Looking at interoperability, at this time interoperability was mainly understood as interoperability of components, devices, data and communications, but not so far of tools. Interoperation of tools is mentioned just once – in the context of model-based development and validation.

Generic cross-domain standards for dependable embedded systems are a separate subchapter, covering non-functional system properties, processes, generic methods/tools/tool chains (here interoperation and integration are mentioned just once), middleware and communication infrastructures, electronics, interfaces and domain-specific adaptation of generic standards. A rather exhaustive list of standards and standardization organizations is provided here (Open Source, IEEE SW, OASIS, OSGi, OMG, CMMI, ISO 9000, PLM, PLMIG, STEP, UML/SYSML VHDL, CORBA etc.).

The international/European standardization groups ISO, IEC, ETSI, CEN, CENELEC, OMG, IEEE, ISA, OSGi, SEI, OSCI, VITA, HSE and OSHA along with experts groups like EWICS TC7 and ERCIM are cited. Separate sections are devoted to Aeronautics & Aerospace, Automotive, Rail, Telecommunications, Health, Private Spaces/Home and Manufacturing/Construction/Infrastructure & Logistics, including international and industrial standardization organizations.

The ARTEMIS goal behind the ProSE deliverable on "Survey and Classification of existing Standardization Bodies" providing a "landscape" on existing standardization activities was (citation from ProSE):

- to overcome the fragmentation of the supply industry and research, cutting barriers between application sectors so as to 'de-verticalize' the industry, sharing across sectors tools and technology that are today quite separate;
- to make the change from design by decomposition to design by composition.

The purpose of standardization was described as (citation from ProSE D1.1):

- aggregation of demand to support innovation;
- facilitation of interoperability and composability, including the seamless connectivity of Ambient Intelligence;
- enhancement of competition by differentiating products and services with measurement standards;
- both reassurance to the public, and enhancement of competition (by enabling new market entrants) through standards for safety, quality, environmental impact, etc.;
- enhancement of industrial efficiency by the application of management standards that embody best practice;
- rapid establishment of markets, accelerating take-up of technology;
- opening and enlarging of markets.

Standards and organizations are classified in more detail and clarity in ProSE D1.1 than before in the first Standardization Agenda:

- Independent Standardization Organizations (international, European, large national ones like ISA, IEEE)
- Industrial Standardization Groups (mostly organized as associations): OMG, OpenGroup, ETSI, OASIS
- De-facto standards (large companies like MicroSoft, SAP, IBM, W3C, …)

Besides these lists and tables, and some detailed information that covers at least all areas already covered in the first ARTEMIS Standardization Agenda, AAL (Ambient Environments) in particular were covered and some major gaps in standards identified, including "Semantic Services" and "Service interaction".

2.3 Standardization organizations and classification of standards

2.3.1 Classification of Standardization Organizations

There are three major groups of standardization organizations (examples do not claim to be complete):

- Independent Standardization Organizations on international or national basis with official status:
  - **International,** based on cooperation of national expert groups or mirror committees: ISO, IEC
  - **European**, based on working groups and forums: CEN, CENELEC
  - **Large national ones**: USA (IEEE, ISA, ANSI), China and India emerging
- Industrial standardization groups/consortia/companies:
  - **International:** OMG (UML, MDA, CORBA, DDS, SysML…), Open Group (e.g. RT and ES Forum, Posix, RT-Linux, safety-critical RT-JAVA), OASIS (e.g. OSLC, SGML, XML, Open Document, MQTT etc.), OSGi, RTCA, ARINC, … (US-dominated)
  - **(Mainly) European:** ETSI (has achieved ESO (European Standards Organization) status by the EC), FlexRay, …, pre-standardization WG (e.g. EWICS TC7)

- **De facto standards (e.g. MicroSoft Windows, IBM, SAP, …)** based on widely used proprietary products, or developed by industrials or others (associations, non-profit organizations):
  - MicroSoft Windows Embedded Standard 2009, Windows Embedded Devices Standard (not recommended for safety-critical applications)
  - Proprietary: e.g. ABB Fieldbus Plug Serial Interface
  - The Open Software or Open Source movement has set de-facto industry standards: Linux examples with widespread adoption of Tools and IDEs (Integrated Development environment): GCC (Gnu Compiler Collection), Eclipse as basis for many IDEs.
  - Multi-domain modelling: e.g. Modelica, Simulink
  - Middleware: AUTOSAR (automotive only, but to become automotive de-facto standard)
  - SoC standards (at the moment de-facto-standards or proprietary standards):
  - AXI,AHB, OCP, etc. to standardize the hardware interface
  - all parts of the software stack will have (de-facto) standards, e.g. for operating system, streaming frameworks, media standards, etc.
  - Web technologies: W3C (in Europe hosted by ERCIM)
  - Operating systems: Tiny OS, OSEK, Nota, …

- Relevant de-facto standards which would need promotion are referenced later

Another classification depends on the preferred use, either generic or in a specific application domain or context (this classification is used in chapter 2.4):

- Generic (cross-domain) standards
  - Non-functional properties (dependability, performance, usability, Q…)
  - Processes (life cycle dependent/independent, supply chain dependent, certification)
  - Generic methods, tools, middleware, interfaces

- **(Application) Domain specific standards (areas).** Examples are:
  - Automotive
  - Aerospace, Air Traffic Management
  - Railways
  - Medical Equipment (devices), Healthcare
  - Process Control, Manufacturing, Enterprise Management (different levels)
  - Telecommunications
  - Ambient Intelligence, AAL (private space, home)
  - Infrastructure, Logistics

- This can be mapped into a **"Matrix"** structure:
- Dimension 1: International/industrial/de-facto
- Dimension 2: generic/application domain specific

This mapping is performed in chapter 2.4 along the generic/domain standards line as a primary priority and the international/industrial/de-facto axis as secondary priority.

2.3.2 Stakeholders with respect to standardization

Stakeholders include:

- Industry (Manufacturers, Suppliers and "Users")
- Standardization bodies,
- EU (and national) officials
- Other ETPs and related platforms/organizations
- Public authorities,
- Professional, trade or industrial associations
- Regulators,
- Certification/licensing agencies and assessors,
- Various interest or user groups (e.g. consumer associations)
- Tool providers, tool system integrators (particularly with respect to interoperability)

The appropriate mix of stakeholders will be invited to contribute their needs and views.

2.3.3 Cooperation of research projects with respect to standardization

As already mentioned above, several studies resulted in requesting more cooperation between research projects and standardization, i.e. results of research projects should aim more to influence standards or to ultimately become standards. Unfortunately, the limited duration of funded research projects (3 – 4 years in general) is prohibitive, since standardization cycles are much longer (5 years and more), and only mature results, normally delivered at the end of the project, can be standardized. But then there is in most cases no time left to start a standardization cycle! Standardization action plans are already being supported for groups of related projects, and some projects have targeted retrospective standardization impact through support actions or industrial or research groups involved in standardization. Examples are:

- COPRAS: Draft document on Standards Action Plan for the Embedded Systems Cluster (RTCA SC 205, ARINC, IEC 61508 MT, AUTOSAR, FlexRay analyzed, action steps for revisions proposed), for other areas as well.
- COPRAS/HIJA (RT-Java for safety-critical systems)
- DECOS results (by partner Audi into AUTOSAR safety, AIT in IEC 61508 MT, TT Architecture by TTTech/AIT in IEC 61508:2010)
- SECOQC (ETSI: Quantum Key Distribution Standard ISG)(AIT)
- CESAR: RTP (cross-sectoral Reference Technology Platform)(co-ordinator AVL);
- ADAMS (promotion of UML MARTE)
- CRYSTAL: IOS – Interoperability Specification(s)
- ARROWHEAD (collaborative production – framework, IPSOS Alliance, IETF)
- EMC^2 (Safety & Security Co-Engineering, Multicore issues)
- And some others contributing to upcoming maintenance of established standards and new standards

2.3.4 Standardization and the ARTEMIS research and application context

The original ARTEMIS Strategic Research Agenda (SRA) proposes a set of research topics to enable a changeover from design by decomposition to design by composition to overcome today's fragmentation of the embedded industry and separation of markets. The research domains addressed by ARTEMIS are:

- Reference Design and Architectures
- Seamless Connectivity and Middleware
- System Design Methods and Tools

For each of the research domains, a specific SRA was created:

- **The Reference Design and Architecture SRA** establishes common requirements and constraints that should be taken into account for future embedded systems, and will establish generic reference designs and architectures for embedded systems that can be tailored optimally to their specific application context.

- **The Seamless Connectivity & Middleware SRA** addresses the needs for communication at the physical level - networks; at the logical level - data; and at the semantic level - information and knowledge. Middleware must enable the safe, secure and reliable organization - even self-organization - of embedded systems under a wide range of constraints.
- **The Systems Design Methods and Tools SRA** sets out the priorities for research into the ways that these systems will be designed in future so as to accommodate - and optimize the balance in achieving - a number of conflicting goals: system adequacy to requirements, customer satisfaction, design productivity, absolute cost, and time to market.

For the Application Contexts, ARTEMIS defines:

- **Industrial systems** - large, complex and safety critical systems that embrace Automotive, Aerospace, Manufacturing, and specific growth areas such as Biomedical
- **Nomadic Environments** – enabling devices such as PDAs and on-body systems to communicate in changing and mobile environments that offer users access to information and services while on the move
- **Private Spaces** - such as homes, cars and offices that offers systems and solutions for improved enjoyment, comfort, well-being and safety.
- **Public Infrastructure** – major infrastructure such as airports, cities and highways that embrace large-scale deployment of systems and services that benefit the citizen at large (communications networks, improved mobility, energy distribution, intelligent buildings ...).

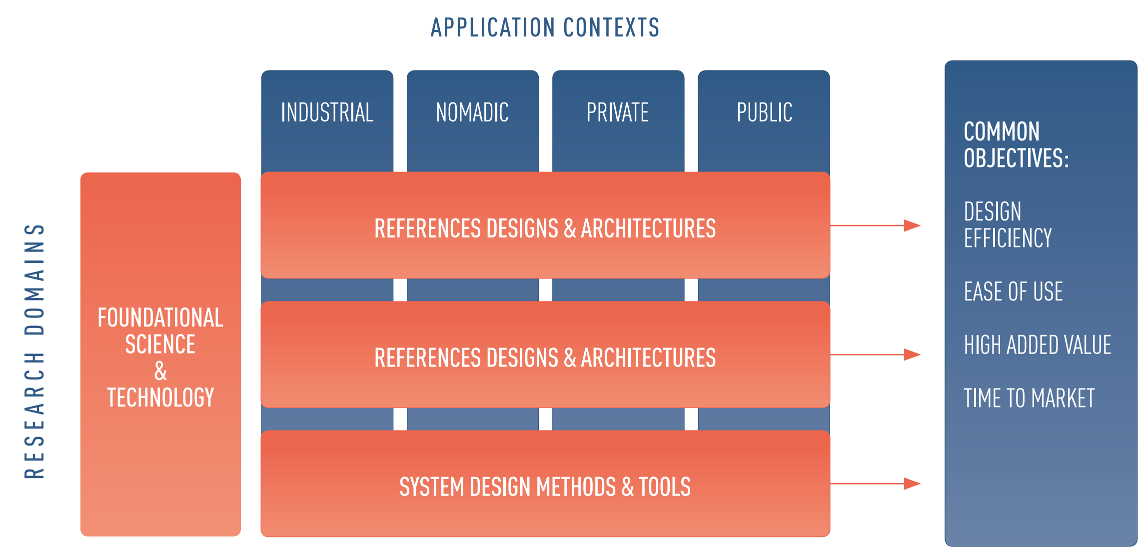

Figure 2 *ARTEMIS Scheme Application Contexts vs. Research Domains (ARTEMIS SRA)*

2.3.5 The new ARTEMIS SRA (Strategic Research Agenda) 2016

The recent ARTEMIS SRA (Strategic Research Agenda) 2016 extends the scope particularly into new contexts. It adapts the structure shown above, taking into account new paradigms such as IoT, CPS, Systems of Systems and the like. The "Digital Transformation" in economic and societal challenges are the basis and new rational for ARTEMIS, and the ARTEMIS Focus Areas are key drivers in the Digital Transformation in a wider industrial context, as there are

- Embedded and Cyber-Physical Systems,
- Internet of Things,
- Digital Platforms,

which will allow new innovative businesses and opportunities for value creation in many sectors that require embedded intelligence.

The ARTEMIS strategy 2016, as always, wants to overcome the silos effect between domains and sectors, addressing research in a cross-domain approach, which particularly includes **standardization** as one of the priorities towards an effective innovative ecosystem. The development of **common building blocks** is considered one of the strategic research challenges, related to

A CPS Architectures Principles (Reference Design and Architecture)
B Design Methods, Tools , Virtual Engineering
C Trust, Security, Robustness and Dependability
D Autonomous and Robotic Systems
E Seamless Connectivity and Interoperability
F Cyber-Physical System of Systems
G Computational Blocks
H Digital Platforms (Cyber-Physical Systems creating smart services)
I Basic Research, Fundamental Research.

The ARTEMIS SRA 2016 Matrix was modified and extended according to the new challenges of the Digital Transformation:

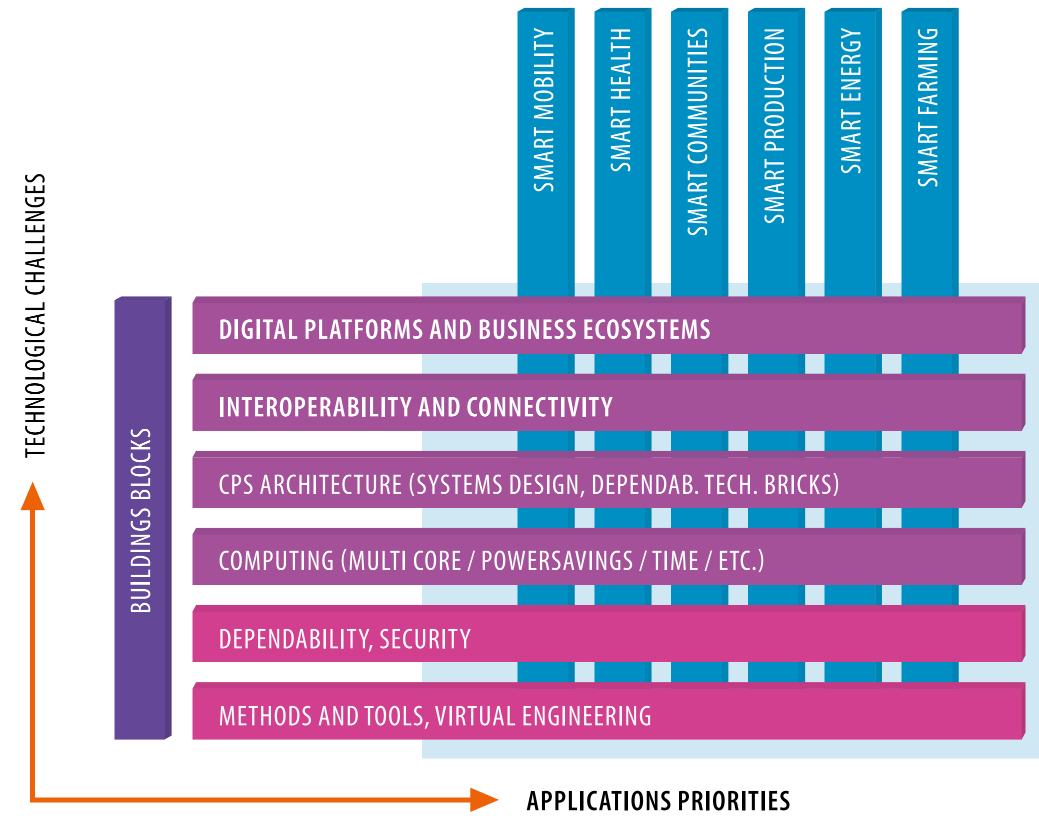

Figure 3 *ARTEMIS SRA 2016: Technological Challenges, Application Priorities and Building Blocks*

According to this SRA 2016 chart, a number of technological challenges have to be considered and taken into account for standardization – and considerable effort has been and still is being invested by new ISO, IEC and ETSI, IEEE, OMG, OASIS and other standardization groups, as outlined below under "Standardization Meeting New Challenges" (chapter 2.5).

The ARTEMIS SRA 2016 considers the following:

- Safety-critical Secure Systems
- Virtual World
- Big Data/Data Analytics
- Systems of Systems
- Cloud Services
- Internet of Things
- Autonomous, Adaptive and Predictive Control
- Computing & Multicore

Although the list of challenges above makes no claim to be complete at all, ARTEMIS considers "Standards and Interoperability" a major issue to foster innovation, to make significant advances towards "design by composition" and to meet the challenges of dependability, cost effectiveness and time to market.

