Deliverable 1.1
Road2CPS State of Art Report

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<thead>
<tr>
<th>Version</th>
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<thead>
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<th>Date</th>
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</tr>
</thead>
<tbody>
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</tbody>
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</tr>
</tbody>
</table>
Table of Contents

1 INTRODUCTION .......................................................................................................................... 16
  1.1 AIMS AND OBJECTIVES OF THIS REPORT ............................................................................. 16
  1.2 LINKS TO OTHER DELIVERABLES ......................................................................................... 17
  1.3 STRUCTURE OF THE REPORT ............................................................................................... 17
  1.4 RESEARCH APPROACH ADOPTED ......................................................................................... 17
    1.4.1 SELECTION OF CPS PROJECTS FOR THIS REPORT .......................................................... 17
    1.4.2 METHODOLOGY ADOPTED ............................................................................................. 18
    1.4.3 CONCEPTUAL FRAMEWORK FOR THE SOA ................................................................. 18
    1.4.4 COLLECTION OF DATA FROM THE 54 PROJECTS, SUPPLEMENTED BY OTHER RELEVANT INFORMATION ............................................................................................................ 20
    1.4.5 RESULTS .......................................................................................................................... 20
    1.4.6 CONCLUSIONS ............................................................................................................... 21

2 DATA COLLECTION: THE VULTURE TOOL ............................................................................... 22
  2.1 WHY THE NEED FOR A TOOL ............................................................................................ 22
  2.2 IMPLEMENTING THE CUSTOM TOOL .................................................................................. 22
  2.3 PROJECTS AND METADATA .............................................................................................. 22
  2.4 ENTERING THE DATA ......................................................................................................... 23
  2.5 ANALYSIS AND VISUALISATION METHOD ....................................................................... 23
    2.5.1 ANALYSIS ....................................................................................................................... 23
    2.5.2 VISUALISATION .............................................................................................................. 24

3 HIGH LEVEL SoA MESSAGES ................................................................................................ 25
  3.1 FOUR CLUSTERS OF ACTIVITY .......................................................................................... 25
    3.1.1 SYSTEMS OF SYSTEMS ................................................................................................. 28
    3.1.2 CPS SUPPORT ECOSYSTEM .......................................................................................... 30
    3.1.3 STRATEGIC TECHNOLOGY RESEARCH ..................................................................... 32
    3.1.4 TECHNOLOGY IMPLEMENTATION ............................................................................... 33
3.2 SUMMARY OF CLUSTER FINDINGS ................................................................. 34
3.2.1 CONCLUDING REMARKS ON CLUSTER ANALYSIS ................................. 35

4 KEY SOA ADVANCES FOUND BY PROJECT ..................................................... 36

4.1 ADVANCE ....................................................................................................... 36
4.1.1 A MULTI-SIMULATION FRAMEWORK ......................................................... 37
4.1.2 THE RODIN TOOLSET ............................................................................... 37

4.2 AGILE .............................................................................................................. 37
4.2.1 PLUGIN AND PLAY CONTROL FOR COMPLEX LARGE-SCALE REAL-LIFE SYSTEMS .... 38

4.3 AMADEOS ...................................................................................................... 39
4.3.1 STATE OF THE ART REPORT ....................................................................... 39
4.3.2 CONCEPTUAL MODEL FOR INFORMATION TRANSFER IN SoS ....................... 40

4.4 AUTOPROFIT ................................................................................................ 41
4.4.1 CONTROL AND MODEL CALIBRATION WITH HIGH LEVELS OF AUTONOMY ........ 41

4.5 AXIOM ............................................................................................................ 41
4.5.1 VIDEO SURVEILLANCE APPLICATION ....................................................... 42

4.6 BALCON ........................................................................................................ 43

4.7 BEMO-COFRA ............................................................................................ 44

4.8 CLAM .............................................................................................................. 45
4.8.1 RECONFIGURATION OF UNDERWATER ACOUSTIC SENSOR NETWORKS .......... 45
4.8.2 UNDERWATER ACOUSTIC WIRELESS SENSOR NETWORKS ......................... 46

4.9 COMPASS ..................................................................................................... 46
4.9.1 REQUIREMENTS FRAMEWORK AND GUIDELINES FOR SoS ENGINEERING .......... 47
4.9.2 ARCHITECTURAL MODELLING PATTERNS FOR SoSs ...................................... 48
4.9.3 SoS ARCHITECTURAL FRAMEWORKS ....................................................... 48
4.9.4 LANGUAGES FOR MODEL-BASED SoS ENGINEERING ................................... 49
4.9.5 FAULT MODELLING (PROFILE AND GUIDELINES) & ANALYSIS (TOOLS) FOR SoSs ... 49
4.9.6 ENSURING CONFORMANCE TO CONTRACTUAL INTERFACE SPECIFICATIONS DURING EVOLUTION IN SoSs ................................................................. 50
4.9.7 COMPASS SYMPHONY: A TOOLS PLATFORM FOR MODEL-BASED ENGINEERING OF SYSTEMS OF SYSTEMS ................................................................. 51

4.10 CONSER ....................................................................................................... 51
4.10.1 DESIGN OF ENERGY-AWARE NETWORKING AND COOPERATION MECHANISMS (CASE STUDIES) ....................................................................................... 52
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.10.2</td>
<td>ENERGY EFFICIENT COOPERATIVE DECISION AND CONTROL SCHEMES</td>
<td>53</td>
</tr>
<tr>
<td>4.11</td>
<td>COSSIM</td>
<td>53</td>
</tr>
<tr>
<td>4.12</td>
<td>CPSETIS</td>
<td>54</td>
</tr>
<tr>
<td>4.13</td>
<td>CPS-SUMMIT</td>
<td>54</td>
</tr>
<tr>
<td>4.14</td>
<td>CPSE-LABS</td>
<td>55</td>
</tr>
<tr>
<td>4.14.1</td>
<td>SMART CITIES</td>
<td>56</td>
</tr>
<tr>
<td>4.14.2</td>
<td>SMART PRODUCTION SYSTEMS</td>
<td>56</td>
</tr>
<tr>
<td>4.14.3</td>
<td>CRITICAL MARITIME SYSTEMS ENGINEERING</td>
<td>57</td>
</tr>
<tr>
<td>4.14.4</td>
<td>AUTONOMOUS VEHICLES</td>
<td>58</td>
</tr>
<tr>
<td>4.15</td>
<td>CPSos</td>
<td>58</td>
</tr>
<tr>
<td>4.15.1</td>
<td>SoA IN TERMS OF RESEARCH</td>
<td>60</td>
</tr>
<tr>
<td>4.15.2</td>
<td>SoA IN TERMS OF TRANSPORT DOMAINS</td>
<td>60</td>
</tr>
<tr>
<td>4.16</td>
<td>CPS-SUMMIT</td>
<td>61</td>
</tr>
<tr>
<td>4.17</td>
<td>CYPHERS</td>
<td>61</td>
</tr>
<tr>
<td>4.17.1</td>
<td>CYPHERS SOA REPORT</td>
<td>63</td>
</tr>
<tr>
<td>4.18</td>
<td>DANSE</td>
<td>64</td>
</tr>
<tr>
<td>4.18.1</td>
<td>DANSE TECHNOLOGY DEMONSTRATION PACKAGE</td>
<td>65</td>
</tr>
<tr>
<td>4.18.2</td>
<td>RELATIONS TO EXISTING WORLD STANDARDS AND PRACTICES</td>
<td>65</td>
</tr>
<tr>
<td>4.19</td>
<td>DYMASOS</td>
<td>66</td>
</tr>
<tr>
<td>4.20</td>
<td>EC-SAFEMOBIL</td>
<td>67</td>
</tr>
<tr>
<td>4.20.1</td>
<td>MODELLING AND CONTROL OF UNMANNED HELICOPTERS</td>
<td>68</td>
</tr>
<tr>
<td>4.20.2</td>
<td>EC-SAFEMOBIL ASSESSMENT OF BEST PRACTICES - MAY 2013</td>
<td>69</td>
</tr>
<tr>
<td>4.20.3</td>
<td>INNOVATION IN TECHNICAL APPROACH</td>
<td>70</td>
</tr>
<tr>
<td>4.21</td>
<td>EMBOCON</td>
<td>71</td>
</tr>
<tr>
<td>4.21.1</td>
<td>THE EMBOCON SOFTWARE PLATFORM</td>
<td>72</td>
</tr>
<tr>
<td>4.22</td>
<td>ENOSYS</td>
<td>72</td>
</tr>
<tr>
<td>4.22.1</td>
<td>ENOSYS METHOD DEMONSTRATED IN AN INDUSTRIAL CONTEXT</td>
<td>73</td>
</tr>
<tr>
<td>4.22.2</td>
<td>THE DESIGN SPACE EXPLORATION METHODOLOGY</td>
<td>73</td>
</tr>
<tr>
<td>4.22.3</td>
<td>METHODOLOGY FOR SOURCE CODE OPTIMISATION USING TRANSFORMATIONS</td>
<td>74</td>
</tr>
<tr>
<td>4.22.4</td>
<td>THE ENOSYS DESIGN FLOW FOR THE MODELLING AND SYNTHESIS OF EMBEDDED SYSTEMS</td>
<td>75</td>
</tr>
<tr>
<td>4.22.5</td>
<td>STATE-OF-ART-ART ANALYSIS FOR EMBEDDED SYSTEMS DESIGN</td>
<td>75</td>
</tr>
</tbody>
</table>
4.23 EOT ......................................................................................................................... 76
4.24 ERA .......................................................................................................................... 77
4.25 EUROCPs .................................................................................................................. 78
4.26 GENESI ...................................................................................................................... 78
4.26.1 ROME UNDERGROUND TEST BED ........................................................................ 79
4.26.2 LONG-LIFE SENSORS EMBEDDED IN THE BUILT ENVIRONMENT FOR USE ON CPSOS ................................................................. 79
4.27 GREENERBUILDINGS .................................................................................................. 80
4.27.1 LIVING LAB ............................................................................................................. 80
4.27.2 ENERGY-EFFICIENT CONTROL OF SENSORS AND ACTUATORS IN LARGE BUILDINGS - CENTRALISED CONTROL APPROACH ........................................................................ 81
4.28 HYCON2 ..................................................................................................................... 83
4.28.1 MATHEMATICAL ANALYSIS OF INTERACTION TOPOLOGY .................................. 83
4.29 HYDROBIIONETS ....................................................................................................... 84
4.29.1 REAL-TIME MICROBIOLOGICAL WIRELESS NETWORKED CONTROL SYSTEM ....... 84
4.30 IMC-AESOP ................................................................................................................ 85
4.30.1 IMC-AESOP - CONTROL OF DISTRIBUTED INDUSTRIAL PROCESSES IN A SoS ...... 86
4.31 IMMORTAL ................................................................................................................ 87
4.32 INTO-CPS ..................................................................................................................... 87
4.32.1 PROJECT CASE STUDIES ......................................................................................... 87
4.32.2 INTEGRATED TOOL CHAIN FOR MODELLING CPS .................................................. 88
4.33 KARYON ...................................................................................................................... 89
4.33.1 FACILITATING COMMUNICATION AND COOPERATION BETWEEN VEHICLES ...... 90
4.33.2 DEVELOPING RESILIENT SAFETY-CRITICAL AUTONOMOUS SYSTEMS .......... 91
4.33.3 APPROXIMATING GLOBAL STATE ......................................................................... 92
4.33.4 AUTOMOTIVE AND AVIATION APPLICATIONS ....................................................... 93
4.34 LOCAL4GLOBAL ....................................................................................................... 93
4.34.1 LOCAL4GLOBAL, SOS CONTROL PROJECT - DISTRIBUTED, 'SWARM' APPROACH . 94
4.35 MADNESS .................................................................................................................. 95
4.35.1 IDENTIFICATION OF KEY ISSUES ............................................................................ 96
4.36 MAKESENSE .............................................................................................................. 97
4.36.1 COMPREHENSIVE MACRO PROGRAMMING ......................................................... 98
4.36.2 CHEAP DEVELOPMENT OF SENSOR NETWORKS ................................................... 99
4.37 MOVES ........................................................................................................... 99
  4.37.1 MICROGRID CASE STUDY ........................................................................ 100
4.38 OPENCOSS .................................................................................................. 100
  4.38.1 COMPOSITIONAL CERTIFICATION FRAMEWORK ....................................... 102
  4.38.2 COMMON CERTIFICATION LANGUAGE ..................................................... 102
4.39 PAPYRUS .................................................................................................... 103
4.40 PLANET ........................................................................................................ 104
  4.40.1 PLANET - WIRELESS-BASED CONTROL OF ECOLOGY-TYPE NETWORKS OF COOPERATING OBJECTS CASE STUDIES ................................................................. 104
4.41 ROAD2CPS .................................................................................................. 105
4.42 ROAD2SOS .................................................................................................. 107
  4.42.1 SOA OF SOS/CPS IN DIFFERENT APPLICATION DOMAINS: MANUFACTURING ... 109
  4.42.2 SOA OF SOS/CPS IN DIFFERENT APPLICATION DOMAINS: TRAFFIC .................. 109
  4.42.3 SOA OF SOS/CPS IN DIFFERENT APPLICATION DOMAINS: EMERGENCY AND CRISIS MANAGEMENT .................................................................................................................. 109
  4.42.4 SOA OF SOS/CPS IN DIFFERENT APPLICATION DOMAINS: ENERGY ............. 110
4.43 SAFURE ...................................................................................................... 110
4.44 SCUBA ........................................................................................................ 111
  4.44.1 ENERGY SAVING RESULTS OF PILOT STUDIES ON SYSTEMS CO-ORDINATION AND CONTROL IN LARGE BUILDINGS .................................................................................................. 112
  4.44.2 ARCHITECTURE FOR BUILT ENVIRONMENT MONITORING AND CONTROL .......... 113
4.45 SPRINT ...................................................................................................... 113
  4.45.1 SYSTEM MODELLING ................................................................................ 114
4.46 T-AREA-SOS ............................................................................................... 114
  4.46.1 SOSE STRATEGIC RESEARCH AGENDA .......................................................... 115
4.47 TAMS4CPS .................................................................................................. 116
4.48 TAPPS ......................................................................................................... 117
  4.48.1 EXTENDING AND CUSTOMISING CPS DEVICES ............................................... 118
4.49 TERESA ..................................................................................................... 118
4.50 U-TEST ...................................................................................................... 119
4.51 UNCOVERCPS ............................................................................................ 121
  4.51.1 CONTROLLING DYNAMIC NETWORKS BY DEVELOPING SPARSE REPRESENTATIONS OF THE FUNCTIONALITY OF THE NODES ................................................................. 122
List of Figures

Cube 2.0 Four clusters of projects .......................................................... 13
Cube 2.0: Summary overlay ................................................................. 14
Cube 2.0 Impact overlay .................................................................... 15
Figure 1.1 Road2CPS Summary of Objectives ....................................... 16
Figure 3.1 Visualisation of the four SoA areas ....................................... 26
Figure 3.2 Artemis Cube (Gide, L. 2013) ............................................. 27
Figure 3.3 System of Systems projects plotted on visualisation of the four SoA areas .................. 28
Figure 3.4 CPS Support Systems projects plotted on visualisation of the four SoA areas .............. 30
Figure 3.5 Strategic Technology Research projects plotted on visualisation of the four SoA areas .... 32
Figure 3.6 Technology Implementation projects plotted on visualisation of the four SoA areas ...... 33
Figure 6.1 Summary of the State of the Art: Cube 2.0 ............................ 144
Figure 6.2 Cube 2.0 Project overlay ..................................................... 145
Figure 6.3 Cube 2.0 Activity overlay ................................................... 146
Figure 6.4 Cube 2.0 Summary overlay ................................................ 147
Figure 6.4 Cube 2.0 Impact overlay ..................................................... 148