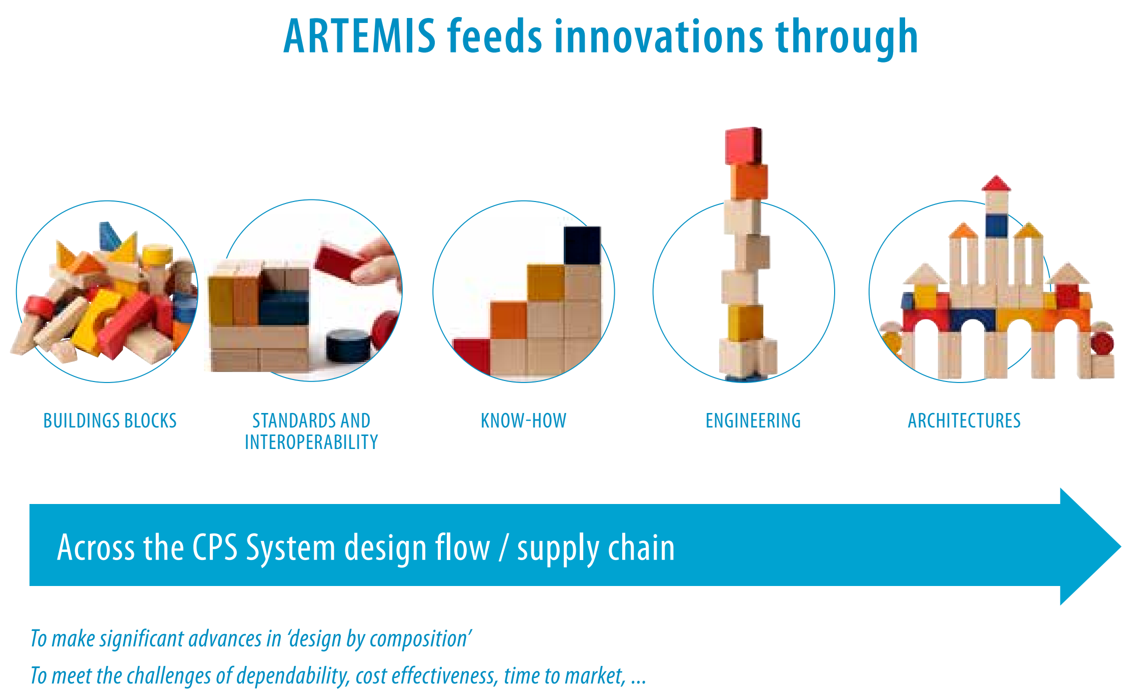

Figure 4 *ARTEMIS SRA - CPS System Design Flow*

2.4 Standardization landscape

2.4.1 Introduction

The Embedded Systems/CPS Standards landscape is at least as fragmented as the Embedded Systems industry and research as stated in the Artemis SRA. There is no coherent approach to Embedded Systems/CPS Standardization internationally, the work items are distributed all over international, industrial and other, particularly sector-specific, standardization groups. Only a few standardization issues are handled by joint working groups or committees, particularly ISO/IEC, but also between SAE/ISO in Automotive Cybersecurity Engineering, between ETSI/CEN/CENELEC in ITS, M2M (IoT); additionally, some standardization activities are shared e.g. between ISA and IEC (e.g. development of the Industrial Automation & Control Security Standard IEC 62443) and ISO and OMG (many OMG standards become ISO standards after completion), just to mention a few examples. In communication, there is cooperation between ISO, IEC and ITU, and ETSI. In many evolving areas, new ad-hoc groups and pre-standardization activities have been started, some as joint working groups as well. Established standards have to be adapted after some time in so-called maintenance phases, e.g. IEC 61508, IEC 61511 and others in functional safety, because of new software and hardware paradigms.

Thus, we have three groups of standards to look at:

- Existing standards to be adapted/maintained (a potential group of candidates is functional safety standards, IoT, Safety & Security in several domains/sectors)
- Evolving standards to be influenced (potential examples could be ISO 26262 or AUTOSAR, a successful example already promoted is the ISG (Industrial Specification Group) of ERCIM/ETSI on Quantum Key distribution)
- New standards to cover new areas (potentially rich fields would be: ambient intelligence, AAL (Ambient assisted Living), autonomous systems and control, cloud services, big data/data analytics, systems-of-systems, computing & multicore)

2.4.2 Standards and standardization organizations

2.4.1.1 Generic/Cross-domain Standards suited for Dependable Embedded/CPS Systems

Given that one of the missions of Artemis is to overcome the fragmentation among application sectors so as to 'de-verticalize' the industry, in the first place an overview is provided on standards that are not specific to any domain, covering:

- Non-functional system properties such as
  - (Functional) Safety
  - Security
  - Performance
  - Quality
  - Usability

- Processes
  - Life-cycle dependent Processes
  - Life-cycle independent Processes
  - Supply-chain dependent issues
  - Certification
- Generic methods/tools/tool chains. Fundamental underpinning for such interoperation and integration is supported by model-based development and validation
- Generic middleware and communication infrastructures (e.g. operating systems, gateways, interfaces, …)
- Electronics
- Interfaces and domain-specific adaptation of generic standards (this will be discussed in a separate chapter)

Specific comment on Software:
In the past, many standardization activities were driven by bodies such as IEEE, often initiated by government agencies, most notably the US DoD. A lesser, but still influential role was filled by academia (think of the CMM model from Carnegie-Mellon's SRI). When PC's became widespread, official standardization was more or less taken over by companies such as MicroSoft and Sun, mostly in the fields of programming languages and, more importantly, in programming or application development environments.

The Open Software or Open Source movement also has set a number of de-facto industry standards: Linux is probably the best known example. Judging from recent developments, this trend is consolidating. Examples can be seen in the widespread adoption of GCC (Gnu Compiler Collection), and of Eclipse for the development of IDE's. This trend is fuelled by the still growing semiconductor market, on the one hand, and the increasing cost of software development, on the other. Many of the above-mentioned tools are seen as 'Silicon Enabling': ensuring increased number of sold chips, not as the IP of any company. On the other hand, increasing application programmer activity is key in managing system development cost: providing standardized application tool platforms is one factor in this.

Integration of development processes and interoperation of developed software and systems require multi-domain modelling capabilities such as those promised by Modelica.

Specific comment on middleware:

- OSGi (Open Services Gateway initiative) Alliance: the OSGi Alliance is an independent non-profit corporation comprised of technology innovators and developers and focused on the interoperability of applications and services based on its open component integration platform at middleware level.
- OMG: The Object Management Group (OMG) is a consortium that produces and maintains computer industry standard open specifications for interoperable enterprise applications. Its members include virtually every large company in the computer industry, and hundreds of smaller ones.

Specific comment on process standards:

- During the early years of software engineering, the realisation of the infeasibility of testing all possible interactions of software-based systems with their environment led the industry to focus on process standards such as ISO9000 and its variants, CMMI, Spice etc.
- In recent years process standardization has become less prominent as the industry (and its customers) have re-emphasized the need to focus on the actual performance of software-based systems, rather than on how they were produced. Even more recently, the concept of 'software as service' is leading to the application of 'service level agreements' to the functioning of software-based systems.
- While process standards have become less important for the specific process of software generation, there has been a parallel increase in interest in the overall product development process that is encapsulated in the notion of 'Product Lifecycle Management' (PLM). This is - or can be (different players have different perspectives) - extremely broad and can encompass not only design, development and test, but also product portfolio management and strategy development.
- PLMIG (Product Lifecycle Management Research Interest Group) is an industry-led grouping whose goal is to promote PLM research within Europe.
- The (main) standards in use or under maintenance include
  - STEP (the Standard for the Exchange of Product Model Data) which describes how to represent and exchange digital product information. It forms a key component in PLM and is encapsulated in an ISO standard (ISO 10303).
  - AP233
  - Doors, Simulink (Proprietary/de facto)
  - UML/SYSML
  - VHDL, RosettaNet
  - U3D, 3DXML
- The priority standard in development is the System Architecture Modelling Language Modelica. This is an open, declarative rather than procedural standard that is intended to facilitate the collaborative design of innovative products.

2.4.3 Standardization and pre-standardization/expert organizations for generic standards

2.4.3.1 Official International/European/US/national standardization groups:

- ISO (International Standards Organisation) (157 members, national standards organizations of most industrial and developing countries) e.g. TC22 (functional safety)
- IEC (International Electro-technical Commission) (68 members, national electro-technical/electronic committees/associations), e.g. TC65 (SC65A for functional safety, SC65B&C for buses, etc.), TC56 (dependability).
- CEN (European Committee for Standardisation) (members are the national standardization bodies of most European countries).
- CENELEC Comité Européen de Normalisation Electro-technique (members are the national electro-technical standardization bodies of most European countries).

- IEEE (Institute of electrical and electronics engineers)
- Other national standardization organizations (preparing for WG and proposing new work items)
- ETSI (European Telecommunications Standards Institute) (has official ESO status)

2.4.3.2 Industrial standardization organizations:

- OMG (Open Management Group) OMG is a consortium that produces and maintains the computer industry's open specifications for interoperable enterprise applications. Membership: virtually every large company in the computer industry and hundreds of smaller ones. NOTE: Most OMG work is taken over by ISO standards.
- The Open Group (Open Source Movement) (300 industrial members)
- ISA (Instrument Society of America)
- OSGi Alliance
- OASIS (Organization for the Advancement of Structures Information Standards) is a consortium that started as "SGML Open" in 1993. When the community shifted to XML it became "OASIS". OASIS is a global non-profit consortium that works on the development, convergence and adoption of standards for security, Internet of Things, energy, content technologies, emergency management and other areas. In our context, OSLC, MQTT, GeoXACML (Geospatial eXtensible Access Control Markup Language) and others are of interest.
- PICMG PCI Industrial Computer Manufacturers Group: consortium of over 450 companies that collaboratively develop open-based computer architectures for telecommunications, industrial and military use
- SPIRIT Industrial consortium which tries to establish IP and tool integration standards to enable improved IP reuse through design automation enabled by IP meta data description
- OSCI Open SystemC Initiative. OSCI members represent a range of worldwide electronics organizations, ranging from SoC companies, tool vendors, intellectual property suppliers and embedded software developers. Specifications are open.
- VITA VME Industrial Trade Association Industry

2.4.3.3 Regulatory organizations:

- HSE (Health and safety Executive (UK)
- OSHA (Occupational Safety and Health Administration)

2.4.3.4 Other (pre-) standardization groups/organizations:

- EWICS TC7 (European Workshop on Industrial Computer systems, TC7, Reliability, Safety and Security)
- ERCIM – European Research Consortium for Informatics and Mathematics
- SEI (Software Engineering Institute, Carnegie Mellon University, Software Processes and Maturity Models)

2.4.3.5 Main standards of the above-mentioned groups in the non-domain-specific standardisation areas:

- ISO/IEC 61508 (Functional Safety of E/EE/PE Systems)
- ISO/IEC 62443/ISA SP99 (Security of Industrial Process Measurement and Control – network and system security)
- ISO/IEC 61784-4 (Profiles for secure communications in industrial networks)
- ISO/IEC TC56 – Dependability (e.g. IEC 60300, Dependability Management)
- ISO 9126 (ISO 25000) (SW Engineering – Product Quality)
- ISO 15504 – SPICE (Software Process Improvement and Capability Determination)
- ISO 15408 – Common Criteria (Security)
- ISO 17799 (ISO 27001, ISO 27002) (Information Technology -- Code of practice for information security management)
- ISO 9000 (Quality Management)
- IEEE 1003 – POSIX

From industrial consortia and academic institutions:

- CMM (Capability Maturity Model, for systems), CMMI (Capability Maturity Model Integration, software) (SEI, Carnegie Mellon University/DoD)
- OMG Standards:
  - The OMG's flagship specification is the Unified Modelling Language (UML) and the multi-platform Model Driven Architecture (MDA).
  - The OMG's own middleware platforms are CORBA and DDS.
  - SysML provides architectural specification methods.
- OSGi standards on universal middleware: JAVATM
- Open Software (Open Group)
- VITA Open Standards Organization for e.g. unmodified VME32/64 backplanes
- PCI specifications: include AdvancedTCA, AdvancedMC, MicroTCA, COM Express, and CompactPCI
- IP-XACT. Defines specifications for electronic elements APIs and will extend in the direction of including also non-functional aspects (SPIRIT consortium).
- OSCI standards: TLM - Transaction Level Modelling
- SoC standards:
- AXI, AHB, OCP, etc. to standardize the hardware interface
- all parts of the software stack will have (de-facto) standards, e.g. for operating system, streaming frameworks, media standards, etc.
- Open Software de-facto Standards: Linux, GNU compilers, Eclipse system,

2.4.3.6 Aeronautics and aerospace standards

Aeronautics and aerospace industry standards are dominated by industrial consortia and regulatory groups.

The main actors are Industry (manufacturers of aircraft, airborne equipment, ATM systems, airlines), the aviation safety agencies (EASA in Europe, FAA in the USA), Advisory Committees (RTCA, SEI), Standardization Organizations (Eurocontrol, EUROCAE, ISO), Conformity Assessment Authorities [ACAA]. Forums include:

- ARINC (Aeronautical Radio Inc.)
- EUROCAE (European Organization for Civil Aviation Equipment)
- SAE (originally Society of Automotive Engineers, now very active in Areospace Standardization)
- ECSS (European Cooperation for Space Standardization)

Main standards in use and under maintenance include:

- AADL (Avionics Architecture Description Language)
- IMA (Integrated Modular Avionics)
- RTCA (DO160, DO178B, DO254, DO255, DO297)
- ARINC (ARINC653, 664)
- EUROCAE standards
- Eurocontrol Standards
- ECSS Standards
- AFDX

Priority standards in development:

- Standards related to safety, security, interoperability, environmental impact.

Changes in the standardization process for the sector will come from adoption of Single European Sky and Clean Sky principles by the aeronautic domain that will lead to a new generation of avionic systems and a new ATM model. In parallel, standards and rules coming out from those EC initiatives will significantly impact avionic systems, ATM structures and the way people will approach air transport system.

To achieve cross-domain re-use and become more cost-efficient, the avionics industry is observing standardization in other mass-product, safety-related areas, e.g. automotive (FlexRay bus, AUTOSAR).

2.4.3.7 Automotive standards

We include here communication within the vehicle, with the infrastructure (2025) and from vehicle to vehicle (2030); control of the powertrain, suspension and chassis, and standardization concerned with development and testing.

Main actors: Industry (safety aspects) and regulators (national, local)

- SAE (Society of Automotive Engineers International (SAE)).
- AUTOSAR consortium
- ERTICO/Transport Telematics Forum (Europe's Intelligent Transportation System Organization)
- ISO TC 22 SC 32 WG 08, WG 11
- ISO/SAE JWG 1 ("Automotive Cybersecurity"), under the new Partnership Standards Development Organization (PSDO) (ISO TC22)
- Intelligent Transportation Systems (ITS): ISO/SAE PSDO agreement between ISO TC 204 and SAE

The main standards in use or under maintenance:

International:

- Road vehicle standards are ISO (DIN, ASI, …) domain. This includes
  - CIA, CAN (Controller Area Network) in automation
  - LIN (Local Interconnect Network)
  - Safety standards (Brakes, lights, reflectors, airbags.....car immobilizer, tire pressure monitors,...)
  - Functional Safety standard (upcoming Ed. 2.0, ISO 26262)
  - Automotive Cybersecurity (ISO/SAE JWG 1, ISO TC 22/SC 32/WG 11)
  - Mechanical standards (DIN, ISO, VDA,......)
  - Certain communication standards

Industrial consortia standards are:

- FlexRay
- AUTOSAR: Automotive Open System Architecture.
- GIFT/ICT (CAN tranceiver specification & testing)
- MOST (Media Oriented System Transport)
- Safe By Wire Plus
- AEC, Automotive Electr. Council - Q100
- ESDA - Human Metal Model
- Supply standards (TS 16949, ...)

Certain standards are defined by directives and international agreements:

- Vienna Agreement
- Environmental standards (exhaust pollution EU3, EU4, EU5,.....)

Priority standards in development:

- Inter vehicle/road structures communications

2.4.3.8 Rail standards relevant for electronics and software

Main actors:

- International organizations, e.g. CER, EIM, ERA, UNIFE, UIC, ETSI, ATOCs, CENELEC, CEN
- other normative bodies
- railway equipment manufacturers
- railway operators

Main standards in use or under maintenance are International or European official standards:

- CENELEC TC9X and TC256
- RAMS (EN-50126, EN-50128, EN-50129),
- IEC-61508 (SILs, basis for EN 50126/28/29 series)
- IEC 61375-1, Train Communication Network
- ERTMS/ETCS (European Railway Traffic Management System/European Train Control System)

Priority standards in development include standards related to:

- safety & security
- interoperability
- EMC

Changes under way in the standardization process for the sector include accommodation of all the EU directives concerning:

- safety
- EMC
- interoperability
- operation
- persons with reduced mobility, ...

2.4.3.9 Telecommunication

N/B. Cellular aspects are excluded, being within respective industry and well established.

Main actors: standards are promoted by industry forums and special interest groups - (Bluetooth SIG, Wifi Alliance, IETF, ...) and endorsed by standard bodies. The role of the telecommunications manufacturing industry and of the consumer electronic industry is fundamental. However, the evolution beyond classic telecommunication services (e.g. convergence of telephony, internet, media, consumer electronics) is strongly increasing the number of competitors and the level of competition.

The most important international/European/US standards bodies are:

- ETSI - European Telecommunications Standards Institute.
- ITU - International Telecommunication Union
- IEEE
- CEN/CENELEC
- ISO (protocols)
- IEC (safety, EMC)

Industrial consortia or alliances are:

- OMA - Open Mobile Alliance
- TISPAN
- IETF
- ISO/IEC
- HGI
- WIMAX forum
- WiMedia Alliance
- DSLForum
- VESA, Video Electronics Standards Association
- UCPS (China)
- BMCO (Broadcast Mobile Convergence Forum)
- EMBC (European Mobile Broadcast Council)
- CELF (CE linux Forum)
- UHAPI (Universal Home Application Programming Interface Forum)
- IGRS (Intelligent Grouping and Resource Sharing, Chinese DLNA counterpart)
- CEA (Consumer Electronics Association)
- MoCA, Multimedia over Coax Alliance
- Mobile DTV alliance
- W3C (World wide web consortium, in Europe hosted by ERCIM)

Standards enforcement is carried out by public regulators; competition rules are defined by the EC in Europe. Main standards in use or under maintenance:

- MIPI - Mobile Industry Processor Interface/Slimbus. This establishes specifications for standard hardware and software interfaces in mobile terminals. The common objective of MIPI members (Intel, NXP, Nokia, STM, TI, HP, Samsung, Sony, etc.) is to simplify the design and implementation of hardware and software by driving consistency in application processor interfaces, promoting reuse and compatibility in mobile devices. No certification program is in place.
- DVB, DVB-H
- Khronos
- 3GPP2
- LTE
- IEEE 802.11
- WiMax
- WiFi
- WiMediaMAC- an open standard for PC and consumer applications by WiMedia Alliance (Industrial - Intel, NXP, Nokia, STM, TI, HP, Samsung, Sony, etc.). A certification program is in place.
- Zig-B
- Bluetooth
- GSM, GSM-R
- EDGE
- UMTS
- WCDMA
- TETRA
- LINK 16
- WNN
- CORBA
- SINCGARS
- PDH/SDH
- ATM
- all the IP network related standards including IPv6
- specialized standards for system management (like TR-069 of DSLForum for CPE management and configuration)
- MPEG standards family (ISO/IEC JTC1/SC29 WG11)
- UPnP
- ISMA (Internet Streaming Media Alliance)
- JVT (Joint Video Team)
- ITU-T, SG16 Q.6 (Video Coding Experts Group)
- OpenCable (US)
- SVP
- SATA-IO
- HDMI

- DPCP/ DisplayPort
- PCI / PCI-Express (point to point computer expansion card interface format) by Intel
- USB-IF (open industry standard for PC and consumer applications : Microsoft, Intel, NXP, NEC). A certification program is in place.

The priority standards in development are:

- WiMedia UWB
- NFC (near field connectivity)
- Bluetooth Wireless
- Software Defined Radio (SDR) & Cognitive radio
- Home Network, Home Gateway
- network elements for meshed networks, MANET

2.4.3.10 Health (medical devices and systems)

There are many developments for standards in the health area and organizations promoting standards, some of which originate from the US but have now international structures. SDO's in the health area are:

Standards institutes:

- ISO (many separate standards for different types of (isolated) medical devices)
- IEC TC62 (electrical equipment in medical practice), e.g. IEC 60601 and IEC 80601-x-yy, includes AAL (Active Assisted Living) and about 300 sub-standards for specific devices and applications
- ISO/IEC co-operation in medical devices and robotics: ISO TC 299 (robotics) includes not only industrial robots (ISO 10218 – safety), but also robotics in health care (e.g. ISO 13482:2014ISO 13482:2014 Robots and robotic devices -- Safety requirements for personal care robots) and
- Surgery robots, the latter together with IEC TC65 **(**which, in fact, makes IEC TCSC62D, e.g. **IEC 80601-2-77 ED1**, Medical Electrical Equipment - Part 2-77: particular requirements for the basic safety and essential performance of medical robots for surgery)
- ISO 13485:2016 Medical devices -- Quality management systems -- Requirements for regulatory purposes; ISO
- CEN with several technical committees (e.g. TC 251)
- IEEE with several committees (e.g. TC215 for data standards and 11073 for medical devices)
- ANSII (e.g. HITSP, HL7, CGL7)

Industrial groups and others:

- ASTM (e.g. CCR) (originally "American Society for Test and Materials")
- NEMA (DICOM)
- Regenstrief Institute, Inc. (LOINC)
- US National Library of Medicine (UMLS)
- SNOMED
- IHE (mainly promotion)
- Continua (an industrial consortium related standards for tele-monitoring

In other standardization activities (e.g. USB, Bluetooth, Zigbee) medical profiles are being developed and also many informal standards are emerging, e.g. in the area of bioinformatics and medical informatics in the form of mark-up languages.

2.4.3.11 Robotics, Additive Manufacturing

"Robotics and robotic devices" were originally part of ISO TC 184 (Automation Systems and Integration, handling the "machinery" aspects in ISO), subcommittee SC 02; in the meantime, robotics has become so important and a topic in its own right that it is now a separate independent TC 299 (Robotics). Current standards and standardization projects cover:

- General aspects (vocabulary, coordinate systems and motion nomenclatures)
- Manipulating industrial robots (several standards on grippers, mechanical interfaces, performance characteristics, …)
- Industrial robots – safety requirements (ISO 10218-1:2011, ISO 10218-2:2011)(update proposed concerning security awareness by AIT)
- Robots and robotic devices -- Safety requirements for personal care robots (ISO 13482:2014)
- Robots and robotic devices -- Collaborative robots (ISO TS 15066:2016)
- Robotics -- Performance criteria and related test methods for service robots -- Part 1: Locomotion for wheeled robots (ISO 18646: 2016)

"Additive manufacturing", a related standardization activity, has become another new topic and popular since "3D-printing" has become a professional method widely used in many sectors. This topic is covered by ISO TC 261, partially in cooperation with ASTM (originally "American Society for Testing and Materials"). Current standards and standardization activities include:

- ISO 17296-1 to 4: Additive manufacturing – General principles (Terminology (1), Overview process categories and feedstock (2), Main characteristics and corresponding test methods (3), Overview of data processing (4)), issued 2014 and 2015
- ISO/ASTM 52900 series: Part 1: Additive manufacturing – General principles (issued 2015)
- ISO/ASTM 52901.2: Additive manufacturing – General principles – requirements for purchased AM parts
- ISO/ASTM 52902: Additive manufacturing – Standard test artefacts

- ISO/ASTM 52903 series: Additive manufacturing -- Standard specification for material extrusion-based additive manufacturing of plastic materials (Part 1: Feedstock, Part 2: Process – equipment)
- ISO/ASTM 529XX: further specific standards/guidelines on details of design, file formats, processes and testing

2.4.3.12 Smart Cities / Smart Buildings / Smart Home related standards

The home domain could be divided into

- Building automation
- Home automation
- Smart spaces from a generic point of view, and
- Smart Cities (many related standards on smart mobility, smart energy/grid, smart water management, smart health, environmental "smartness", safety & security, privacy, etc. which influence/should allow people to live in large and mega cities in a sustainable manner ("smart living"), includes social aspects like inclusion, active participation of people, culture, leisure, local business infrastructure etc., not just technologies).

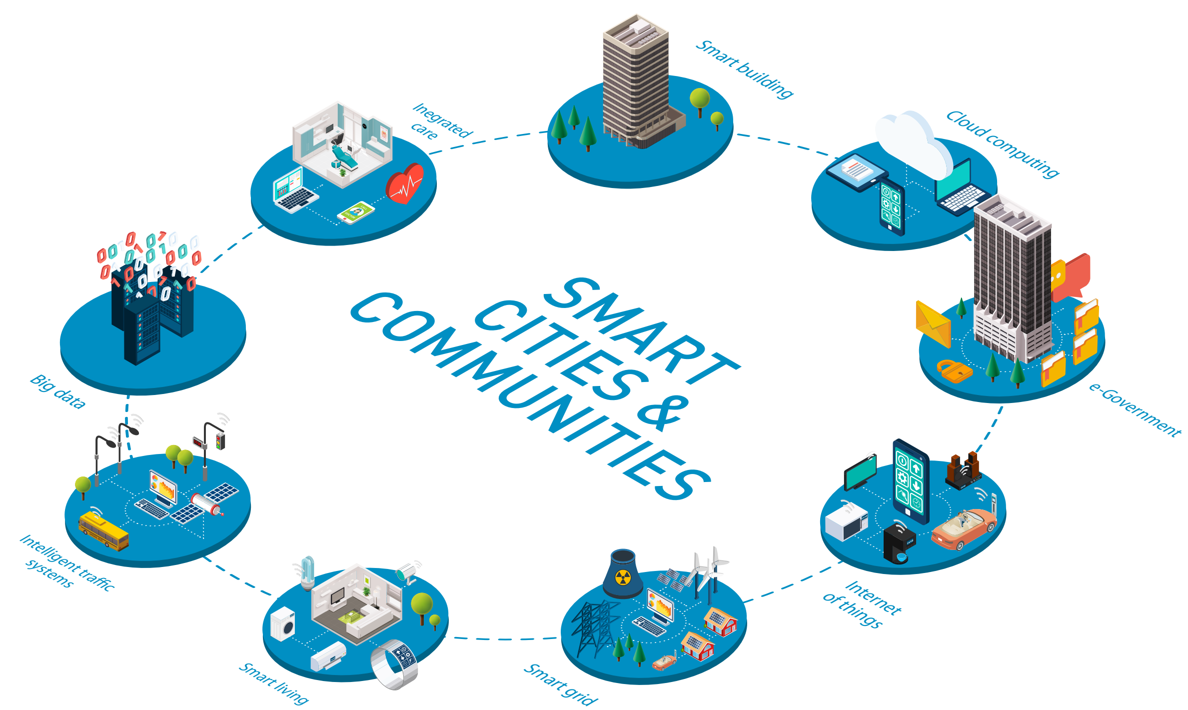

Figure 5 *The ARTEMIS SRA 2016 "Smart City Vision" – a multitude of actors, activities and challenges*

The main difference between building automation and home automation is, however, the human interface. In home automation, ergonomics is of particular importance.

Specific domotic standards include INSTEON, X10, EIB/KNX (standard promoted by "Konnex Association"), HomePlug, LonWorks, System Box, C-Bus, Universal powerline bus (UPB), UPnP, ZigBee and Z-Wave that will allow for control of most applications. In the area of "intelligent building", there are additionally ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers: an international organization for heating, ventilation, air conditioning, or refrigeration -- HVAC&R), BACnet (a network communications protocol adopted worldwide as ISO 16484-5:2003), ARCNET, RS-232, RS-485, DALI, DSI, Dynet, Energy Star (a programme created by the US government to promote energy-efficient consumer products), LonTalk (a protocol created by Echelon Corporation for networking devices), Modbus and oBIX.

Standardization bodies, which also affect the home domain, are

- CENELEC, the European Committee for Electro-technical Standardization, works on "Smart Homes" standards
- ISO/IEC
- IEEE,
- CEN

Industrial standardization groups include:
OMA - Open Mobile Alliance, WiMedia Alliance, CELF (CE linux Forum), UHAPI (Universal Home Application Programming Interface Forum), IGRS (Intelligent Grouping and Resource Sharing), CEA (Consumer Electronics Association) and MoCA, Multimedia over Coax Alliance. Eu.bac is the European building automation and controls association.

In the area of **entertainment,** the most important alliances are the Digital Living Network Alliance (DLNA) and HDMI. DLNA is an international, cross-industry collaboration of consumer electronics, computing industry and mobile device companies with the objective to establish a wired and wireless interoperable network of personal computers, consumer electronics and mobile devices in the home and on the road, with design guidelines based on internationally recognized open industry standards together with a certification program to verify conformance.

Some standards use control wiring, some embed signals in the powerline, some use radio frequency (RF) signals, and some use a combination of several methods. Control wiring is hardest to retrofit into an existing house. Some appliances include USB that is used to control and connect to a domotics network. Wireless interconnection is mostly based on Wi-Fi 802.11b/g, Bluetooth, DECT, 802.15.4/ZigBee, Z-Wave, EnOcean (exploitation of slightest changes in the environmental energy using the principles of energy harvesting), and Consumer_IR (protocols for remote control). Bridges translate information from one standard to another (eg. from X10 to EIB). Other standards in use or under maintenance are WiMax, WiMediaMAC, COBRA, HDMI, PCI / PCI-Express and USB-IF. The large variety of standards and standards groups will raise the convergence issue "beyond bridges" as well.

Some ARTEMIS projects have considerably contributed to the "Smart Space" area, like SOFIA (Smart Objects for Intelligent Applications). An outcome was the basis for a "next generation middleware" named "SMOOL", although it is really just an evolution of SOFIA. SMOOL was developed following the open source concept and was adopted by industry (INDRA) as SOFIA2.

Standards that apply for "Smart Spaces" are generally the aforementioned communication standards (ZigBee and the like), and middleware standards that support the client-server paradigm, for example, CORBA, Ice, Web Services, Java RMI or OPC. Standards for the implementation of a publish/subscribe communications paradigm are, for example, DDS, Icestorm, SOFIA Middleware, the CORBA Event Service, the CORBA Notification Service and Java JMX.

2.4.4 Ambient Environments and AAL – Active Ageing/Inclusion

2.4.4.1 General Overview

The vision of Ambient Intelligence is based on the ubiquity of information technology, the presence of computation, communication and sensorial capabilities in an unlimited abundance of everyday appliances and environments. The most prominent publications that have had an impact on wide fields of science and research within the last few years are:

1. ISTAG report on scenarios for Ambient Intelligence 2010 (Ducatel K, Bogdanowicz M, Scapolo F, Leijten J, Burgelman J-C.: Scenarios for ambient intelligence 2010, ISTAG report, European Commission, Institute for Prospective Technological Studies, Seville (November ARTICLE IN PRES2001). URL ftp://ftp.cordis.lu/pub/ist/docs/istagscenarios2010.pdf);
2. The outline description of Ambient Intelligence given in Shadbolt N.: Ambient Intelligence. IEEE Intelligent Systems 2003; 2–3 and
3. An article of one of the inventors of the notion Ambient Intelligence (Aarts E., Ambient Intelligence: a multimedia perspective, IEEE Multimedia 2004; 12–9).

The notion of Ambient Intelligence (AmI) was developed in 1998 during a series of internal workshops commissioned by the management board of Philips.

It is obvious that Ambient Intelligence will make substantial contributions to science (as well as to the economy) if its realization contributes noticeably to human well-being. But some paradigm shifts regarding technology development and technology usage have to be made. Up till now, it has been the user's responsibility to manage his or her personal environment, to operate and control the various appliances and devices that are available for support. It is obvious that the more technology is available and the more options there are, the greater the challenge of mastering one's everyday environment, of not getting lost in an abundance of possibilities. Failing to address this challenge adequately simply results in technology that becomes inoperable and thus effectively useless. Through Ambient Intelligence, the environment gains the capability to take over mechanical and monotonous control tasks - as well as stressful feature selections and combinations - from the user and manage appliance activities on his or her behalf. To do this, the environment's full assistive potential must be mobilized for the user, tailored to individual goals and needs. The user becomes an active part of her environment in realizing this, more than only a user trying to reach his or her goals by using the available environment technologies.

Consequently, AmI extends the technical foundation that was laid by former initiatives like Ubiquitous Computing and Pervasive Computing. These technologies triggered the diffusion of information technology into various appliances and objects of everyday life. But now, Ambient Intelligence has to guarantee that those smart devices behave reasonably and that they unburden - instead of burden - the user (for more details, see [Aarts, Encarnação 2006].

Recent research initiatives follow elderly care (→ Ambient Assisted Living) or sensor-quipped environments (→ Wireless Sensor Networks, WSN) or special topics in Human-Computer Interaction.

The topics

- Architecture / Middleware
- Semantic Services
- Service Interaction

are being most important for the realization of AmI environments and applications, hence the concentration on a survey on these topics and on the selection of the most promising candidates in that research field.

2.4.4.2 Architecture/Middleware

In principle, an architecture/middleware for Ambient Intelligence should provide a technological platform that allows the seamless and natural access to AmI services as well as communication and cooperation of devices and application within an AmI environment. Furthermore, It should provide some means for plug-and-play capabilities, so that device (or application) ensembles can be integrated in an ad-hoc fashion. In the past, agent platforms or platforms in which software components communicate and exchange messages, were applied to realize such distributed applications. A key feature of this agent approach is a high degree of autonomy in the software components included. Internal processing gives the exchanged messages a high level of semantics while the component systems have special parts that contain rules about the message flow or the organization of the components. The different approaches vary from common publish-subscribe mechanisms to the realization of distribution strategies between different agents. Representatives of this kind of technology are the

- FIPA initiative – Foundation for Intelligent Physical Agents (http://www.fipa.org)
- KQML initiative – Knowledge Query and Manipulation Language (http://www.cs.umbc.edu/kqml/)
- And projects like Ask-IT (http://www.ask-it.org/) or OASIS (Open architecture for Accessible Services Integration and Standardization, see http://www.oasis-project.eu/) that apply the FIPA standard for realizing the underlying component platforms.

Because FIPA and KQML are already established standards (with roots mainly in the US), PRoSE concentrates on recent service-oriented platforms that distinguished components as service providers and service consumers and make physical and logical architectures for networked nodes available to provide the necessary communication and service discovery and service binding needs.

Prominent representatives are the AMIGO system (http://www.amigo-project.org) whose goal is the development of an open, standardized and interoperable middleware. The middleware here is a piece of software which has to be implemented on each device. Amigo views itself as a service-oriented architecture, which distinguishes between service providers and service clients (but it is possible that one application can play both roles). The goal of the AMIGO architecture is to make the composition of abstractly described services possible (see figure 4). The PERSONA system (http://www.aal-persona.org) comprises a middleware and a set of specific functional components. The middleware realizes the communication buses and enables the orchestration of the ensemble based on a set of specified ontologies, protocols and strategies. The functional components provided by the PERSONA platform are:

1. Situation Reasoners for deducing higher level contextual info,
2. Dialog Manager representing the system as a whole,
3. Service Orchestrator providing facilities for defining and enacting composite services using existing services,
4. Profiling Component,
5. Privacy-Aware Identity and Security Manager,
6. a context history entrepôt,
7. AAL-Space Gateway, and
8. a set of so-called I/O handlers responsible for (a) presenting the modality- and layout-independent system/application output to the user in a context-aware and personalized manner, and (b) collecting user input in an environment with several I/O channels distributed in the AAL space. Other examples are DECOS (http://www.decos.at), ARLES or LEICA.

The GENESYS platform (http://www.genesys-platform.eu/) is developing a cross-domain reference architecture for embedded systems that can be instantiated for different application domains to meet the requirements and constraints documented in the ARTEMIS strategic research agenda. These requirements are composability, networking, security, robustness, diagnosis, integrated resource management and evolvability. The reference architecture will address common issues, such as complexity management, separation of communication and computation, support for different levels of quality of service, security, model-based design, heterogeneity of subsystems, legacy integration, optimal power usage, and diagnosis.

The (de-facto) standards for devices, communication protocols or even service description specification or service discovery protocols developed in the last few years and brought to market by key players of the IT industry are often used as a basic technology to realize (more semantic) architectures.

- Universal Plug and Play (UPnP) (www.upnp-ic.org)
- HAVi (Home Audio Video Interoperability) (http://www.havi.org)
- JINI (new: RIVER) (http://www.jini.org, or new: http://incubator.apache.org/river)
- OSGi (or R-OSGi) Open Services Gateway initiative (http://www.osgi.org)
- Bluetooth

These are the most prominent examples that will have to be considered. There is a huge overlap with standards in the area of Communications, Smart Cities/Homes/Buildings and Ambient Assisted Living/Ageing/Inclusion.