List of Tables

Table 1.1 List of projects assessed in this Deliverable ............................. 18
Table 3.1 System of Systems Projects ............................................... 29
Table 3.2 CPS Support Ecosystem Projects ....................................... 31
Table 3.3 Strategic Technology Research Projects ............................... 33
Table 3.4 Technology Implementation Cluster Projects ....................... 34
Table 5.1 Potential Impacts ................................................................. 129
Executive Summary

This work has used a collaborative approach to categorise data relating to 53 EU-funded projects all concerned with research into and applications of Cyber physical systems. To facilitate this activity an online tool, the “Vulture Tool”, was created and populated with text snippets annotated with metadata describing the nature of the snippet. A further feature of this tool is that it allows rapid ad hoc exploration of the data using the metadata categories in combination with user customisable search facilities. In this respect, it is easier to explore the data dynamically by using the Vulture Tool, rather than in the static form of this report.

Analysing the data collected using the Vulture Tool found evidence for four clusters of activity characterised by the metadata classification on the Infrastructure and Infrastructure scales. These clusters are independent of the Domain axis, and indicate the broad cross domain nature of the issues covered by the projects. The diagram, Cube 2.0 below, has formed the basis of a useful visualisation of the large dataset produced by this work.

Mapping the project activity for each project or group of projects facilitates a further useful summary of the state of art as being within the following areas:

3 Higher resolution versions of these charts are included in the appendices.
4 Details of the projects that are members of each of these clusters are to be found in section 3 of this report.
Making an assessment of project impacts proved problematic due to the limited amount of public domain information available. However, following the same approach of mapping projects with reported impacts on the Cube 2.0 visualisation supports a provisional view that impacts follow activity without any obvious bias using the Infrastructure and Interoperability categorisations. It is also reasonable to assume impacts may not be reported publicly for legitimate reasons such as commercial sensitivity. With these caveats, it is fair to assume that the projects covered in this report have overall delivered, or will deliver positive impacts to the CPS domain in particular and the economy in general. However, gaps in activity inevitably will equate to gaps in impact.
When examining projects by their categorisations a number of deeper observations have been made:

- **Gaps in Education, Training and Financial Arrangements**
  - “Contracts & financial arrangements” and “Education” are poorly represented in the coverage of projects. This observation is supported by Gap Snippets also entered into the Vulture Tool.

- **Strategic CPS Research is Cross Domain**
  - This observation suggests that strategic CPS research classified to a specific domain. This may impact the type of industrial support available for strategic research.

- **Domain Bias in Technology Implementation**
  - Energy; IT&C; Manufacturing; Smart Community; and Transport are well represented as domains covered by projects in the Technology Implementation cluster. Conversely, Environment and Agriculture; Healthcare; and Security are almost completely ignored. Further research will be required to understand this observation.
1 INTRODUCTION

1.1 AIMS AND OBJECTIVES OF THIS REPORT

Figure 1.1 below provides a summary of the objectives of the Road2CPS project. In the first column will be found ‘Analyse the impact from past and present projects’; this Deliverable presents the findings from the analysis.

This deliverable relates to the project objectives as summarised in Figure 1.1 contributing directly to Analysis of impacts of previous and ongoing projects, and Identification of the gaps within the portfolio of projects reviewed as part of this deliverable. In particular this work contributes to the project goals of:

- Impact assessment of past and ongoing projects will be pursued by internet search, interviews with relevant stakeholders and project coordinators, and an online survey
- Gap analysis – this analysis will entail analysing the top-down (theoretical CPS) view and map it with the industrial / application-oriented (bottom-up) view in order to identify gaps to be filled on both sides so that CPS applications become practice in the future
- Impact multiplication will be pursued by identifying overlaps and connections to fill gaps, bringing knowledge together and matching technology push and market pull
1.2 LINKS TO OTHER DELIVERABLES

This report, deliverable D1.1, is a part of WP1 forms a baseline for other tasks in this workpackage and supports D2.2 (Evaluation of concepts, research challenges and enabling technologies) in WP2. This work also feeds directly into D2.1 by identifying the areas technology-push (T2.2, T2.4). These tasks for part of the balance between technology push and market pull which is a key aspect of the overall philosophy that underpins the Road2CPS project.

The main findings will be published in: State of the Art and current impact report (D1.1), Gap Analysis report (D1.2), Impact assessment (D1.3), Summary of programme achievements and impact for dissemination for WP6 (D1.4), Programme achievements, exploitation opportunities, and impact multiplication activities (D1.5).

1.3 STRUCTURE OF THE REPORT

The report is presented as the following sections:

- **Section 1** (this section) provides an introduction to this deliverable and sets its context within the Road2CPS project.
- **Section 2** Describes the development of the so called Vulture Tool, the collection of open source software used to collaboratively collate the information on the projects. Subsections describe in sufficient detail the data processing techniques used so this work may be replicated.
- **Section 3.** Presents the visualisations and findings as a series of key messages.
- **Section 4.** Provides an interpretation of the results as key advances
- **Section 5.** Describes project impacts
- **Section 6.** The conclusions and recommendations for further work.
- **Section 7.** References
- **Section 8.** Appendices: Including links to the data collected, raw data files and code.

1.4 RESEARCH APPROACH ADOPTED

1.4.1 SELECTION OF CPS PROJECTS FOR THIS REPORT

The consortium agreed (Kick-off Meeting, Karlsruhe, March 3 /4, 2015) that the workpackage would focus on a specific set of both completed and current, on-going Commission-funded projects, all falling within the domain of Cyber-Physical Systems and Cyber-Physical Systems of Systems and constituting a widespread base on which to develop and commission future projects within this domain. A list of 54 EU-funded projects was assembled, and this Deliverable is an analysis of these 53 projects to define the current (2015) State of the Art that they represent and to assess the impact that these projects have had in developing this domain.

Table 1.1 below lists the projects that were assessed for this Deliverable.
Table 1.1 List of projects assessed in this Deliverable

<table>
<thead>
<tr>
<th>ADVANCE</th>
<th>EC-SAFEMOBIL</th>
<th>OPENCOSS</th>
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<td>DYMOSOS</td>
<td>MOVES</td>
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1.4.2 METHODOLOGY ADOPTED

A systematic approach was undertaken, modelled on the principles utilised by the Cochrane Collection in their detailed, evidence-based, biomedical surveys (Higgins and Green 2008), but adapted to the timeframe and contents of this project (their core process of Concepts, Studies, Results and Conclusions). This approach, as adapted for this report, is developed in the following sections, but the key principle of collation of data for the study being independent of any expected conclusion has been followed. In fact, the geographically dispersed nature of the consortium has enabled access to a larger number of domain experts working independently of each other which may be perceived as adding value to the quality of the data collation process.

1.4.3 CONCEPTUAL FRAMEWORK FOR THE SOA

While the 54 projects mentioned above in Table 1.1 represent the projects sponsored by the EC within the sequence of Framework Programmes and in Horizon 2020, there are many other funded projects both within the EU and elsewhere around the world. In view of this, it was decided that three dimensions would capture the findings of the 54 projects as well as fitting these into a more general framework suitable for most other projects elsewhere. These three dimensions were:

- Domain of interest,
- Networking and Interoperability, and
- Infrastructure.

In view of the current and future significance of the industry-focussed ARTEMIS Joint Technology Initiative (Gide 2013), its successor ECSEL, and the ARTEMIS Industry Association, it was decided that the Domain dimension should adopt the domains utilised in ATREMIS:

- Environmental & agricultural information
- Healthcare
The Network & Interoperability dimension was developed from the generic Interoperability Framework (NCOIC 2006) and the energy-related Grid-Wise Architecture Council (http://www.gridwiseac.org), both concerned with interoperability within large-scale systems;

- Political/economic/regulatory/business board
- Business objectives: strategy and policy levels
- Business context: aligned operations
- Business context: aligned procedures
- Semantics: knowledge sharing
- Semantics: information sharing
- Syntactic interoperability
- Network interoperability
- Physical interoperability

The Infrastructure dimension was created partly based on ARTEMIS, for the same reasons as above, extended by prior knowledge within the Road2CPS consortium to include many more organisational aspects. This was justified on the grounds that the Road2CPS project is focussed on the steps to implementation, which necessarily will happen through organisations:

- Ubiquitous autonomy
- Architectures
  - Business models/enterprise design
  - Modelling & simulation
  - Privacy
  - Security
- Big data
- Contracts & financial arrangements
- Resilience & fault tolerance
  - Design/development of functions/devices
  - Safety
- Education
- Skills & training
- Human & machine awareness
  - Human interfaces for control
  - Human/community/social issues
- Interfaces & interoperability issues
- Methods/protocols/procedures
- Regulations & policies
- Standards & codes of practice
Tools (including simulation)

However, in the case of assessing the impact of the projects, a different dimension was thought necessary, replacing the interoperability dimension, since the latter did not assess impact. This dimension was adapted from the expectations outlined in the ICT1 Call.

- Contributes to networked embedded ICT
- Contributes to inclusion of SMEs in networked embedded ICT
- Improvements to collaboration
- Provision of platforms
- Contributes to development & uptake of architectures
- Contributes to development & uptake of business models
- Contributes to development & uptake of standards
- Contributes to development & uptake of tools, methods
- Improvements in Capability
- Reduction in Time to Market
- Reductions in Costs to Market

1.4.4 COLLECTION OF DATA FROM THE 54 PROJECTS, SUPPLEMENTED BY OTHER RELEVANT INFORMATION

The data collection focussed on publicly accessible information on the 53 projects including EU websites, Project websites, academic publications and other online resources. Project documentation was also used, where available.

These deliverables were assessed by members of the Consortium, and condensations ("snippets") were created as short descriptions of important findings and achievements of these projects, tagged for the three dimensions discussed above. These were entered into a database (the “Vulture”, described below), and subsequently analysed and rearranged to provide the results, as documented in this report. This analysis process was supplemented by the addition of extra, non-project information snippets from other organisations such as the IEEE Standards Association and Directives of the EC.

The essential aspects of the data collection protocol were:

- Assign each of the partners approximately 10 projects to review;
- Break each project into a series of “snippets” describing key technologies, activities and impacts;
- Assign metadata to each snippet from a predefined nomenclature along with a short narrative about the snippet.

1.4.5 RESULTS

The collected data was reviewed using data mining techniques to produce a series of groups and visual views of the data and a narrative was then developed around those views.
The findings derived from this process were then analysed for two classes of ‘message’; ‘headline messages’ that cover a number of classes on the dimensions and therefore approach a generic status, and ‘category messages’ that apply to one class on each dimension and are therefore particular to the category. It should be understood that these latter messages are not less important; as US Admiral Rickover said 50 years ago, in a different context, “The devil is in the detail, and everything we do in the military is a detail”.

These two classes of messages are described in the sections of this report, below.

1.4.6 CONCLUSIONS
As in the case of the results, the conclusions are summarised and reported in the sections below.
2 DATA COLLECTION: THE VULTURE TOOL

2.1 WHY THE NEED FOR A TOOL
The agreed approach of breaking the data into small snippets and the categorisation of those snippets required the development of a custom software tool. The requirements for the tool were:

1. Collate text, files with associated custom metadata;
2. Usable by all consortium members with minimal training;
3. Permit analysis of the data and collation into a report;
4. Be quick and simple to implement;
5. Updatable as required.

No existing software tool was known that could meet all these requirements, thus a custom tool was needed.

2.2 IMPLEMENTING THE CUSTOM TOOL
Potentially there are many solutions to the simple requirements specification of 2.1, but focussing on requirements 4 and 5, a physical implementation was realised as:

1. Provide an internet based service using a LAMP (Linux Apache MySQL PHP) to enable all consortium members to access the tool;
2. Use DRUPAL to provide a custom graphical user interface for consortium members to input data;
3. Analyse the data programmatically using the R! data analysis language in conjunction with the GGobi data visualisation software. This permitted the development of the visualisation process on partial datasets and effectively minimising the time delay between collation of data and final analysis.

It should be noted that the tool was not a monolithic piece of custom software: it was assembled from an array of software system blocks to meet the requirements of the task in hand. As such, the required functionality of this approach could have been met in other ways. However, the method chosen was very fast to develop and easy to modify so was entirely appropriate for the required application.

Finally, as the general purpose of the tool was to scavenge data, it was given the name “Vulture Tool”.

2.3 PROJECTS AND METADATA
The previous sub-sections described the implementation of the Vulture Tool, but key to its usefulness was the preloading of the projects of interest and metadata definitions. Section 1.4.1 describes how a set of projects had already been identified by the EU project officer. By confining this work to those projects enabled a far more focussed effort than otherwise would have been possible within the allocated resources and enabled the rapid progress towards data collection phase of the task.
The CPS domain also benefits from a rich existing metadata describing the nature of research and commercial effort. As introduced in section 1.4.3, the broad acceptance of the metadata terminology reduced the degree of explanation required to introduce the terminology used.

Additional the presentation of projects and metadata within the on-line tool enabled linking to appropriate online resources as well as ensuring that all contributors were working to the latest versions of metadata and project descriptions.

2.4 ENTERING THE DATA
To brief contributors on how to use the Vulture tool, and a set of instructions were developed (see: VultureGuidence.pdf) and two YouTube videos were recorded to assist with consistency of input:

- Introduction to Vulture (http://youtu.be/s7rF79A_HoI)
- Creating a SoA Snippet (http://youtu.be/Fi5tyAVUJv4)

There were few queries from the expert contributors and this was taken to mean a general endorsement of the process and terminology. Overall 255 snippets were collated and categorised, comprising:

- State of Art Snippets: 144
- Gap Snippets: 59
- Impact Snippet: 52

The outcomes of the analysis of this data is described in section 3 while the method is described in section 2.5 below.

2.5 ANALYSIS AND VISUALISATION METHOD

2.5.1 ANALYSIS
A particular feature of the output from the Vulture tool is that the fields relating to the metadata terms may comprise of a list of multiple terms. For compatibility with most data analysis software, each field must be a single value, not a list of values. It was therefore necessary to “explode” the raw data into many rows of data, each with a single value for each field, prior to data analysis. The method chosen was a variant of “Bootstrap Resampling”.

Essentially Bootstrap Resampling produces a new set of data by extracting a row of data randomly from the raw pool of data. In the case of the Vulture data a second step was applied to each sample: A single value was randomly chosen from each field that had multiple values. The resulting sample was saved to a set of data for subsequent analysis and the original data returned to the pool of data to be included in further resampling.

This process does not introduce any bias due to the number of metadata categories applied to samples and although the resultant data set is now very large, the efficiency of the R! programing language and
the Ggobi visualisation is such that there were no problems with data manipulation due to scale. R scripts were used to analyse the bootstrapped data and search for clusters. (For completeness the scripts used are included in the appendices).