Also the field of tiny (or better: embedded) platforms have to be looked at. The requirements of operating systems and protocols for sensor nodes and embedded systems are different to those of systems running on larger machines (obvious reasons: energy consumption, limited processing power). Here discovery protocols like ZigBee, Operating Systems like TinyOS and results of projects like RUNES (for Reconfigurable Ubiquitous Networked Embedded Systems, http://www.ist-runes.org) and the ProSE survey have to be taken into account for future possible standardization candidates.

2.4.4.3 Semantic Services:

Services are the main feature of components and applications that are part of any device ensembles. Services represent functions that are offered by the variety of participating devices and applications. Of the different paradigms developed in the past, the service-oriented architectures (SOA) and the agents are the most well-known. All comprise the specification of

- Language
- Protocols
- Ontologies
- Dispatch strategies

to allow the description of services and the services capabilities, to define non-functional aspects of proposed services and to allow the realization of strategies for

- Service Discovery
- Service Binding
- Service Composition
- Service Decomposition.

Prominent specifications for service descriptions are:

- Universal Plug and Play (UPnP) (www.upnp-ic.org)
- OWL (that builds on RDF and RDF Schema and stems from DAML+OIL.) (see www.w3.org)
- Web Services for interoperability between different software applications (SOA; see www.w3.org/2002/ws/)
- Or OWL-S (see http://www.daml.org/services/owl-s/) to allow the description of the properties and capabilities of Web services in an unambiguous, computer-interpretable form.

2.4.4.4 Service Interaction:

Concerning service interaction examples of quite mature standards for technical tools, specification models and design methodologies (also for accessibility and usability) in the market or in development are:

- ISO 13407 Human-centred design processes for interactive systems
- ETSI EG 201 472 HF: Usability evaluation for the design of telecommunications systems, services and terminals.

- ISO/DIS 9241-20 Ergonomics of human-system interaction – Part 20 Accessibility guidelines for information/communication technology (ICT) equipment and services (in development phase)
- DIN-Norm 33455 for barrier free products, policies and requirements
- Web accessibility initiative that refers to the practice of making websites usable by people of all abilities and disabilities (W3C's Web Accessibility Initiative (WAI), http://www.w3.org/WAI/, Guidelines: (http://www.w3.org/WAI/intro/wcag.php)
- "Design for all" that specifies some requirements for designing devices that are manageable by people of different age groups with special respect to security, children, elderly and handicapped people
- DIN EN ISO 6385:2004-05 that describes policies for ergonomics

There is a big lack of user interaction in the distributed environment in terms of the variety of different available services and functions. The objective must be to have specifications that cover technological platforms including authoring and simulation frameworks as well all the necessary technical tools, specification models and design methodologies (also for Ambient Assisted Living accessibility and usability). Service interaction in a form that was intended by Ambient Intelligence means much more than definitions and specifications of menu-oriented, dialogue-oriented, goal-oriented vs. function-oriented approaches or even multimodal issues. We think that an integrated approach to guarantee integrated service access means integrating interaction issues in service description standards.

2.4.5 Changes under way in the standardization process for the CPS sector

Changes under way in the standardization process for the CPS sector include:

- Increasing emphasis on the formalization of industry organizations so as to shorten the endorsement cycle at the official standard body (e.g. ETSI, ISO, IEC).
- A push to adopt international standards by several bodies (ETSI, ITU, IEEE, IETF) co-opting same (or similar) standards.
- Growing concern about the IPR embedded in the standards. There is a need to regulate the conditions for use of standards and define the rules for IPR that might be part of the standards. The notions of royalty-free (RF) or fair, reasonable, and non-discriminatory (FRAND) standards are becoming important topics (ISO and IEC have already adopted a common strategy).
- New organizations and forums are appearing to address specific areas still not covered by existing organizations; **this may imply convergence and interoperability issues across domain and device boundaries for cooperating objects, ubiquitous computing, ambient environments!!!**
- **Tool interoperability: interoperability is becoming a severe concern.** Approaches are being taken, e.g. by OASIS (OSLC group, see further information on IOS) and the OMG SysML task force. The latter has established a working group on interoperability. All the tool providers have worked together to share common examples and XMI formats. Based on the success of test cases, the OMG BPMN task force started the interoperability working group that is progressing very well.

2.5 Standardization to Meet New Challenges

Recent developments in international standardization are very promising, ARTEMIS members are involved in many of them driving in the right direction as indicated by the ARTEMIS SRA priorities and research challenges addressed.
In terms of international standardization, awareness is rising particularly for the topic of Smart Manufacturing, Safety, Reliability and Cybersecurity in industrial automation and control, transportation, smart cities, buildings and associated targets, in Cloud Computing including particularly Cloud Security, and IoT as a complex, but moreover the overarching topic of standardization.

2.5.1 Functional Safety and Human Factors in Industrial Domains and Transportation

A short note about "human-in-the-machine-loop": the relevance of supporting humans in connection with highly automated (autonomous) systems, smart manufacturing and industry 4.0, in monitoring, controlling, interaction and cooperation with such systems, replacing conventional indicators and displays, technologies like Augmented and Mixed Reality (AR, MR) is growing for CPS scenarios such as https://www.youtube.com/watch?v=efMIVaZLk-E, demonstrating a strategic new approach.

By way of example, the application of CPS – Cyber-Physical systems – in the oxygen level control of an additive manufacturing system prevents titanium corrosion. The CPS comprises

- Wireless sensors
- A sensor inductive supply system
- Position detection radio beacons.
- A decision support system
- A digital platform with data repository
- Protection against cyberattacks
- A vibrating bracelet.
- Augmented reality helmet
- Augmented reality software.

There are many standards related to AR, and particularly helpful in an industrial environment/scenario are geo-location based AR methods. One main standardization body is OGC (Open Geospatial Consortium) (see chapter 2.5.6).

Within IEEE there is a VRAR (Virtual Reality and Augmented Reality) working group helping to develop the emerging standard IEEE P2048 (http://standards.ieee.org/develop/wg/VRAR.html).

P2048.5 - Standard for Virtual Reality and Augmented Reality: Environment Safety from IEEE - sets its scope as (citation): *"This standard specifies recommendations for the workstation and content consumption environment for Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and all related devices where a digital overlay might interact with the physical world, potentially impacting user perception. This standard focuses on setting quality assurance and testing standards for qualifying products in these environments, achieving satisfactory safety levels for the creation and*

consumption environment for all or the majority of related products available for consumer and commercial purposes."
Even in the context of conventional "Functional Safety Standardization", IEC TC 65, WG 17 is working on a TR (Technical Report) on human factors and functional safety (see 2.5.2).

2.5.2 Functional Safety and Cybersecurity in Industrial Domains and Transportation

IEC TC65 [6], Industrial-process measurement, Control and Automation, had started an ad-hoc group AHG1 to investigate the issue of coordinating safety and security, and was looking at a broad variety of domains and standardization groups starting to think about including (cyber-)security aware safety considerations. This had already been achieved in part in IEC 61508, Ed. 2, by a group with members from ARTEMIS-IA.

It is now also starting in the railway sector (DKE in Germany, integrating requirements from IEC 62443 in the railway standards (proposal, addressing EN 50129 and EN 50159 issues) in DIN VDE V 0831-104 "Electric signalling systems for railways – Part 104: IT Security Guideline based on IEC 62443".

IEC TC44 (Safety of machinery – electro-technical aspects) has started a new work item as well, somehow triggered by the general IEC concerns on cybersecurity impact on safety: "Security aspects related to functional safety of safety-related control systems". IEC 62061 from TC44, Safety of Machinery, is a domain-specific standard implementing IEC 61508 for machinery. It is listed in the Official EU Journal since 31.12.2005 as a standard with presumption of conformity with EC Machinery Directive 2006/42/EC. A guideline for using IEC 62601 and ISO 13849-1 (general machinery safety standard) was jointly developed and published by IEC TC 44 and ISO/TC 199 (safety of machinery) (IEC/TR 62061-1 and ISO/TR 23849).

In the meantime, AHG1 has completed its work with a report recommending preparation of an IEC TS on the topic "Framework to bridge the requirements for Safety and Security" and started a new working group IEC TC65 WG 20 under this title. There have been already a few Face-to-Face meetings (one in Vienna at AIT) and work is done via web and telephone conferences (almost monthly). Our goal is to keep our ARTEMIS-triggered intention to foster safety & security co-engineering and remain at a level to produce a basic safety & cybersecurity standard bridging IEC 61508 and IEC 62443 for industrial automation. This impacts not only production facilities and manufacturing industries, but also related industries in the transport, logistics, machinery and energy sectors. A further concern is to keep this notion in line with the developments in e.g. other domain-specific standards where ARTEMIS-IA members are active (e.g. automotive cybersecurity engineering, as explained later).

The "Human factors and functional safety" group IEC TC65 WG17 successfully restarted with a new convenor, Mr. Schaub, IABG, in Munich (Ottobrunn) from 4.-5.10.2016. The intention is now to write a TR (Technical Report) instead of a TS (Technical Specification) because this is easier to accomplish and finalize. This report should be fed into the IEC 61508 update cycle for Ed. 3.0 (or later), so it made sense for ARTEMIS project partners who are involved in IEC 61508 Ed. 3.0 to take part.

The maintenance cycle for IEC 61508-3 (Software) started in a "preparatory mode" two years ago because so many software paradigms that had arisen in the meantime are already used in safety-critical systems' development but not covered by existing standards (or even quasi "forbidden"). Hardware- and systems people were not so eager to start (Part 1 and 2), but they are impacted by some of the proposed changes in IEC 61508-3 as well (because in many cases the system aspect is most important, not just software or hardware). Some concepts developed and explored in ARTEMIS projects, like contract-based development, run-time certification and guidelines or mandatory requirements to achieve security-aware safety have already been brought into the maintenance cycle as topics.

In the automotive domain, with the start of the work on Ed. 2.0 (ISO 26262: 2018) of the functional safety standard for road vehicles, the scope was extended to trucks, buses, certain types of off-road vehicles, and motor cycles (part 12). A completely new part 11 was developed for semiconductors addressing the challenges of new semiconductor chips and their assessment and analysis in a system context. This fits in very well with the challenges listed in the ARTEMIS SRA 2016, see 2.3.5. Proposals were forwarded to ISO TC22 SC32 WG08 (ISO 26262) by AIT concerning the need to address the interaction between safety and security as part of the mitigation of the potentially dangerous cybersecurity impact on safety. This was triggered by the work done in several ARTEMIS projects, e.g. ARROWHEAD and EMC², for high security in automation. There are significant changes and additions now in ISO 26262 DIS (2017).

Unfortunately, an important part on "SotiF – Safety of the intended Functionality" could not be included in the current Ed. 2.0 (2018) version, but will be continued as a PAS 21448 (Publicly Available Specification) [15] to be later integrated into ISO 26262 (Ed. 3.0?) or become a separate standard (not decided at the moment). This part could be most important for self-driving autonomous vehicles because without failure of a component or constituent in the sense of ISO 26262 Ed. 1.0, a system may fail in its intended functionality e.g. by wrong interpretation of sensor input, unexpected environmental conditions and wrong perception of a situation. However, a majority of national mirror committees considered it not to be sufficiently mature at the moment for inclusion in ISO 26262:2018. Nevertheless, the SotiF issue will play an important role in many application areas of highly automated systems of all kinds as well in highly automated M2M systems.

Since both sides, SAE and DIN/DVA, proposed cybersecurity automotive engineering standardization work items, a PSDO agreement (Partnership Standards Development Organization) recently signed between ISO and SAE came into force by founding a joint working group ISO/SAE JWG1, which should develop an agreed standard, now called "Road vehicles – Cybersecurity engineering" (in ISO: ISO TC22 SC32 WG11). This type of cooperation between two groups organized in such totally different ways, with different voting and decision mechanisms, is absolutely new. The kick-off meeting was in Munich, 19.-21.10.2016. Our goal was, as mentioned above, to keep developments in line with other cybersecurity/safety standards and co-engineering. The first ideas collected in brainstorming groups at the kick-off meeting look quite promising for a holistic solution which would conform somehow with the results of EMC² and ARROWHEAD (and related ARTEMIS/ECSEL projects). ARTEMIS-IA partners like AVL and AIT were active at this meeting. This is another good example that overarching topics have to be addressed jointly.

2.5.3 Smart Manufacturing Standardization

But this was not the only resulting process towards rather holistic approaches in IEC TC65 and SC65A: In the recently established new ad-hoc working groups of IEC TC65 (Industrial process measurement, control and automation) AHG2 (Reliability of Automation Devices and Systems, meeting 1.-3.6.2016, Vienna, AT) and AHG3 (Smart Manufacturing – Framework and System Architecture, kick off meeting 4.4.-6.4.2016, Frankfurt, DE, a follow-up meeting again in Frankfurt from 11.-14.10.2016) the forthcoming topics to identify frameworks for smart manufacturing on a higher level are another opportunity to disseminate and find a path to standardization for ARTEMIS SRA 2016 strategies (selected topic "Sustainable Production"), based on the Industry 4.0 RAMI 4.0 reference model. In complement, IEC SC65E (Devices and integration in enterprise systems) started with an ad-hoc group AHG1 (Smart Manufacturing Information Models), covering the aspects of information models for exchange in the context of enterprise systems, which has some impact on the work in IEC TC65A AHG3.

Since standardization in the field of machinery (except the electro-technical aspects) is done in ISO TC 184 and ISO TC 199, voting for a new work item is happening right now in a joint working group ISO/IEC JWG21 "Smart Manufacturing – Reference Models" between IEC TC 65 and ISO TC 184, which is supported by several countries of ARTEMIS members and project partners, some of them already active in this process.

2.5.4 M2M (Machine to Machine) Communication and IoT (ETSI, oneM2M)

ETSI is one of the European Standardization Organizations (ESOs) officially mandated by the European Commission to take care of M2M Communication Standards and Compliance Testing in this area. Important industries and research organizations worldwide (not just from Europe) are members of ETSI (in total 819, including industry, SMEs, operators, RTOs and Universities), working on communication standards, also in (cyber-) security and some industrial sectors. Many ARTEMIS partners are ETSI members, and a few persons are directly involved in ETSI. ETSI is fully financed by its members and projects (e.g. EC mandates), so all standards can be downloaded from the ETSI websites free of charge.

Machine-to-Machine Communication is a key issue today – it is of interest for ARTEMIS members not only to use existing standards but also to try to influence emerging standards.

In the case of M2M, ETSI is a key member of oneM2M, an alliance to develop global standards in the M2M and IoT field.

Formed in 2012 by eight of the world's leading information and communications technology (ICT) standards development organizations, with more than 200 member companies, oneM2M provides a necessary framework for interoperability between the many M2M and IoT technologies being introduced. oneM2M is developing globally agreed, access-independent, end-to-end specifications for an M2M and IoT communications and management system that can be easily embedded within various hardware and software. oneM2M is experiencing major growth and progress towards connecting billions of devices in the field with the worldwide M2M application servers that power the IoT.

Existing oneM2M's specifications include:

- TS 0001: Functional Architecture
- TS 0002: Requirements
- TS 0003: Security Solutions
- TS 0004: Service Layer Core Protocol
- TS 0005: Management Enablement (OMA)
- TS 0006: Management Enablement (BBF)
- TS 0007: Service Components
- TS 0009: HTTP Protocol Binding
- TS 0010: MQTT Protocol Binding
- TS 0011: Common Terminology
- TS 0012: oneM2M Base Ontology
- TS 0014: LWM2M Interworking
- TS 0015: Testing Framework
- TS 0020: Websocket Protocol Binding
- TS 0021: oneM2M and AllJoyn Interworking
- TS 0023: Home Appliances Information Model and Mapping
- TS 0024: OIC Interworking
- TR 0001: Use Cases Collection
- TR 0007: Study of Abstraction and Semantic Enablements
- TR 0008: Security
- TR 0012: oneM2M End-to-End security and Group Authentication
- TR 0016: Study of Authorization Architecture for Supporting Heterogeneous Access Control Policies
- TR 0017: Home Domain Abstract Information Model
- TR 0018: Industrial Domain Enablement
- TR 0022: Continuation and Integration of HGI Smart Home Activities
- TR 0024: 3GPP Release 13 Interworking

To view the specifications in detail, please visit: http://www.onem2m.org/technical/published-documents

Interoperability: oneM2M's specifications enable interworking with the following popular IoT device systems:

- AllSeen Alliance's AllJoyn
- Open Connectivity Foundation's IoTivity
- Open Mobile Alliance's Lightweight Machine-to-Machine

Security: oneM2M's specifications provide enhanced security by enabling secure information exchange between applications and host servers, as well as implementing security and access control, allowing dynamic authorization of new devices during device on-boarding. While oneM2M has a horizontal approach to IoT, different applications may have very different security needs. IoT security has the following specificities:

- Is more difficult to achieve due to "constrained environments" (harsh operating conditions, limited CPU resources, battery power, unattended objects)
- Is very critical as IoT systems often directly control actuators that affect our physical environment (e.g. insulin pump, autonomous car), hence attack on the system may directly affect safety

Experts developing and deploying IoT applications tend to be field domain experts so may not be acquainted with cybersecurity risks.
Despite the diversity of application's security needs, a Service Layer standard such as oneM2M can build on the experience and expertise already accumulated by the ICT industry, to provide M2M application developers with a "toolbox" of security tools able to address the needs of most IoT applications.

IoT applications supported by M2M: The oneM2M architecture, standards and specifications provide a common means for communications service providers to support applications and services for many different industries, including:

- eHealth and telemedicine
- Enterprise automation
- Transportation
- Energy
- Public services

Related standards that are widely used in the industry or defence sector include OPC-UA, MTConnect, MQTT, specific DDS implementations etc. OPC Unified Architecture (**OPC UA**) is a machine-to-machine communication protocol for industrial automation developed by the OPC Foundation.

2.5.5 Joint IoT (Internet of Things) Standardization in ISO and IEC

There are already many fragmented standardization activities around (I)IoT, (Industrial) Internet of Things, because IoT is not just one technology but a huge variety of technologies and technology areas, so IEC and ISO list a huge number of "related standards".