The essential features of the overall approach are:

- Contributor introduced bias is unlikely as it was not possible deduce the final visualisation during data entry;
- The final visualisations are underpinned by the overall dataset so may be verified by additional and subsequent analysis of the data;
- The characterised CPS project data represents an additional output to the deliverable and may contain further useful information.

2.5.2 VISUALISATION

The clusters have been arrived at by using a process that splits the overall data into a dendrogram or tree. The clusters are effectively generated by cutting the tree at the height where it splits into four. This is an empirical process and only works well on data that is reasonably balanced, as indeed proved to be the case. Four clusters were found to be sufficient to simply characterise the projects. The inferences drawn from this useful observation are described in section 3.

The following description may help when interpreting the charts in section 3:

- Each dot on the charts below indicates that one or more snippets has metadata that corresponds to that point
- For each cluster, the points show where members of that cluster have one or more snippets with metadata that correspond to that point.
3 HIGH LEVEL SoA MESSAGES

3.1 FOUR CLUSTERS OF ACTIVITY

The data analysis as described above and used on the SoA snippets has resulted in the identification of four clusters of activity within the projects considered:

- **Systems of Systems** (High level activities where the component parts are also systems)
- **CPS Support Ecosystem** (A broad range of activities that engage with technologies and services to support CPS. i.e Regulation, Standards, Enabling technologies to support communication between systems etc.)
- **Strategic Technology Research** (Strategic activities including building collaborative networks of expertise)
- **Technology Implementation** (Activities typically focussed on hardware or software for CPS)

Figure 3.1 “Visualisation of the four SoA areas” is a stylised illustration of the clusters described in this section, and conveys a number of messages about the SoA without the need to examine the underpinning data in detail. Since these clusters correspond, more or less, to the goals outlined in the respective project Calls, this is reassuring, indicating that the funding was spent well.
The first observation is that the **Domain axis does not feature as a discriminating factor** in the highest level clusters found within this dataset, however, the **Infrastructure and Interoperability axes together are sufficient to usefully characterise CPS projects**. The implication is that CPS activities are not strongly coupled to application domain. In other words, while projects may have been aimed at a particular domain, the findings are more general indicating that future projects could aim at combining findings. However, while this is an enticing thought, the lack of a common framework may mean that the peculiarities of each project may be hard to overcome.
The second observation relates to the ordering of the Infrastructure and Interoperability axes. These scales both move from a high level of abstraction (lower left corner Fig 3.1) to a low level of abstraction (top right corner Fig 3.1). This may also be viewed as traversing from a high level of uncertainty to a low level of uncertainty. The terminology used on these scales is widely used within the CPS community and shares much commonality with useful representations such as Figure 3.2 “Artemis Cube”, which also shows domains as being completely crosscutting and uses similar terminology to classify CPS activity. Figures 3.1 and 3.2 are effectively equivalent representations of CPS differing only in that Figure 3.1 uses a pair of ordered axes. This work is therefore seen as adding to the Artemis Cube rather than contradicting it.

Finally gaps and overlaps are also of interest are gaps in the classification matrix. These gaps may occur because the permutation of classification does not arise because of a natural exclusion condition, or they may indicate a more systematic gap in activity or reporting. Many of these gaps seem important for the future effectiveness and efficiency of CPS, and may be of concern for the Commission, in planning future Calls.
### 3.1.1 SYSTEMS OF SYSTEMS

The Systems of Systems cluster is categorised by higher level of abstraction infrastructure elements and is applicable across all Interoperability levels. Represented by projects considering high levels of system abstraction and systems of systems. This cluster is also characterised by a very weak coupling to Interoperability and Domain axes, which in practice means this cluster applies to all Domains and NCIOC levels.

Snippets from many projects fall into this cluster and most of the included projects have snippets that fall into other clusters too.

![Figure 3.3 System of Systems projects plotted on visualisation of the four SoA areas](image-url)
These projects typically address high level complex distributed systems and enabling strategies, architectures and methodologies. Also within this cluster are projects describing: nomenclatures; security; CPS concepts; uncertainty; and other enablers. Overall these projects may be summarised as covering:

- Regulation;
- Control of Distributed CPS;
- Designing Safe and Secure Systems.

Table 3.1 System of Systems Projects

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<thead>
<tr>
<th>ADVANCE</th>
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<td>EC-SAFEMOBIL</td>
<td>LOCAL4GLOBAI</td>
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3.1.2 CPS SUPPORT ECOSYSTEM

Initially this cluster was subdivided into two sub clusters:

INTER-ORGANISATIONAL SYSTEMS: Categorised by mid level infrastructure and high level Interoperability applicable across all domains. Differentiated from Technical Ecosystems by high level Interoperability.

and

TECHNICAL ECOSYSTEMS: Categorised by mid level infrastructure and low level Interoperability applicable across all domains. Differentiated from Inter-Organisational Systems by low level Interoperability.

Further examination of the data revealed considerable overlap of the projects, so the two clusters have been combined into one entitled CPS Support Ecosystem, a name intended to convey the diverse supporting nature of the issues covered by the projects within this cluster.
Table 3.2 CPS Support Ecosystem Projects

Note that there is considerable overlap with the Systems of Systems cluster. These projects may be described as supporting, underpinning or enablers - and may be summarised as covering two main themes:

- Building, Training & Educating a Safe and Secure CPS Constituency;
- Designing Safe & Secure CPS.

The following observations are of note:

**Few projects cover “Contracts & financial arrangements” on the Infrastructure scale**, and those that do are also classified on the Interoperability scale as: Political/ Economic/ Regulatory/ Business Board level; Business objectives: strategy & policies level; and Business context: aligned procedures level. Lower levels on the Interoperability scale ignore “Contracts & financial arrangements” completely.

**Few projects cover “Education” on the infrastructure scale.** Again those that do are have high classifications on the Interoperability scale: “Political/ Economic/ Regulatory/ Business Board level” and “Business objectives: strategy & policies level”. Conversely “Skills & training” on the infrastructure scale broadly indicated across all Interoperability levels.

The observations above are indicative of gaps in the projects reviewed. Clearly “Contracts & financial arrangements” and “Education” are complete gaps. The good coverage of the closely related “Skills & training” requires investigation to eliminate ambiguity of the classification as a confounding cause.
3.1.3 STRATEGIC TECHNOLOGY RESEARCH
(Market or Needs driven)

Figure 3.5 Strategic Technology Research projects plotted on visualisation of the four SoA areas

The Cluster is categorised by low level Infrastructure and mid to high level Interoperability axes - it is differentiated from Technology Implementation which is represented by low level Interoperability. The main project themes may be summarised as:

- Building a CPS Research & Operational Community;
- Enabling Technologies for CPS Design & Control.

<table>
<thead>
<tr>
<th>ADVANCE</th>
<th>AMADEOS</th>
<th>EC-SAFEMOBIL</th>
<th>OPENCOSS</th>
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<td>KARYON</td>
<td>U-TEST</td>
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</tbody>
</table>
Table 3.3 Strategic Technology Research Projects

All domains are represented within this cluster implying that **strategic research is always cross domain**. This may impact the type of industrial support available for this type of research.

### 3.1.4 TECHNOLOGY IMPLEMENTATION

![Diagram](image)

**Figure 3.6 Technology Implementation projects plotted on visualisation of the four SoA areas**

This Cluster is categorised by low level Infrastructure and low to mid level Interoperability axes - it is differentiated from *Strategic Technology Research* which is represented by high level Interoperability.
Table 3.4 Technology Implementation Cluster Projects

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</table>

The projects in this cluster may be summarised as covering:

- CPS Simulation Control & Validation;
- Energy, Actuators & Sensors for CPS.