Therefore there are many competing standardization activities in (I)IoT, such as (but not an exhaustive list)

- ISO/IEC JTC1, WG 10, Internet of Things; SWG 5
- ISO/IEC JTC1, WG 7, Sensor networks
- ISO, IEC: Many IoT relevant related standards in the communication area
- IEEE: many IoT related standards and standards projects: IEEE has an ongoing IoT Ecosystem study and the IEEE P2413 draft standard for an Architectural Framework for the Internet of Things
- ITU working group SG20 on "IoT and its applications, including smart cities and communities",
- IPSO alliance where Internet technology IETF standards like 6LoWPAN and CoAP are developed and supported

- Particular protocols, e.g. the open AllJoyn protocol, now supported by the AllSeen Alliance (Qualcomm, Cisco, Linux, MicroSoft, …)
- Open Interconnect Consortium (Intel, Atmel, Dell, Samsung, WindRiver, …)
- Thread protocol (Google)
- Particular protocols for e.g. home devices etc.

Without claiming being exhaustive, a list of IoT-related ISO Standards comprises:

- ISO/IEC CD 20924 - Information technology -- Internet of Things (IoT) -- Definition and vocabulary
- ISO/IEC WD 30141 Internet of Things Reference Architecture (IoT RA)
- ISO/IEC FDIS 29341-30-2 Information technology -- UPnP Device Architecture -- Part 30-2: IoT management and control device control protocol -- IoT management and control device
- ISO/IEC FDIS 29341-30-1 Information technology -- UPnP Device Architecture -- Part 30-1: IoT management and control device control protocol -- IoT management and control architecture overview
- ISO/IEC FDIS 29341-30-10: IoT management and control device control protocol -- Data store service
- ISO/IEC FDIS 29341-30-11: IoT management and control device control protocol -- IoT management and control data model service
- ISO/IEC FDIS 29341-30-12: IoT management and control device control protocol -- IoT management and control transport generic service
- ISO/IEC 29161 Information technology -- Data structure -- Unique identification for the Internet of Things
- ISO/IEC AWI 18574 – 18577: Internet of Things (IoT) in the supply chain

It is of interest that the ISO/IEC JTC1 (Joint Technical Committee 1) has just now decided to propose the foundation of a new Subcommittee ISO/IEC JTC1 SC41 “Internet of Things and related Technologies”. These efforts are being undertaken to avoid duplicating standards, overlapping standards and unclear, diverse terminology – the overall (international) standardization landscape is already very fragmented and diverse, so every attempt at cooperation is supported by research and company members. These activities to align standardization with the new technology and market developments (emerging and disruptive) can be only be judged positively, and hopefully will be successful in simplifying and aligning the diverse issues arising, particularly in disruptive cross-domain areas like IoT, Cloud Computing, Smart Anything, where there are always many existing but not holistic standards.

2.5.6 ARTEMIS Standardization and AIOTI – Alliance for Internet of Things Innovation

IoT is becoming a more and more intriguing issue. The recently founded AIOTI has worked in 11 Working Groups on Recommendations for an IoT Research Programme for the European Commission, and the first IoT Calls were issued in 2016. WG 3 on “Standardization” has issued three documents:

1. IoT LSP Standard Framework Concepts (LSP means “Large Scale Pilots”, an EC Large Projects’ Initiative)
2. IoT High Level Architecture
3. Semantic Interoperability

Particularly in 3.), tools are addressed, and more precisely the need for appropriate tools and semantic interoperability. In the IoT environment, the landscape is even more fragmented than it was 10 years ago in the embedded system environment, so there may be another option here for the application of the IOS – ICF ideas in this fast evolving field.

It should be mentioned that the European IoT Community in Research founded AIOTI (Alliance for Internet of Things Innovation) which this year became an Association as a first step towards a cPPP (contractual Public-Private Partnership) to be able to influence future European Research Pogrammes in IoT. AIOTI currently has 13 Working Groups.

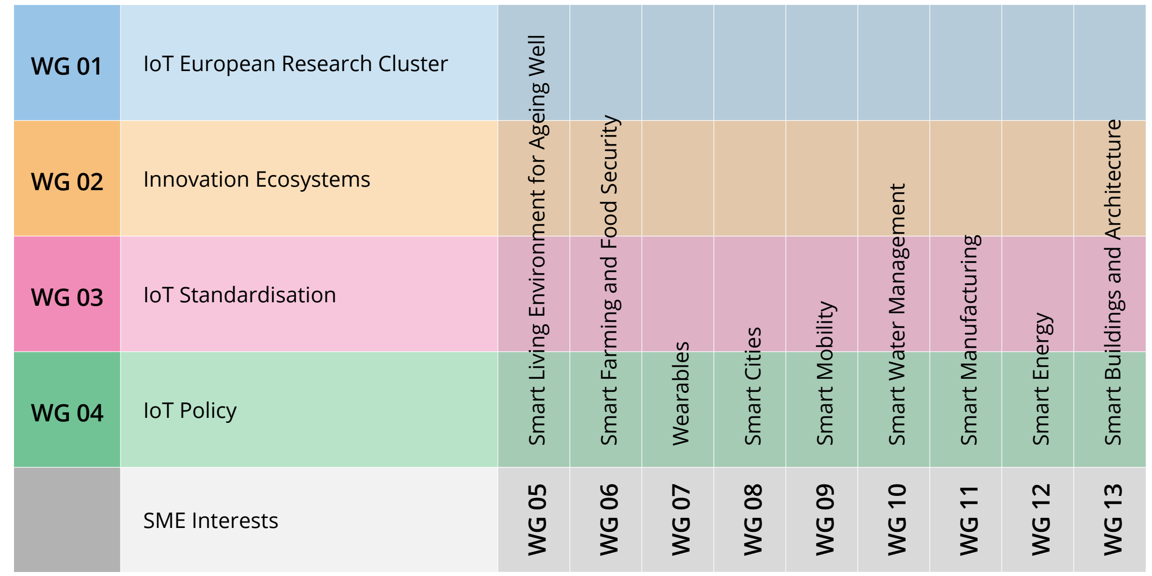

Figure 6 *Structure of AIOTI Working Groups*

As can be seen in Figure 6, most domain-related Working Groups are of interest for ARTEMIS. Therefore, ARTEMIS-IA has become member of AIOTI whose members already include several ARTEMIS-IA members. The goal is to join forces, since IoT is a major challenge for CPS in research and development, as outlined in the ARTEMIS SRA 2016. ARTEMIS-IA has expressed its intention to become member of WG3, standardization, which provides a very good fit with the overall strategy and the ARTEMIS Strategic Agenda for Standardization. AIOTI itself is not a standardization organization but it has close cooperation with international standardization organizations, including ETSI, ITU-T, CEN/ISO, CENELEC/IEC, IETF, IEEE, W3C, OASIS, oneM2M and OGC (Open Geospatial Consortium).

2.5.7 Standards in the Cloud

To facilitate Cloud Computing and Communication in a secure and reliable manner, also in the case of safety-relevant or safety-critical or highly availability-driven applications (e.g. smart energy, smart mobility, smart cities, smart health, etc.), a Joint Working Group of ISO and IEC was already created some time ago. The Joint Technical Committee of ISO and IEC, JTC1, Subcommittee 30 ("Distributed Application Platforms and Services") started foundational work on the Cloud Computing Standards:

- ISO IEC 17788 – Cloud computing – overview and vocabulary
- ISO/IEC 17789 - Cloud computing - Reference architecture,

These standards are recommended and supported by ITU-T, the International Telecommunication Union. In the meantime, related standards like ISO/IEC 19831:2015 have been published ("Cloud Infrastructure Management Interface (CIMI) Model and RESTful HTTP-based protocol").

New standardization projects are another window of opportunity for ARTEMIS/ECSEL project partners, particularly when not just file services but more complex digital industrial services should be addressed in future:

- Service level agreements,
- Interoperability and portability,
- Data and their flow across devices and cloud services,
- Security issues

This covers the main topics of interest of the work done in ARTEMIS/ECSEL for the Platform and Framework activities. Involvement in these groups is encouraged, but this is a mid-term goal because it takes several years and needs consensus in sometimes diverse groups and group interests.
Besides ISO/IEC, a number of standards and specifications from IETF, W3C and OASIS are relevant in the area of Cloud and Web Services. For addressing many common security requirements standardized protocols and specifications can be used, like SSL/TLS (RFC 5246), IPsec (RFC 4301), XML Signature and XML Encryption, SAML, XACML and others (see [2], Chapter 10 of ARROWHEAD Book). The IPSO Alliance and IETF are examples of ARROWHEAD solutions finding their way into standards. Standardization as an ARTEMIS SRA Priority has already been successful in many cases, and only a few recent examples have been mentioned here.

3

THE ARTEMIS INTEROPERABILITY SPECIFICATION(S)

3.1 Introduction

The development and engineering of Cyber-Physical Systems poses huge challenges, caused (a) by their ever increasing complexity and functionality and (b) by strong requirements on their properties like safety, security, reliability, and many more. To assist developers in this task, many different software tools exist and are used by OEMs and Supplier industries. These tools assist developers in all phases of the development process – from specification via implementation to integration – covering a wide spectrum of so called 'Engineering Concerns', such as requirements engineering, software engineering, architecture exploration, validation, testing and many more, as well as 'Management Concerns' like reporting, controlling, accounting and similar. Literally, more than 1000 of these tools are used today to build a new aircraft and several hundred to build a new car.

All of these software tools are proven in use and highly optimized to fulfil their respective tasks. However, they stem from different tool vendors and are not designed to work together, i.e., to exchange data or other information. In addition, the choice of which concrete tools are used for developing a specific CPS is an individual one for each developing team, and depends on the concrete CPS to be developed, on company policy, and on demands set by certification authorities or similar regulations. Developing companies therefore need to spend huge effort in setting up a so called 'Engineering Environment' for each CPS they develop, in which the specific tools chosen for the specific development project are combined and can exchange data, allowing fast and efficient development of CPS as well as smooth cooperation of all stakeholders (e.g., engineers, system architects, product managers, decision makers or analysts). This integration, however, poses huge challenges for CPS developing organizations, which are stuck between two extremes: either to develop their own hard-to-maintain, in-house and ad-hoc Engineering Environments or to be locked-in with proprietary solutions, which are typically not fully tailored to support their special needs.

To overcome this challenge, past and ongoing large-scale R&D projects – most in the context of the Joint Undertaking ARTEMIS, e.g., iFEST, CESAR, MBAT, HOLIDES, CRYSTAL and others – have proposed open standards for data and tool interoperability in CPS development, namely the so called **IOS (Interoperability Specifications)**.

The Interoperability Specifications cover many different aspects and all phases of the development process. Although originally envisioned to be a single specification, it became quickly clear that it is neither feasible nor particularly desirable to put all these concerns within a single standard. In addition, there is already a number of standards that cover interoperability and/or data exchange between engineering tools, each of them covering specific aspects of CPS development, and it would be unwise not to take advantage of their existence and the trust that stakeholders already put into their usability.

The IOS therefore consists of different parts, each of which (a) deals with a specific aspect of CPS development (so called Engineering Concern), like for example *Lifecycle Data Integration and Data Exchange* or *Heterogenous Co-Simulation* and (b) is based upon existing standards and possible extensions of them, whenever an appropriate standard exists. For *Lifecycle Data Integration and Data Exchange*, the underlying existing standard is OSLC (Open Services for Lifecycle Collaboration, see http://open-services.net/), for *Heterogenous Co-Simulation* FMI (Functional Mock-Up Interface, http://www.fmi-standard.org) is under consideration.

There are several noteworthy issues to bear in mind regarding the structure of IOS:

A IOS parts based on an existing standard do not necessarily include all the specifications of this particular standard, but only those parts that are relevant for the respective Engineering Concern.

B IOS also includes specifications that are not yet part of an existing standard. These are either extensions of existing standards (if the standard does not yet completely cover the Engineering Concern), or as an independent specification (if there is no existing standard yet covering this particular Engineering Concern).

C IOS also includes so called Bridges that describe the relationships between the different Engineering Concerns and the corresponding interoperability specifications and standards. These bridges are essential to guarantee that the IOS indeed covers the whole development process, yet they are specifications that by definition do not belong to a single (extension of an) existing standard.

The figure below illustrates this particular structure of the IOS. Since IOS combines and extends specifications from different existing standards together with new ones, we call it a **Multi-Standard**.

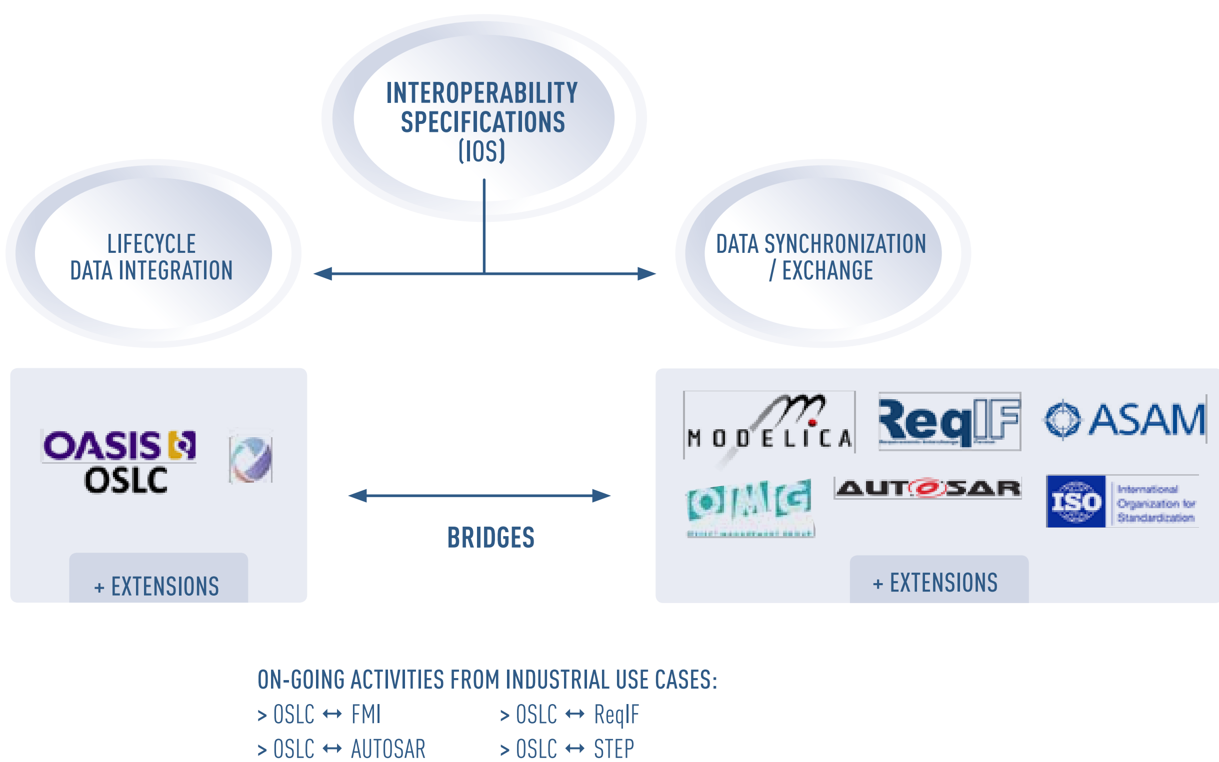

Figure 7 *IOS Structure (from ARTEMIS project CRYSTAL)*

3.2 The Multi-Standard Approach

Structuring the IOS as a Multi-Standard (c.f. previous section) has a number of highly valuable advantages:

- **Stakeholder Trust and Completeness of Specification**. Using existing standards and specifications, that have already proven their usefulness for specific Engineering Concerns and that have managed to gather a sufficiently large community of stakeholders behind them to warrant the existence of a formal standard, increases the trust that stakeholders put in the IOS specification and thus furthers industrial acceptance. On the other hand, by allowing (a) the IOS to include both extensions to these existing standards and specifications that are not based on an existing standard, and (b) especially by having bridge specifications within the IOS that describe the relations between different parts of the IOS, it is guaranteed that the IOS can indeed cover *every Engineering Concern* throughout the *whole development process*.
- **Focused Specifications**. Breaking down the IOS in parts – essentially one for each Engineering Concern addressed – and allowing each part to include (a) relevant parts of an existing standard or specification as well as (b) extensions/modifications of this existing standard or (c) new specifications not based on any existing standard enables the definition of specifications that are ideally focused on each particular Engineering Concern. Compared to the initial idea of having one IOS specification for all Engineering Concerns, the advantage of a Multi-Standard is obvious.
- **Stakeholder focus**. In the same way that the IOS is focused on each particular Engineering Concern, a Multi-Standard also allows stakeholder attention and activity to be focused on those parts of the specification that are relevant for them. Especially when tool interoperability is concerned, many stakeholders, e.g., the tool vendors, are only interested in very specific Engineering Concerns, namely those for which they develop tools. Although each stakeholder needs to be able to get any information and specification from the whole IOS, their active participation, their efforts and their activities can easily be concentrated on exactly those parts of the IOS that concern them.

However, a Multi-Standard also imposes new challenges regarding formal standardization, extensions and industrial acceptance. All of these challenges have their root cause in the lack of a single place or organization, where all information about the specification is available, and that can serve as a focal point for harmonization and coordination of stakeholder activities.