There is a strong pattern to domains covered by the projects: **Environment and Agriculture; Healthcare; and Security are almost completely ignored.** As there is a strong implementation focus in the cluster, **this may represent aversion to applied research in these domains, rather than a lack of challenges.** Given the problems of researching a negative association, **further research will be required to understand this observation.**

Conversely: Energy; IT&C; Manufacturing; Smart Community; and Transport are well represented as domains covered by the projects.

### 3.2 SUMMARY OF CLUSTER FINDINGS

- **OVERALL DOMAIN INDEPENDENCE OF CLUSTERS**
  - No top level cluster of CPS projects is defined by domain. The clusters are defined entirely by their categorisations within the Infrastructure and Interoperability scales. This is not to say that the Domain scale is unimportant, but rather Domain categorisation is not useful when trying to group projects into clusters. A potential application of this finding is the placement of information gathered at workshops, roadmaps and other sources into natural groups based on the Infrastructure and Interoperability axes.

- **GAPS IN EDUCATION, TRAINING AND FINANCIAL ARRANGEMENTS**
  - "Contracts & financial arrangements" and "Education" are poorly represented in the coverage of projects. This observation is supported by Gap Snippets also entered into the Vulture Tool.

- **STRATEGIC CPS RESEARCH IS CROSS DOMAIN**
  - This observation suggests that strategic CPS research classified to a specific domain. This may impact the type of industrial support available for strategic research.

- **DOMAIN BIAS IN TECHNOLOGY IMPLEMENTATION**
Energy; IT&C; Manufacturing; Smart Community; and Transport are well represented as domains covered by projects in the Technology Implementation cluster. Conversely, Environment and Agriculture; Healthcare; and Security are almost completely ignored. Further research will be required to understand this observation.

3.2.1 CONCLUDING REMARKS ON CLUSTER ANALYSIS
The cluster analysis has allowed for observation of large scale features within the dataset that may have been hard to find through other analytical approaches. No attempt has been made to apply a rigorous statistical analysis as only obvious findings have been included, but such an analysis might uncover other useful associations. In this context the raw dataset of CPS projects and associated categorisations may be a useful resource for other work packages and projects. However, anonymisation and removal of personally attributable remarks would be required.
4 KEY SOA ADVANCES FOUND BY PROJECT

The aim of this section is to summarise from a study of a selected set of recent and on-going EU funded projects and a general literature review the current state of the art in CPS design, implementation, operation and control. Each of the 54 projects identified by the EU Commission is summarised below with an indication of SoA advances claimed. SoA advances gleaned from additional sources are also provided.

The Vulture Tool essentially comprises of many snippets of information that have been categorised with descriptive metadata by consortium members. The tool offers facilities to rapidly browse through the snippets with user configurable searches based on the metadata. This enables a far richer view of the supporting data than is possible within the medium of a printed report.

Presenting the information on a project by project basis offers one particular view of the data underpinning this report.

4.1 ADVANCE
(Advanced Design and Verification Environment for Cyber-physical System Engineering)

The overall objective of ADVANCE is the development of a unified tool-based framework for automated formal verification and simulation-based validation of cyber-physical systems. Unification will be achieved through the use of a common formal modelling language supported by methods and tools for simulation and formal verification. An integrated tool environment will provide support for construction, verification and simulation of models. The delivered methods and tools will overcome significant deficiencies in current practices in cyber-physical systems engineering that make verification and validation hugely costly and time consuming. The focus of ADVANCE is to develop and deliver Methodology and Tools that fit well together in a rigorous and Integrated Process that will be validated with two industrial case studies, Dynamic Trusted Railway Interlocking and Smart Energy Grids.

Interoperability:
2. Business objectives: strategy & policies level

Domain:
1. Energy
8. Transport

Website: http://cordis.europa.eu/project/rcn/104887_en.html
4.1.1 A MULTI-SIMULATION FRAMEWORK

The specification within the associated deliverables focuses on the structural mechanism needed to integrate a simulation tool into the framework, possibly as a plug-in, and the communication mechanisms that need to be supported to ensure the efficient transfer of data between cooperating simulation tools. The requirements for the final multi-simulation framework are expressed and an architecture will be specified.

Domain:
1. Energy
8. Transport

Infrastructure:
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
21. Tools (including Simulation)

4.1.2 THE RODIN TOOLSET

Rodin supports the event-B language. The considered Rodin toolset consists of the Rodin core platform and the plug-ins created or maintained in the frame of the ADVANCE project: ProB, UML-B, ProR, Camille, Theory, Composition, SMT.

UML-B: UML-B provides a diagrammatic front end to Event-B to assist in constructing models. UML-B is UML-like but differs semantically and syntactically. Some improvements have been made to the plug-in.

Infrastructure:
21. Tools (including Simulation)

4.2 AGILE

(RAPIDLY DEPLOYABLE, SELF-TUNING, SELF-RECONFIGURABLE, NEARLY-OPTIMAL CONTROL DESIGN FOR LARGE-SCALE NONLINEAR SYSTEMS)

Based on recent advances on convex design for Large-Scale Control Systems (LSCSs) and robust and efficient LSCS self-tuning, the AGILE project aims at developing and evaluating an integrated LSCS-design methodology, applicable to large-scale systems of arbitrary scale, heterogeneity and complexity and capable of:

- Providing proactive, arbitrarily-close-to-optimal LSCS performance;
- Being intrinsically self-tuneable, able to rapidly and efficiently optimise LSCS performance when short- medium- and long-time variations affect the large-scale system;
- Providing efficient, rapid and safe fault-recovery and LSCS re-configuration;
- and achieving all the above, while being scalable and modular.
Interoperability:
4. Business context: aligned procedures level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
1. Energy
4. IT&C
7. Smart Community
8. Transport

Infrastructure:
1. Ubiquitous autonomy
2. Architectures
10. Design development of function(s) or device(s) or both
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
21. Tools (including Simulation)

Project Website: http://www.agile-fp7.eu

4.2.1 PLUG AND PLAY CONTROL FOR COMPLEX LARGE-SCALE REAL-LIFE SYSTEMS
One of the main reasons for the limited deployment of control systems to complex, real-life Large-Scale Systems (LSS) and especially to Systems of Systems (SoS) and Large-Scale Cyber-Physical Systems (LS-CPS) is the inability of conventional control methodologies to provide efficient control designs for such systems unless a very tedious procedure is employed. Such a tedious procedure typically requires an "expensive" and consuming initial design phase as well as constant calibration and re-configuration of the control system throughout its lifetime: plug and play control systems address this deficiency.

Interoperability:
6. Semantics: information & interoperability level
Domain:
1. Energy
2. Environment and Agriculture
3. Health Care
4. IT&C
5. Manufacturing
6. Security
7. Smart Community
8. Transport

Infrastructure:
4. Modelling and Simulation
9. Resilience and Fault Tolerance

4.3 AMADEOS
(Architecture for Multi-criticality Agile Dependable Evolutionary Open System-of-Systems)

The objective of this research proposal is to bring time awareness and evolution into the design of System-of-Systems (SoS), to establish a sound conceptual model, a generic architectural framework and a design methodology including tools for prototyping, for the modeling, development and evolution of time-sensitive SoS with possible emergent behaviors.

The development of the conceptual model, the architectural framework, the design methodology and some extensions to UML-based tools will form the core of the project work. Instead of using traditional guarantees that were the target for more closed and static systems, the architectural framework will be based on the concept of guaranteed best adaptation under the given constraints, sometimes just monitoring how the environment evolves, and influencing how the SoS takes mitigating actions.

Project Website: http://amadeos-project.eu

4.3.1 STATE OF THE ART REPORT

The AMADEOS project has carried out an analysis of the state of the art of Systems of Systems (SoS) engineering, with a focus on two topics of particular concern in the project: time awareness and evolution. The analysis utilises viewpoints based on: i) System-of-Systems (SoS) constraints, ii) semantics of communication, iii) architecture and Relied Upon Message Interface (RUMI), iv) dynamicty, v) evolution, vi) emergence, vii) governance, viii) handling of time, ix) dependability, x) security, and although with a minor attention through the document, xi) quality metrics.

Interoperability:
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level

Domain:
7. Smart Community
8. Transport

Infrastructure:
2. Architectures
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.3.2 CONCEPTUAL MODEL FOR INFORMATION TRANSFER IN SoS
System of Systems (SoS) integration is achieved by the exchange of information among constituent systems (CSs). With the advent of SoSs the context dependence of the information representation in the diverse constituent systems becomes a central issue that must be dealt with by a proper conceptual model. Kopetz - working with the AMADEOS project, presents such a conceptual model for information transfer in an SoS that takes account of dissimilar representations of the same semantic content in the diverse constituent systems. The concept of an Information Atom, (Itom) is introduced to comprise data and an explanation of the data in an atomic unit. Depending on the context of interpretation, the representation of the data and the explanation may change, while the semantic content, the information carried by an Itom must remain invariant. Work also focuses on the impact of the progression of real-time on the utility of information

Interoperability:
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level

Infrastructure:
4. Modelling and Simulation
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
4.4 AUTOPROFIT
(Advanced Autonomous Model-Based Operation of Industrial Process Systems)
This project aims at improving the operational efficiency of large-scale dynamic plants as found in petrochemical, chemical and other process industries. Costs related with industrial implementation of current model-based operation support systems, like Model Predictive Control, Real-Time Optimization and soft-sensors for these complex processes are currently very high. Given the importance of increasing demands on economic and sustainable process operation, there is a strong need to reduce the costs and increase the performance of model-based operation support systems.

Project Website: http://cordis.europa.eu/project/rcn/95579_en.html

4.4.1 CONTROL AND MODEL CALIBRATION WITH HIGH LEVELS OF AUTONOMY
The project intends to develop model-based operation support technology that enables control and model calibration at a considerable higher level of autonomy than currently possible. The technology enables autonomous maintenance by automated surveillance, continuously monitoring the process and operation support system performance. If performance degradation is anticipated then proactive adaptation of the model-based operation support system is initiated. The technology will operate on the basis of the least costly principle. The influence of the invasive testing on process operation and economics will be minimised, to the extent possible given the necessary accuracy of the resulting identified model. Moreover all decisions are based on an economic trade-off between process operation costs and benefits. This system should be able to optimise plant performance under varying operational conditions and adapting to changing circumstances.

Interoperability:
9. Physical interoperability level

Domain:
5. Manufacturing

Infrastructure:
9. Resilience and Fault Tolerance
17. Interfaces and interoperability issues

4.5 AXIOM
(Agile, eXtensible, fast I/O Module for the cyber-physical era)
The project focuses on HW/SW techniques to allow easy programmability of multi-core multi-board systems. A key challenge is the convergence between HPC (high performance computing) and Embedded computing (EC).
Use cases: smart video surveillance (coordination of multiple cameras towards a single event), smart living/home (new smart thermostat).

Project Website: http://www.axiom-project.eu/axiom-an-introduction/

Interoperability:
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Infrastructure:
10. Design development of function(s) or device(s) or both
15. Human interfaces for control
17. Interfaces and interoperability issues
20. Standards & Codes of Practice

4.5.1 VIDEO SURVEILLANCE APPLICATION
AXIOM will apply their technology to video-surveillance:
"For the Video-Surveillance, we may have to process a large amount of data (Video-Surveillance is also called “the Biggest Data” in that respect) for smart multi-focus recognition or coordination of multiple cameras towards a single event with context shift. The application required coordination of multiple cameras, presumably across a network.

Interoperability:
8. Network interoperability

Domain:
6. Security

Infrastructure:
7. Big Data
10. Design development of function(s) or device(s) or both
This technology will also be applied to SMART Homes and will focus on a simpler system that could replace the omni-present ambient thermostat with a much smarter device (similar to the Nest concept). This device will be scalable from the small house to big buildings and may be capable of acting as a small network server or proxy for a large number of existing or near future services in collaboration with the municipality or even in a peer-to-peer scenario.

Interoperability:
1. Political/ Economic/ Regulatory/ Business Board level
8. Network interoperability

Domain:
1. Energy
7. Smart Community

Infrastructure:
10. Design development of function(s) or device(s) or both
15. Human interfaces for control
17. Interfaces and interoperability issues

4.6 BALCON
(Boosting EU-Western Balkan Countries research collaboration in the Monitoring and Control area)

BALCON is a Support Action which aims to reinforce research cooperation between the academic and industrial communities from the EU and the Western Balkan Countries (geographical orientation) that are active in the design, development and implementation of systems and applications for Monitoring and Control (scientific orientation), with a special focus on 3 application areas (industrial orientation):

- Energy management
- Traffic/Transport management
- Intelligent industrial production

The project will achieve its objectives via a wide range of activities that include the: the delivery of a common set of research interests in the field of M & C; possible collaboration routes /sources of action and setting up a consultation and validation mechanism (“EU-WBC High-level Working Group in M&C area”) that will engage key recognised stakeholders of both regions in project activities. The project will organize a range of networking, training and awareness raising activities together with appropriate dissemination activities.
Interoperability:
1. Political/ Economic/ Regulatory/ Business Board level
3. Business context: aligned operations level

Domain:
1. Energy
4. IT&C
5. Manufacturing
7. Smart Community
8. Transport

Infrastructure:
8. Contracts & financial arrangements
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
19. Regulations & Policies

Project Website: [http://www.balcon-project.eu/mainpage](http://www.balcon-project.eu/mainpage)

4.7 BEMO-COFRA
(Brazil-Europe - Monitoring and Control Frameworks)
Smart Camera as a Sensor
The project develops procedures for managing smart cameras as sensors. Through this it was possible to apply the logic commented in Linksmart to devices like the smart cameras. There are currently several initiatives working on these aspects in different domains such as smart parking, but initially the use of cameras in WSN was not a common since its communication requirements and the applications that rely on them are more challenging in terms of bandwidth and latency.

Project Website: [http://bemo-cofra.eu/](http://bemo-cofra.eu/)

Interoperability:

Domain:

Infrastructure:

4.8 CLAM
CoLLaborative eMbedded networks for submarine surveillance

The CLAM project aims at developing a collaborative embedded monitoring and control platform for submarine surveillance by combining cutting edge acoustic vector sensor technology, underwater wireless sensor network protocols, collaborative situation-aware reasoning and distributed signal processing techniques for horizontal and vertical linear sensor arrays. The result will be a cooperative, flexible and robust underwater sensing, reasoning and communication platform for online surveillance of submarine environments accommodating pervasively deployed heterogeneous sensor nodes deployed at different water depths, enabling sensing and actuating devices to exchange data, autonomously network together, and collaboratively and locally assess their observation environment and act upon. Horizontal and vertical collaboration between sensor arrays in form of collaborative routing and beam forming, sensor fusion and distributed processing and reasoning enables fine-grained monitoring of the submarine environment and collaborative event detection as well as transmission of the network information to the monitoring stations. CLAM's consortium has experience and knowledge needed to deliver, exploit, and commercialize a complete solution right from the sensor node platform design, collaborative communication and networking protocols, adaptive, robust and scalable collaborative data processing and reasoning, up to the application requirements and market analysis. Participation of the international, external advisory board in this project indicates that the demand and potential market for such monitoring platforms goes beyond Europe. This can offer Europe a great opportunity in becoming an international leader in this emerging area which is still very much in its infancy.