For 'Single-Standard Specifications', an appropriate standardization approach is described in section 4.1. of this document. It involves as a central point the choice of a standardization body, in which stakeholders form a working group or similar to develop and, at a later stage and if need be, extend the standard. A Multi Standard can – by definition – not be mapped to a single standardization body. In addition to involving multiple existing standards probably hosted by different standardization bodies, it typically also involves parts that are either not at all or at least only weakly connected to existing standards and specifications. Once the Multi-Standard reaches a certain 'size', i.e., it involves a non-trivial number of parts, each of them either based on an existing standard or on no standard, and/or it involves a non-trivial number of stakeholders whose main interests are in different parts of the Multi-Standard, the following essential activities become almost impossible:

- **Extensions of the Multi-Standard.** Finding gaps in the specification – i.e., in the case of IOS, identifying Engineering Concerns that are not yet covered at all by the specification or that are not yet covered in sufficient detail or maturity – requires an up-to-date overview of what is and what is not covered by the specification. With the IOS, the same goes for the definition of bridges (i.e., specifications that describe the relations between various parts of the IOS), which require in-depth knowledge of the two IOS parts that are to be bridged.
- With this information scattered amongst various publicly funded projects with various, sometimes overlapping, extensions to some IOS parts, various existing standards being used as a basis for existing parts, and various repositories that host some, but not all, specifications of IOS parts, compiling this overview is challenging, to say the least.
- **Pursuing formal standardization of (parts of) the Multi-Standard.** Standardization requires the strong involvement of a sufficiently large number of stakeholders that 'push' this specification to a formal standard (or, as is sometimes the case for IOS, 'push' inclusion of extensions into existing standards). This process tends to take a long time, normally longer than what is available in a typical project after the results that are to be standardized have been acquired. To continue this work, stakeholders need a place where they can gather, discuss and work on the formal standardization. For Single Standards, this is normally done within a working group of a chosen standardization body. For a single part of a Multi-Standard, this might be possible, too. However, because of the interconnected nature of the different parts of a Multi-Standard, good knowledge is needed about the state and the maturity of 'neighbouring' parts (especially bridges). As in the case of extensions, this knowledge is difficult to compile.
- **Industrial take-up.** The usefulness of any (multi-)standard is measured by its industrial take-up; in the case of the IOS this essentially means by the number of tools that implement the IOS (or, to be more precise, those IOS parts that are relevant to their purpose). With a Multi-Standard with scattered information like the IOS, industrial take-up is hindered by the fact that it is extremely difficult to get to the current, most up-to-date specification of any IOS part.
- **Coordinated, harmonized and focused effort of stakeholders.** Although a Multi-Standard allows each individual stakeholder to focus their effort to exactly that aspect or part of the specification that they are interested in, some standardization activities greatly benefit from the harmonized, coordinated effort of stakeholders. Decisions like 'what extensions should be developed with highest priority?', 'which part of the specification should be formally standardized and with which priority?', 'given a planned extension of a specific part of the specification, are there any implications for possible extensions of other parts?', and many similar decisions require coordination between stakeholders and harmonization of their respective goals. In case of a Multi-Standard, which cannot be mapped to a single standardization organization, the stakeholders lack a forum to coordinate their efforts and harmonize their goals.

For a Multi-Standard, it is therefore essential that a stakeholders establish some kind of organizational structure that

- Collects, maintains and makes accessible all information about the Multi-Standard, especially the current specifications of each part, their maturity level, links – if any – to standardization bodies, etc.
- Serves as a communication forum, i.e., as a place where stakeholders can meet (physically or virtually) to coordinate their activities, plan extensions of the specification and formal standardization of its parts, and which generally supports all of these activities.

In the specific case of the IOS (as the only known instance of a Multi-Standard now), the CP-SETIS project, funded from the Horizon 2020 ICT-1 call, set out to derive and implement such an organization structure for the Multi-Standard IOS.

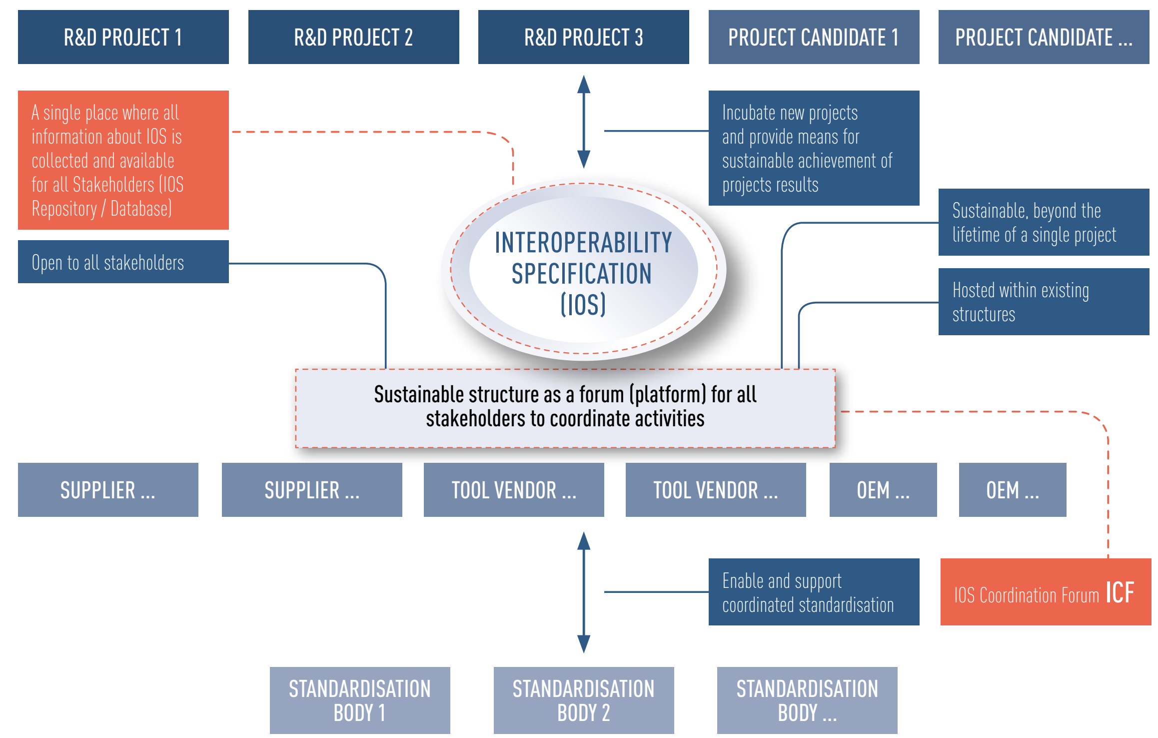

Figure 8 *ICF: The IOS Coordination Forum*

Figure 8 depicts the corresponding goals of the project: an organizational structure to be set up by CP-SETIS that serves as a coordination and harmonization forum for all IOS related activities of the stakeholders – here called the IOS coordination forum (ICF) – and that at the same time sets up and maintains the IOS Database, a place where all IOS related information is stored. This is described in more detail in Section 4.2.

As has been explained above, the existence of a coordination forum like the ICF is absolutely essential to handle Multi-Standards. To fully exploit the benefits of these kinds of forums even beyond the essential needs, one has to carefully exploit and weigh up implementation alternatives against each other:

- Obviously, the coordination forum needs to be sustainable, i.e. it has to have a lifetime that goes beyond the lifetime of typical projects. Defining the financing and organizational structure is therefore very important.
- The coordination forum needs to be independent and neutral to ensure openness of the specification as well as openness and equal participation rights for all stakeholders.
- The coordination forum needs to be, or at least to be supported by, a legal body, to be able to act as a legal entity (i.e., hire personnel, buy infrastructure, etc.). On the other hand, stakeholders often dislike creating 'yet another legal body'. Ideally, one would be able to establish this structure within an existing legal structure. Care has to be taken to choose this 'hosting structure', which needs to be neutral and sustainable as well as trusted by stakeholders so as to be fit for this purpose.

When these implementation alternatives are met, stakeholders can take full advantage of the benefits that such a coordination forum offers (in addition to being the only effective way in which a Multi-Standard can be handled). They can

- use ICF as an independent, neutral forum, to meet other stakeholders at eye level
- find allies
  - i.e., for standardization activities and project incubation
- find experts for the Multi-Standard to help them adopt it
- shape the Multi-Standard according to own needs regarding
  - extensions
  - further developments/concretization of existing parts
  - drive efficient, formal standardization
- be able to guarantee sustainability and accessibility for their Multi-Standard related project results
  - by bringing them into ICF and into the Database, where they are stored and publicly available
  - by advertising them
- be the first to know
  - current baseline or version of each part of the Multi-Standard
    - including maturity level of each part, thereby also allowing fast take-up
  - new extensions
  - standardization activities
- be able to focus on those parts of the specification that are actually of interest to them, while at the same time being aware of all Multi-Standard related activities

3.3 Possible Influence of IOS as a Multi-Standard on related standards for functional safety and IoT regarding Tool Interoperability

It was already noted at the beginning when describing the original ARTEMIS Standardization Agenda that tool interoperability had only been mentioned but no effort had been invested to look for particular standards in this respect. In functional safety standards the role of tools is considered with respect to qualification of tools required to be applied in a safety-critical context defined by SILs (Safety Integrity Levels in IEC 61508 and related standards like IEC 61511) and ASILs (Automotive Safety Integrity Levels, in ISO 26262).

3.3.1 Tool Qualification in IEC 61508-3 (2010)

In **IEC 61508-3** (Software part, software tools are addressed here), tool qualification requirements depend on their impact on code. Therefore, the standard differentiates between on-line support tools (which are critical and have to be evaluated as any critical software in the system, e.g. an Operating System) and off-line support tools. If the off-line tool impacts the run-time properties of the system, e.g. a code generator, it is of the highest criticality class T3; if it has an impact on the results e.g. of V&V, which is safety related, like a test case generator, it is T2 class (it cannot reveal a fault but the developer relies on the test results). Text editors, etc. are less critical (T1).

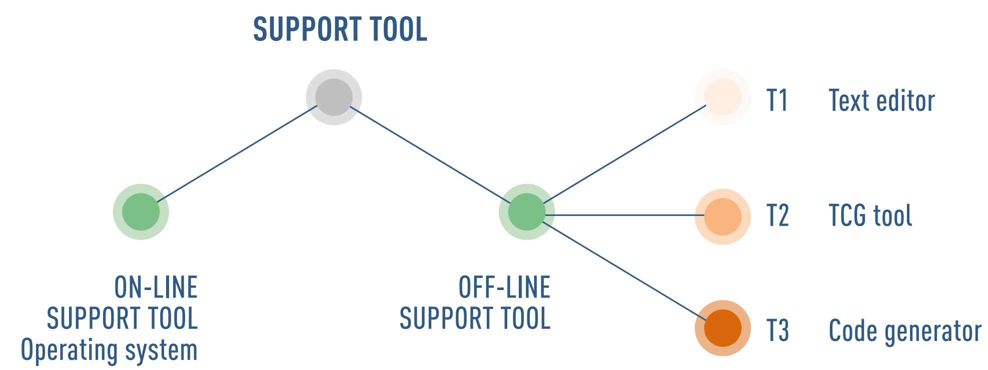

Figure 9 *Tool qualification in IEC 61508: Criticality classes T1, t2 and T3*

Citation from the standard:
Clause 7.4.4 in IEC 61508-3: some general requirements for **off-line support tools** are:

- Shall all be selected as a coherent part of the software development activities,
- Shall be selected to be integrated to minimize the possibility of introducing human errors,
- Selection and use shall be justified.

Support tools in classes T2 and T3 shall have

- A specification or product manual that defines the behaviour of the tool together with instructions and constraints on its use.
- To be assessed with the aim to determine the level of reliance that shall be placed on the tool, on potential failure mechanisms that may affect the executable software (T3 only).

Examples of how to achieve this:

- Perform software HAZOP,
- Restrict tool functionality,
- Check tool output
- Use diverse tools for the same purpose.

Requirement for T3 class tool applications:
Tool validation:
evidence shall be available that the tool conforms to its specification or manual, (Clause 7.4.4.7 in IEC 61508-3), e.g. based on a combination of history of successful use in similar environments and for similar applications (proven in use) and of tool validation.

Tool validation shall cover:

- A chronological record of the validation activities
- The version of the tool product manual being used
- The tool functions being validated
- Tools and equipment used
- The results of the validation activity; the documented results of validation shall state either that the software has passed the validation or the reasons for its failure
- Test cases and their results for subsequent analysis
- Discrepancies between expected and actual results
- Every new version of a support tool shall be qualified/certified.

Tools for software module testing with automatic test case generation:

- Annex C in IEC 61508-3 describes conditions to reach a required level of rigorousness for the assessment of software systematic capability properties.
- Model based testing techniques, high levels of rigorousness are reachable if TCG is used (e.g. Table C.5 in IEC 61508-3).

3.3.2 Tool Qualification in ISO 26262

In ISO 26262 we have a similar situation:
Qualification requirements of software tools covered by **Clause 11 of Part 8**:

- General Requirements similar to IEC 61508 (documentation, version handling)
- A certain confidence is required in that these tools shall achieve:
  - Minimization of the risk of systematic faults in the developed product due to malfunctions of the software tool leading to erroneous outputs
  - An adequate (SW) development process with respect to compliance with ISO 26262, if activities or tasks required by ISO 26262 rely on the correct functioning of the tool.

Two metrics for confidence, needs analysis of the tool and its role in the development chain:

1 **TI (Tool Impact):** Can the malfunctioning tool and its corresponding output introduce or fail to detect errors in a safety-related item or element being developed (TI1 if no error/detection failure possible, supported by argument, else TI2)
2 **TD (Tool error Detection):** confidence in preventing or detecting such errors in the output of the tool

A **TD1:** high confidence that malfunction / erroneous output will be prevented or detected
B **TD2** medium confidence
C **TD3** other

Qualification can be done independently from development, but confidence level has to be confirmed.
Tool confidence level according to ISO DIS 26262:

	TD1	TD2	TD3
TI1	TCL1	TCL1	TCL1
TI2	TCL1	TCL2	TCL3

Table 1 *Confidence level according to ISO 26262*

TCL1: no qualification measures.
TCL2, TCL3: methods described in ISO DIS 26262-8, clause 11.4.6.
General: the higher the safety integrity level of the tool target, the more formal the requirements, e.g. for **TCL3** or **TCL2** in combination with **ASIL D**:

- The tool has to be developed in compliance with a safety standard (or a suitable subset of such), e.g. IEC 61508 or ISO DIS 26262.
- A validation according to ISO 26262 is required (ISO DIS 26262-8, clause 11.4.9.)

Tool confidence level according to ISO DIS 26262:

- Planning of the tool usage,
- Validation by analysis,
- Or: validation of tool development process.

Methods		ASIL			
		A	B	C	D
1a	Increased confidence from use in accordance with 11.4.7	++	++	+	+
1b	Evaluation of the tool development process in accordance with 11.4.8	++	++	+	+
1c	Validation of the software tool in accordance with 11.4.9	+	+	++	++
1d	Development in accordance with a safety standard [a]	+	+	++	++

[a] *No safety standard is fully applicable to the development of software tools. Instead, a relevant subset of requirements of the safety standard can be selected.*

EXAMPLE: DEVELOPMENT OF THE SOFTWARE TOOL IN ACCORDANCE WITH ISO 26262, IEC 61508 OR RTCA DO-178

Table 2 *ISO 26262 Qualification of software tools classified TCL3*

METHODS		ASIL			
		A	B	C	D
1a	Increased confidence from use in accordance with 11.4.7	++	++	++	+
1b	Evaluation of the tool development process in accordance with 11.4.8	++	++	++	+
1c	Validation of the software tool in accordance with 11.4.9	+	+	+	++
1d	Development in accordance with a safety standard [a]	+	+	+	++

[a] *No safety standard is fully applicable to the development of software tools. Instead, a relevant subset of requirements of the safety standard can be selected.*

EXAMPLE Development of the software tool in accordance with ISO 26262, IEC 61508 or RTCA DO-178

Table 3 *Qualification of software tools classified TCL2*

3.3.3 Tool Interoperability – the Tool Chain Issue in Functional Safety Standards

An important note was raised for first time, to my knowledge, in SafeComp 2012 by partner KTH: Tool Chain issues insufficiently (imprecisely) covered by Functional Safety Standards.

Since by now both IEC 61508 for Ed. 3.0 and ISO 26262 – 2018 are under revision and the tool qualification issue was discussed again, partners were able to raise awareness that the tool qualification requirements should be extended towards tool interoperability requirements if tool chains or IDEs are used for development and testing, including both data exchange protocols and semantic and data exchange interoperability. This may be a "window of opportunity" if the right approach is identified and requirements have already been drawn up from the side of CP-SETIS ICF.

3.4 The Multi-Standard Approach – a pattern for other standardization areas?

As already mentioned several times, the standardization landscape is very fragmented, not only concerning stakeholders, standardization organizations and sectors, but also even among competing organizations and working groups within the same standardization organization.

There are also many related standards, which are considered and worked upon independently, but not handled in a multi-standard approach as for the IOS for tool interoperability. In ISO and IEC, advisory committees and groups have some supervision of what is going on within the various Technical Committees, but this could be extended to similar concepts such as the ICF (IOS Coordination Forum, see Section 3.2) to achieve a more common, joint view of the standardization landscape. ISO and IEC in particular have managed to cooperate in certain areas by a JTC1 (Joint Technical Committee 1) with various working groups already mentioned in previous chapters, and a few special JWGs (Joint Working Groups) between TCs and WGs.

One example is shown in Figure 9, an overview provided by Bertrand Rique in IEC TC65 Ad Hoc Group 1 "Bridging the requirements of safety, security", which certainly requires a joint common view of the standardization landscape and the will to achieve some harmonization, which is only taking place partially. Another example could be the issue of tool qualification across several safety standards of different sectors and organizations.

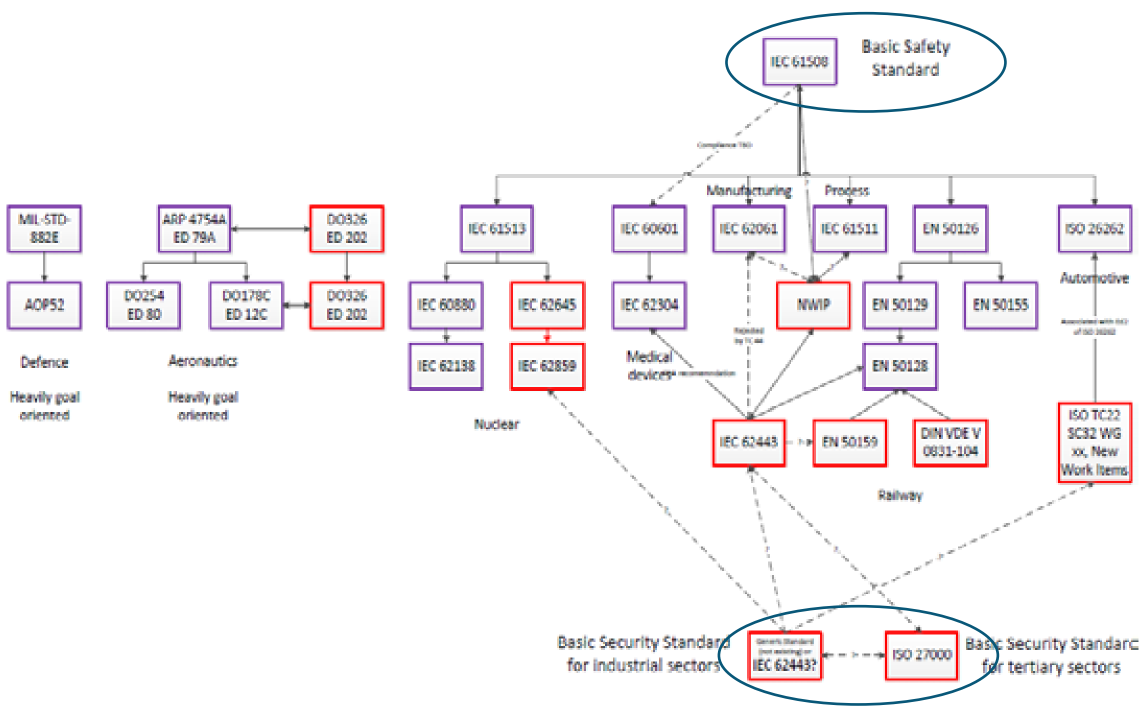

Figure 10 *A view of the International Standardization Framework of Safety & Security (Bertrand Rique, 2015)*

IoT and IIoT (Industrial Internet of Things) are other areas with the risk of diverging standardization activities:

- ISO/IEC JTC1, WG 10, Internet of Things; SWG 5
- ISO/IEC JTC1, WG 7, Sensor networks
- ISO, IEC: Many IoT relevant related standards in the communication area
- IEEE: many IoT related standards and standards projects: IEEE has an ongoing IoT Ecosystem study and the IEEE P2413 draft standard for an Architectural Framework for the Internet of Things
- ITU working group SG20 on "IoT and its applications, including smart cities and communities",
- IPSO alliance where Internet technology IETF standards like 6LoWPAN and CoAP are developed and supported.
- Particular protocols, e.g. the open AllJoyn protocol, now supported by the AllSeen Alliance (Qualcomm, Cisco, Linux, MicroSoft, …)
- Open Interconnect Consortium (Intel, Atmel, Dell, Samsung, WindRiver, …)
- Thread protocol (Google)
- Particular protocols for e.g. home devices etc.

Here the model of an ICF-like structure could be applicable – ARTEMIS-IA with its Standardization Working Group cooperating with AIOTI as an AIOTI member will engage in this direction or try at least to fulfil such a stakeholder-forum function unofficially – this could be part of the Standardization Agenda!

4

PROCESS-ORIENTED GUIDELINE TOWARDS EFFECTIVE STANDARDIZATION ACTIVITIES IN RESEARCH PROJECTS

4.1 The ARTEMIS/ProSE conventional "Single-Standard" Approach

The final ARTEMIS/ProSE Strategic Agenda for Standardization goes beyond just collecting, classifying and identifying gaps in the existing standardization landscape. It paves the way forward by providing guidelines and criteria for prioritization of standards activities which should help those responsible for the projects to focus on the most promising standardization activities and to find the most promising organization (in fact, there are often overlaps in standards between different types of organizations). Figure 10 shows the ProSE High Level Process (a candidate is a standardization item which should be evaluated according to criteria, if worth the effort of standardization (or being included in an existing/evolving standard):

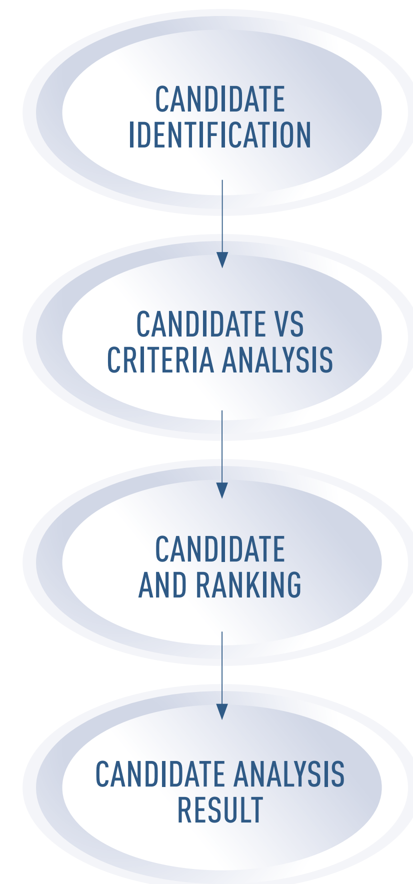

Figure 11 *ProSE High Level Process*

Table 4 shows the rather extensive list of criteria which could be applied when looking at just one standardization item for selection.

ID	CRITERIA	RATIONALE
1	Area	Does the candidate fall clearly into one or more of the ARTEMIS Application Domains?
2	Sub area	Does the candidate fall clearly into one or more of application sub-domains such as Automotive, Aerospace, Air Traffic Management, Railways, Medical Equipment (devices), Healthcare, Process Control, Manufacturing, Enterprise Management (different levels), Telecommunications, Ambient Intelligence, AAL (Private Space, Home), Infrastructure, Logistics, etc.?
3	Status	Does the candidate fall clearly into one of the three categories of existing, evolving or potential standards?
4	Promoted by	Does the candidate have clear promoters, significant for the field of embedded systems?
5	Rationale	Does the candidate have solid technical standardization objectives, significant for the field of embedded systems?
6	Activity	Does the candidate present evidences of sustained and substantial activity?
7	Acceptance	Does the candidate standardization activity have significance acceptance? Acceptance is key in several aspects, such as in training and technical staff availability. Finding staff, trained and experienced in standardized technologies is considerably easier – and hence cheaper – than finding the same staff trained to work with proprietary technology.
8	Scope	Does the candidate scope represent major benefits for the industry of embedded systems?
9	Impact	Does the candidate standardization activity provide improved sales efficiency?
10	Regulation / Bodies	Does the candidate present links with key regulatory or standardization bodies?
11	Synergy effect	Does the candidate provide evidences of possible cross-domain synergies across technical areas or application domains?
12	Market maturity	Does the candidate target mature markets, ready to embrace and accept standards?
13	Technical maturity	Does the candidate show technical maturity?
14	Improve competitiveness	Does the candidate standardization potential / impact provide increased market access and product or service acceptance?
15	European role	Does the candidate support the advancement of European Technologies?
16	Increase of efficiency	Does the candidate standardization activity support economies of scale, providing the means for systematic reusability of modules and artefacts?
17	Facilitating innovation	Does the candidate facilitate innovation by providing technical layers for actors that can benefit the candidate technology by developing innovative products and services on top of them?

ID	CRITERIA	RATIONALE
18	Enable interoperability	Facilitating interoperability and composability of standardized technologies and domains.
19	Increase quality	Does the candidate standardization activity provide the means for quality products/ services, through prototyping, testing, certification etc.?
20	Provide safety	Does the candidate serve the public by safe and dependable products?
21	Foster trade	Does the candidate standardization activity provide simplification of contractual agreements or lower trade barriers?
22	Lower regulatory barrier	Does the candidate lower regulatory barriers in national or regional markets by providing norms or recommendations required to deliver technologies in those geographical markets?
23	Openness	Does the candidate provide openness in for "open standards"?
24	Applicable in S/M term	Does the candidate standardization activity provide short-term market applicability? Products that use standards are less likely to require short-medium term replacement in order to integrate with other, newer products and standards organizations often provide migration paths to newer versions of standards that support next generation products.
25	Sustainability in the long term	Does the candidate standardization activity provide long-term market applicability? Investments are better protected since the market generally provides replacement for standards based products where technologies have to retire.
26	Cross-fertilisation	Does the candidate show potential for cross-domain applicability even if not considered from the beginning?
27	IPR management	Does the candidate standardization IPR policy deliver appropriate practices?

Table 4 *The ProSE criteria for candidate assessment*

The next step is (if the standardization item does not already fit an existing standardization group, e.g. IEC TC 65 SC65A, functional safety) to select an appropriate standardization organization. For this purpose, stakeholders (see Figure 11) and experts have to be included in the process to:

- Enrich standardization candidates in a way that proposed candidates reach a mature status to be successfully promoted, a standardization body is found and first contacts between body and candidates are established. Obviously this requires intense interaction between the promoting team and the stakeholders and experts (including standardization organizations). As the most efficient form of interaction, personal addressing (number one choice) and indirect addressing via workshops or booths on conferences were chosen.

- Broker standardization candidates to appropriate Standardisation Bodies means either initiating a new work item or influencing evolving standards respectively initiating or influencing maintenance of existing standards. Here, the promotion function does not aim at writing standards, but feels responsible for establishing contacts between responsible experts from the Standardization Bodies as well as from other stakeholders as appropriate.

Obviously both processes – enrichment and brokering – have to run in parallel, in order to identify most promising standardization candidates, help define a mature status (approved by the experts involved), identify standardization needs (regarding existing (maintenance phase, updating), evolving (influencing) and potential new ones in areas not yet covered), and establish contacts between promising standardization candidates and appropriate standardization bodies.

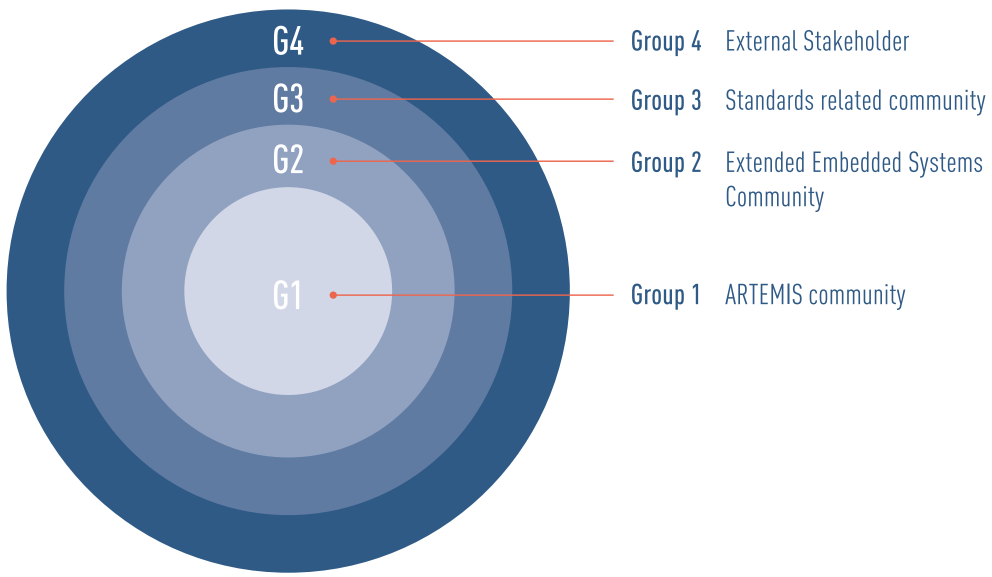

Figure 12 *ProSE Standardization Stakeholders*

4.2 The IOS-Multi-Standard-Approach

4.2.1 Short Description of the approach

As described in Section 3.1 and 3.2, the IOS harmonization of different research projects' efforts and results, and between different stakeholders, cannot be channelled into just one standardization line as originally was the intention (particularly based on OSLC, which is a group in OASIS), although several initial "success stories" and results, e.g. in CRYSTAL or MBAT/SafeCer, are based on OSLC adoptions. That requires a different, broader approach. The short description here is needed to understand the comparison in chapter 3.2.

The IOS is a specification for Tool and Data Interoperability in heterogeneous System Engineering development environments (c.f. Section 3.1). Therefore, it covers three aspects:

- Communication paradigms and protocols for exchanging information between tools and data repositories
- Specification of data exchange formats (syntax)
- Specifications of the semantics of information exchanged between tools and data repositories.

During the last few years, two main lines of IOS evolved:

- Lifecycle interoperability (to support collaboration, reporting, traceability, analysis etc.). This is based mostly on OSLC.
- Non-lifecycle interoperability (to support in-depth engineering activities (semantics, co-simulation, combined analysis and testing, variability management, formal static analysis etc.). In most cases this is based on existing, widely used and well established engineering standards

This short description already demonstrates that the IOS cannot be a single specification. We have to look at a set of standards, specifications and guidelines, including extensions to existing standards and bridges detailing the interrelationship between relevant related standards and specifications. Therefore, the picture is not as linear as assumed in the ProSE processes. Figure 12 shows such a collection of standardization items of different levels of maturity for the IOS (only the IOS relevant parts are included in the database, not the whole gamut of standards/guidelines/specifications; on the other hand, particular extensions and explanatory "bridges" between the standardization items will be part of the IOS, c.f. Section 3.2).

Thus, IOS becomes a Multi-Standard, consisting of different parts, most of which include specifications from existing standards and their extensions, others of which are specifications without an underlying existing standard and some of which are bridges between other parts.

As described in Section 3.2., it is essential for a Multi-Standard, that there is (a) a single place (repository), where up-to-date information of each part of the Multi-Standard is available – for the IOS this is called the IOS-Database – and (b) an organizational structure in which Stakeholders can meet and discuss and coordinate their activities – in the case of IOS this is called the IOS Coordination Forum, or ICF for short.

A key issue for long-term sustainability is that a well-established organization takes over the hosting role for the ICF (Interoperability Coordination Forum), which consists of the interested stakeholders, but needs a basic infrastructure and support of such an existing organization. To identify one is a major task of CP-SETIS. There are fewer criteria than in the ProSE processes because it is just for the selection of the hosting structure and not for a feasible standard for adoption:

Trustworthiness, sustainability, openness and fitness for purpose – the host should allow the ICF to work as unrestricted as possible in a lightweight infrastructure that is not encumbered by too much cost of maintenance and operation.

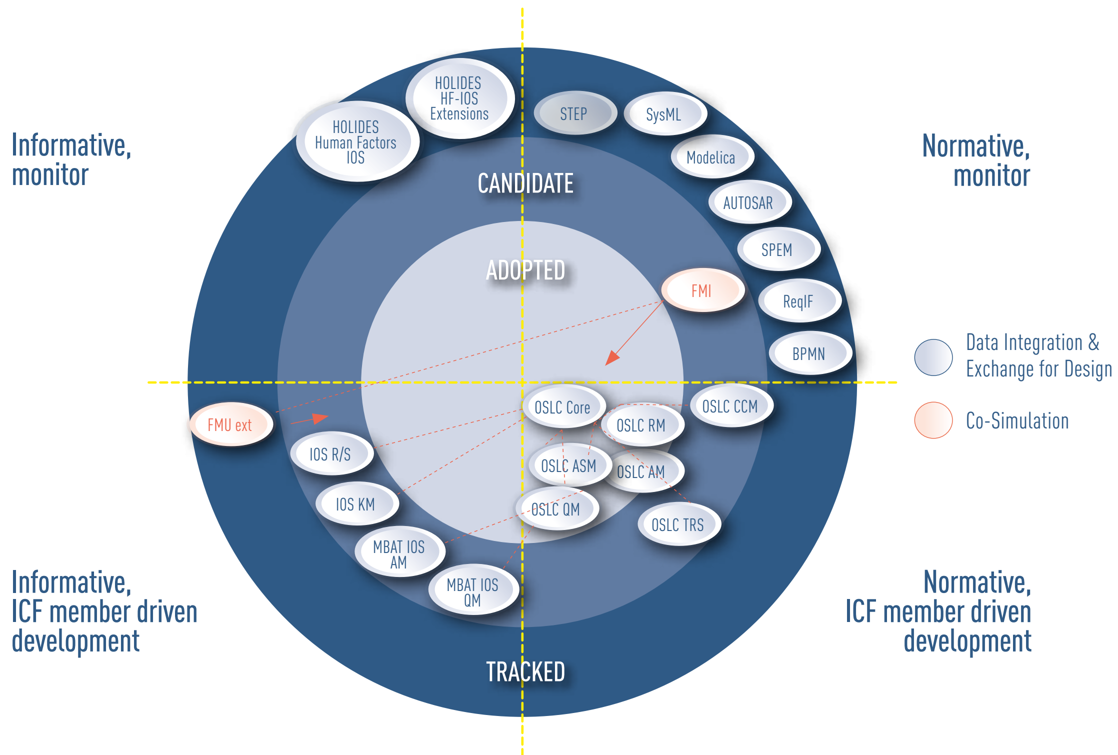

Figure 13 *Visualization of the IOS example database, showing some standards on different levels of integration (maturity, adoption)*

4.2.2 What could be used/what is new in the Multi-Standard Sustainable Model

The Multi-Standard Sustainable Model requires two different selection processes:

1. Selection of an existing sustainable structure for implementing Sustainable IOS activities (the ICF – Interoperability Coordination Forum)
2. During operation, defining a process for tracking candidates, selecting and adopting (adapting, enhancing) candidates (see Figure 12).

For the first process, the following criteria have been chosen:

- Trustworthiness (in standardization, community building, project incubator, high visibility and industrial acceptance)
- Sustainability (high probability for long-term existence, long-term accessibility of the hosted data (IOS – ICF data))
- Openness (platform should be open to all stakeholders – neutral, independent, not too many restrictions on membership, no commercial interests in IOS work)
- Fitness for purpose (some thematic relationship with IOS/ICF)

The basic high-level decision process is identical to that used in ProSE (the data have been assessed via a questionnaire – as in ProSE):
The second process used is during operation of the ICF: the process on how to collect candidates for standardization and how to enhance/develop and assess their maturity leading to adoption (or adoption of parts of the standardization items).

4.2.3 Standardization Activities for a Multi-Standard

For a Multi-Standard like IOS, two different selection – or 'standardization' – processes have to be accomplished:

1. Selection of new specifications **for inclusion and adoption into the Multi-Standard**. In the case of IOS, these specifications are new IOS parts, i.e. specifications covering a specific Engineering Concern, which are (a) based on existing standards including extensions of these, or (b) not based on an existing standard (usually because there is no existing standard for this particular Engineering Concern), or (c) bridges between other parts of the IOS (c.f. 3.1.).
2. **Formal Standardization** of parts of the Multi-Standard. In the case of IOS, this includes (a) for those parts of the IOS that are based on existing standards, including the IOS specific extensions into these standards, (b) for those parts that are not based on an existing standard yet, the creation and development of an appropriate formal standard and (c) for bridges the same as for (b).

4.2.3.1 Adoption of new parts into the Multi-Standard

With respect to process 1 above, i.e., the selection of new specifications for inclusion and adoption into the Multi-Standard, a stepwise approach depicted in Figure 13 is appropriate.

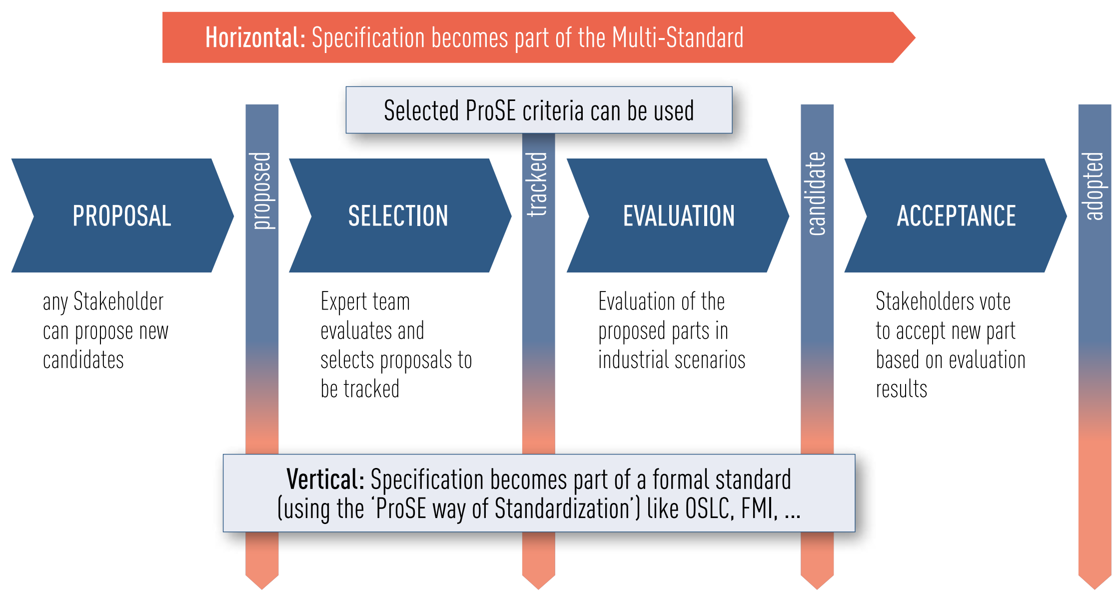

Figure 14 *Multi-Standard Approach: Horizontal and Vertical Maturity-Level Advancement Process*

This approach assumes that there is a structure/organization whose members decide about inclusion and maturity advancement of new parts and new specifications within the Multi-Standard, much like a standardization body would do for a single standard. In the case of the Interoperability Specification, this organization is the IOS Coordination Forum (ICF, c.f. 3.2.). We will give a high level description of this process, which we think is appropriate for any Multi-Standard. A more detailed description of the process as implemented specifically for the IOS can be found in the Deliverables of the CP-SETIS project.

At any time, each part of the Multi-Standard is in one of four states with regard to its maturity level (or adoption status):

- **Proposed**. A specification that has been proposed by a (group of) stakeholder(s) to become part of the Multi-Standard.
- **Tracked**. A specification that has been deemed appropriate for inclusion into the Multi-Standard. The development, evaluation and application of this specification is tracked by the organization handling the multi-standard.
- **Candidate**. A specification that has successfully been applied to and evaluated with appropriate use cases.
- **Adopted**. A specification that is adopted as a part of the Multi-Standard.

Each part of the Multi-Standard undergoes maturity level advancement according to the following process. Any stakeholder can **propose** a specification for inclusion into the Multi-Standard. At this point in time, there need not even be all the information about the new part available, probably not even the full specification. The minimum information to be supplied depends on the specific Multi-Standard in question. In the case of IOS, this minimum information includes

A The name of the specification,
B Which Engineering Concern is (or will be) covered by this specification,
C Which, if any, existing standard does this specification build on (and possibly extend), and
D The names of the promoters of this specification, i.e., the stakeholders that plan to develop this specification. For other Multi-Standards, the required information may differ, but in any case not too much information is needed at this early stage.

A quick check by a – probably small – team of experts will determine whether a proposed specification becomes **tracked**. Typical evaluation criteria will be the fit with the scope of the Multi-Standard, check for minimal or even no overlap with existing parts of the Multi-Standard, and perhaps size and impact of the promoter group. Note that these criteria are a subset of the criteria used for selection of a single-standard (c.f. Table 4 in Section 4.1.).

While in tracked state, additional information about the part must be supplied by the promoters. Obviously, the specification itself is needed for further evaluation. Use cases to show the applicability and usefulness of the specification should be provided as well as reference (prototype) implementations (where appropriate) and any further information needed to assess the new part. In the case of IOS, both the development of the specification as well as its application to use cases and the set-up of reference implementations were done for most IOS parts in publicly funded projects. Depending on the specific Multi-Standard in question, this might or might not be an appropriate model, especially considering the long run-time of these projects and the corresponding time these parts stay in tracked state. The tracked state is concluded with an evaluation by an expert team in cooperation with the promoters. Again, a subset of the criteria for a single-standard depicted in Table 4 is used here together with criteria about technical maturity, especially the appropriateness of the use case selected, the applicability and 'success' of applying the specification to the use case and its incorporation in the reference implementation. A successful evaluation leads to the part becoming a **candidate**. In the candidate state, the part is voted upon by stakeholders for adoption into the Multi-Standard. The evaluation results from the candidate stage are the basis for this vote and a positive vote leads to the state **adopted**, i.e., the specification is now a full member part of the Multi-Standard. If stakeholders deem it necessary to modify/extend this specification in the future, a new version of this part will be **proposed** and the process starts again (depending upon the concrete criteria used for state tracked in this specific Multi-Standard, the process for those updates and modifications could start in the state **tracked**).

At least two aspects are noteworthy within this process:

First, the existence of a managing organization is absolutely necessary for this process to work. Handling all the bookkeeping (which part of the Multi-Standard is in which state, which information about this part is available where, which promoters/stakeholders are associated with each state, and much more) is only one part of the work that this organization has to perform; keeping the process running, supplying experts for evaluation and being able to supply up-to-date information about all parts of the Multi-Standard to the multitude of other processes that are running in parallel – evaluation and maturity level advancements of different parts, formal standardization activities of different parts, implementations or application activities of different parts, etc. – are mandatory for the success of a Multi-Standard.

The second noteworthy aspect concerns the similarities of this process with the standardization for single-standards: groups of promoter organizations propose, develop (i.e. specify) and evaluate a candidate for a standard, which then becomes a formal standard through a defined process managed by the rules of a support organization (similar to the standardization body hosting a single standard), where this process involves all stakeholders/promoters of this specification. Although these processes differ in detail – especially for Multi-Standards where the maturity level advancement of each part requires considerably more knowledge about other parts of the Multi-Standard than what is typically the case for a single standard – the processes are similar enough to use experiences and methods known from standardization of single standards. This observation applies, for example, to the various criteria for selecting standards originally collected in the PROSE project, which also apply to the various steps of maturity level advancement for parts of a Multi-Standard.

4.2.3.2 Formal Standardization of parts of a Multi-Standard

In principle, each part of a Multi-Standard can be standardized – i.e., become a formal standard managed by a standardization body – independently of any other part. For each part, this standardization would basically follow the same process as for a single standard (c.f. 4.1.), that is, stakeholders would decide which parts to formally standardize, select an appropriate standardization body and work towards setting up a corresponding formal standard within this standardization body. Here, we will only describe the characteristic differences between formal standardization of a single standard against that of a part of a Multi-Standard.

For a Multi-Standard, note that stakeholders may decide for some parts not to formally standardize specific parts at all. Especially for bridges, but also for small or 'less important' specifications, it might be sufficient to be an adopted part of the Multi-Standard and a formal standard might not be required, not be worth the effort or even be infeasible.
For Multi-Standards like the IOS, where some parts already build upon existing standards and extend them, there is obviously no need to decide whether this part should become a formal standard or which standardization body to choose. Here, the process would comprise activities to modify/update the existing standard within the standardization body to include the new extensions (c.f. 4.1.).

For any Multi-Standard, one has to decide about the maturity level a specific part needs to reach before it can become a formal standard. Obviously, adopted parts of the Multi-Standard are candidates for standardization, but there are probably many cases in which it is beneficial to even start standardization at lower maturity levels. For example, the capability to become a formal standard – with its implication of having support from a large enough group of stakeholders – might be part of the evaluation criteria to become a candidate in a specific Multi-Standard, or there might be a need to set up a formal standard quickly to enable fast industrial take-up. As an example, the IOS standardization of parts based on OSLC started while these parts were in the tracked state. As for the question of the minimum maturity level requirement for formal standardization, this specifically depends upon the Multi-Standard in question, and might even depend upon the specific part considered for standardization. Therefore, it is advised not to define this minimum level in advance, but leave the stakeholders to decide on a case-by-case basis.

Last, but not least, note again how important the existence of an organization managing the Multi-Standard is for all these standardization processes. Apart from providing all the information a stakeholder group needs to set up a formal standard for a specific part of the Multi-Standard, it will also organize and support the selection process for which parts of the Multi-Standard will be standardized, which minimum maturity level should be considered and which standardization body to choose. It can also support the standardization process by providing contacts and 'how-to' information about different standardization bodies, contact information with these bodies and/or existing related stakeholder groups within these bodies, as well as feeding back the results of the standardization activities into the Multi-Standard.

4.2.4 Concluding remarks

The document tries to provide an overview on the manifold landscape of stakeholders, standardization organizations and standardization areas as well as on most of the key standards in the field of Cyber-Physical Systems (CPS) and their main application areas. The relation to the Strategic Research Agenda of ARTEMIS-IA, the ARTEMIS Industrial Association, is outlined, according to the intention to become the ARTEMIS Strategic Agenda for Standardization. An important part is dedicated to guidelines on how to approach successfully standardization as exploitation means of publicly funded research projects.

A key part of the document is dedicated to the description the new approach to further develop and maintain in a consistent, harmonized manner a multi-standard set of standards, specifications and guidelines belonging together from a thematic viewpoint, but handled by different standardization and stakeholder groups. The work on the IOS, the Interoperability Specification(s), for tool interoperability between tools and tool chains supporting the development of CPS and CPS systems-of-systems, is chosen as a concrete example.

The approach described to manage and maintain multi-standards can also be applied as a model to other strategic activities, particularly in all cases where multiple strategies and agendas should be coordinated and maintained in a sustainable manner, although the stakeholder and individual tasks are performed by different groups. Strategic research agendas covering a multitude of domains and targeting several goals are one example, with the cooperative models of Joint Undertakings very close to this approach.

5

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5.2 Abbreviations

AAL	Active and Assisted Living
AIOTI	Alliance Internet of Things Innovation
ARROWHEAD	Service Interoperability enabling automation collaborative (ARTEMIS project 332987)
ARTEMIS	Advanced Research and Technology for Embedded Intelligent Systems
ARTEMIS-IA	Industrial Association of ARTEMIS
ASIL	Automotive Safety Integrity Level
ASTM	American Society for Testing and Materials
CEN	European Committee for Standardization
CENELEC	European Committee for Electro-technical Standardization
CMMI	Capability Maturity Model Integration
CORBA	Common Object Request Broker Architecture
CP-SETIS	Towards Cyber-Physical Systems Engineering Tools Interoperability Standardization
CPS	Cyber-Physical Systems
CRYSTAL	CRitical sYSTem engineering AcceLeration (Artemis project 332830)
DECOS	Dependable Embedded Components and Systems (FP 6 project 511764)
ECSEL	Electronic Components and Systems for European Leadership
EMC²	Embedded multi-core systems for mixed criticality applications in dynamic and changeable real-time environments (ARTEMIS project 621429)
ERCIM	European Research Consortium for Informatics and Mathematics
ETSI	European Telecommunications Standards Institute
EWICS	European Workshop on Industrial Computer Systems
HSE	Health Service Executive
ICF	Interoperability Coordination Forum
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IBM	International Business Machines
IOS	Interoperability Specification(s)
IoT	Internet of Things
ISA	International Society of Automation
ISO	International Standardization Organization
MBAT	Combines Model-Based Analysis and Test
MOGENTES	Model-based Generation of Tests for Embedded Systems
OASIS	Organization for the Advancement of Structures Information Standards
OMG	Object Management Group
OSCI	*Online Services Computer Interface*
OSGi	Open Service Gateway Initiative
OSHA	*Occupational Safety and Health Administration*
OSLC	Open Services for Lifecycle Collaboration
PLM	Product Lifecycle Management
PLMIG	PLM Interest Group
ProSE	Promoting Standardization for Embedded Systems
SafeCer	Safety Certification of Software-Intensive Systems with Reusable Components
SAP	Systems, Applications & Products in Data Processing
SEI	Software Engineering Institute
SIL	Safety Integrity Level
STEP	*STandard* for the Exchange of Product model data
SW	Software
SYSML	Systems Modelling Language
TC	Technical Committee
UML	Unified Modelling Language
VHDL	VHSIC Hardware Description Language
VHSIC	Very High Speed Integrated Circuits
VITA	VMEbus International Trade Association
W3C	World-Wide Web Consortium
WG	Working Group

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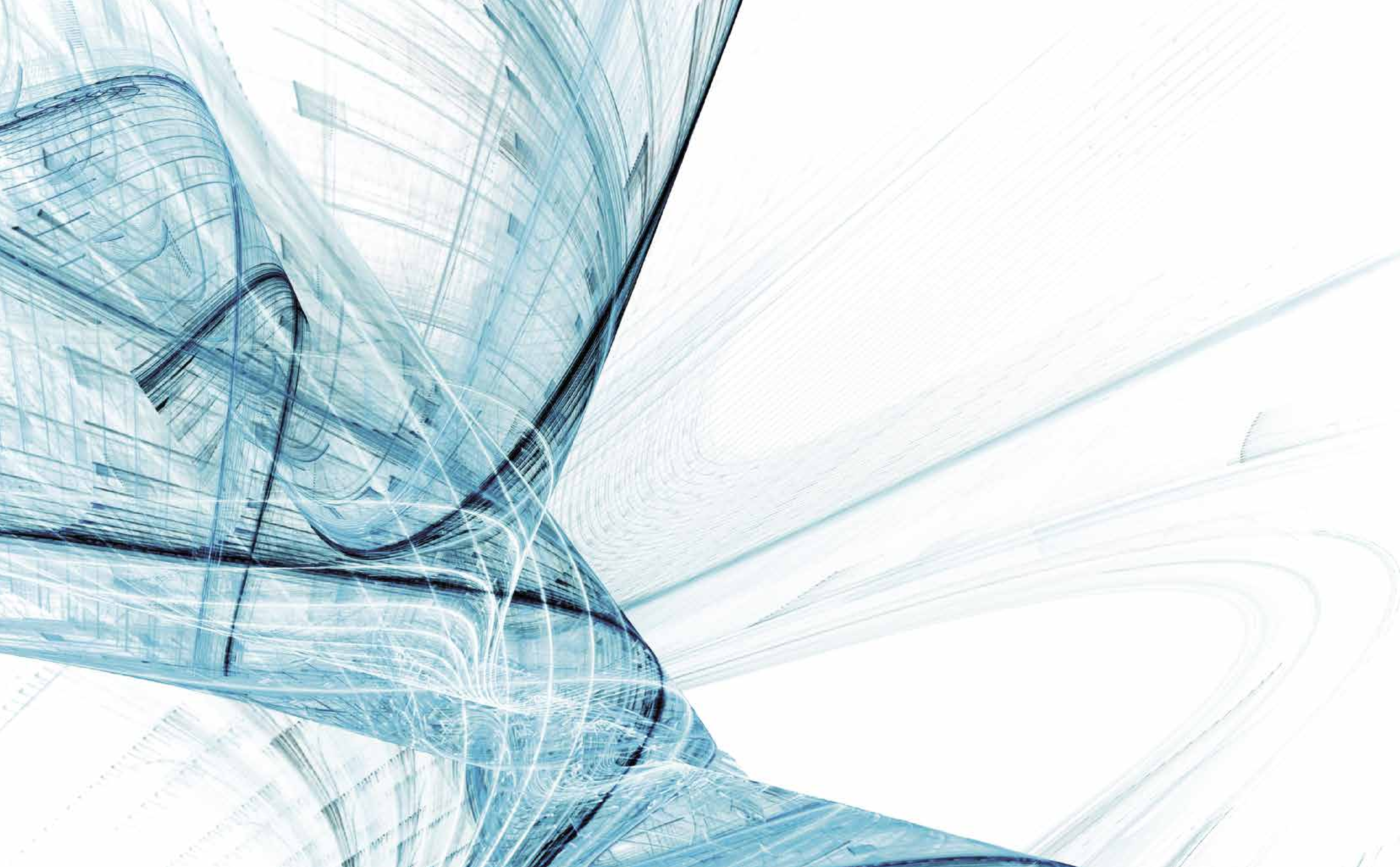

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