4.8.1 RECONFIGURATION OF UNDERWATER ACOUSTIC SENSOR NETWORKS

"This paper presents a novel system to remotely control and reconfigure an heterogeneous underwater acoustic sensor network in scenarios with no direct access to all the underwater nodes after their deployment. The system uses the SUNSET framework to interact with and to operate the underwater network via single-hop and multi-hop acoustic transmissions. Users can remotely configure the underwater devices and the tests to run without the need to retrieve or bring to the surface the deployed nodes.

Interoperability:
8. Network interoperability
9. Physical interoperability level
4.8.2 UNDERWATER ACOUSTIC WIRELESS SENSOR NETWORKS

This survey aims to provide a comprehensive overview of the current research on underwater wireless sensor networks, focusing on the lower layers of the communication stack, and envisions future trends and challenges. It analyzes the current state-of-the-art on the physical, medium access control and routing layers. It summarizes their security threats and surveys the currently proposed studies. Current envisioned niches for further advances in underwater networks research range from efficient, low-power algorithms and modulations to intelligent, energy-aware routing and medium access control protocols.

Interoperability:
8. Network interoperability
9. Physical interoperability level

Infrastructure:
2. Architectures
10. Design development of function(s) or device(s) or both
17. Interfaces and interoperability issues 18. Methods / protocols / procedures

4.9 COMPASS
(Comprehensive Modelling for Advanced Systems of Systems)

The COMPASS project developed and validated comprehensive foundations, methods and tools for the model-based engineering of Systems of Systems (SoSs). SoSs are characterized by the operational and managerial independence of their constituent parts, their geographical distribution, the capacity of constituents to evolve independently, and particularly by the fact that reliance is placed on global behaviors emerging from the interaction of the constituents. Most of these are characteristics shared by large-scale CPSs, and so the project is relevant to this study.
The project’s aim was to develop rigorous approaches that permit the machine-assisted verification of emergent properties in SoS models that describe the interfaces between constituent systems in a contractual (assumption, commitment) manner, allowing their continuing independence to be taken into account. The approach was to develop a unified formal framework for the semantics of constituent system models, based on a modelling language CML that allows for the description of constituent system interfaces in contractual terms (assumption, commitment), and build tools that exploit this to allow the construction of architectural models in SysML, a notation supported by extensive industry practice. The main technical outputs are: modelling guidelines and patterns for SoS engineering, the formal CML language with a dynamic semantics, tools supporting the construction and analysis of models, and evaluation of the technology on industrial case studies in several sectors.

Interoperability:
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level

Domain:
4. IT&C

Infrastructure:
2. Architectures
3. Business models/Enterprise design
4. Modelling and Simulation
9. Resilience and Fault Tolerance
10. Design development of function(s) or devices) or both
18. Methods/protocols/procedures
21. Tools (including Simulation)

Project Website: [http://www.compass-research.eu/](http://www.compass-research.eu/)

4.9.1 REQUIREMENTS FRAMEWORK AND GUIDELINES FOR SoS ENGINEERING
A framework has been specified for model-based requirements engineering (SoS Approach to Context-based Requirements Engineering - SoS-ACRE), based on the examination of requirements from all relevant stakeholder contexts.

Each of the views making up the framework has been described and may be implemented in semi-formal or formal notations. Views support description of requirements sources, definition rules, requirements themselves, contexts, validation and traceability. The approach was subsequently piloted successfully using SysML in industry case-studies within the COMPASS project.
Interoperability:
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level

Infrastructure:
2. Architectures
3. Business models / Enterprise design
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
18. Methods / protocols / procedures

4.9.2 ARCHITECTURAL MODELLING PATTERNS FOR SoSs
COMPASS has started to accumulate a catalogue of modelling patterns to support the architectural analysis of systems of systems (SoSs), covering SoS structure, behaviour and layout. The work considers support for reasoning about architectural patterns and the architectures built using them.

Interoperability:
4. Business context: aligned procedures level
6. Semantics: information & interoperability level

Infrastructure:
2. Architectures
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
18. Methods / protocols / procedures

4.9.3 SoS ARCHITECTURAL FRAMEWORKS
Methods are required to help set up architectural frameworks (AFs) for the development of architectures in SoSs or their constituent systems, often for particular application domains. Such an AF is made up of viewpoints that define the information that can be presented. COMPASS provided a systematic method for defining AFs for given engineering projects. This is in effect a meta-framework, and so it is named the “COMPASS Architectural Framework Framework” (CAFF). The CAFF methodology is applied well before the actual construction of target SoSs, whereas the resulting framework is used in situ by SoS engineers.
Interoperability:
3. Business context: aligned operations level
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level

Infrastructure:
2. Architectures
4. Modelling and Simulation
18. Methods / protocols / procedures

4.9.4 LANGUAGES FOR MODEL-BASED SoS ENGINEERING
Modelling languages with well-defined semantics are required to enable analysis of interface compatibility and compositional analysis of SoS-level properties. In COMPASS, a unique language (the COMPASS Modelling Language – CML) covers SoS structure (as communicating concurrent processes), interface specification in terms of data and contractual-style descriptions of operations, and operational behaviour in terms of constrained traces of interactions. SoS architectural models developed using a subset of SysML can be translated to CML, enabling the application of a range of advanced analytic tools (automated proof, model checking, test generation, etc.).

CML’s key principles are support for analysis of emergence, contractual interface specification and management of semantic heterogeneity. Its own semantic basis is given in terms of the Unifying Theories of Programming (UTP), because the UTP allows for ready extension of new features (such as explicit support for location and mobility) reflected in several semantic forms, including operational and axiomatic forms that support simulation and proof respectively.

Interoperability:
4. Business context: aligned procedures level
6. Semantics: information & interoperability level
7. Syntactic interoperability

Infrastructure:
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
18. Methods / protocols / procedures
21. Tools (including Simulation)
4.9.5 FAULT MODELLING (PROFILE AND GUIDELINES) & ANALYSIS (TOOLS) FOR SoSs

A Fault Modelling Architectural Framework (FMAF) was developed to address the need for a systematic approach to capturing fault tolerance and dependability aspects of SoSs within model-based development methods. A recommended set of fault modelling viewpoints for describing faults and recovery processes was initially described informally.

Interoperability:

4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level

Infrastructure:

2. Architectures
4. Modelling and Simulation
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
11. Safety
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.9.6 ENSURING CONFORMANCE TO CONTRACTUAL INTERFACE SPECIFICATIONS DURING EVOLUTION IN SoSs

As SoSs evolve, it is necessary to ensure ongoing conformance of constituent systems (CSs) to the declared contractual (assume/guarantee) interfaces. COMPASS proposed novel methods for contract support for evolving SoSs, focusing on monitoring the performance of CS contracts. This monitoring is performed during SoS operation. Violations are reported to all constituent systems communicating with the violating system, so that appropriate action can be taken at a higher level. Adapting methods from passive testing and from the field of hardware debugging to the SoS context, potential root causes of the violations can be identified. These forms of contract support can be simulated in the RT-Tester (https://www.verified.de/products/rt-tester/) model-based testing environment for SoS in combination with the Symphony co-simulation environment (http://symphonytool.org/).

Interoperability:

6. Semantics: information & interoperability level

Infrastructure:

2. Architectures
4. Modelling and Simulation
9. Resilience and Fault Tolerance
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.9.7 COMPASS SYMPHONY: A TOOLS PLATFORM FOR MODEL-BASED ENGINEERING OF SYSTEMS OF SYSTEMS

SoS engineering is inherently collaborative, and tools for model-based SoS engineering should be Collaborative Development Environments (CDEs) supporting the joint production of models that can be systematically analysed even though one constituent system's owner might not wish (or be able) to disclose every part of their system's model. COMPASS has integrated architectural models of SoS structure and constituent system capabilities with formal contractual models of constituent system interfaces. The architectural modelling was done using SysML and contractual specifications were delivered through CML. CML incorporates data and functional modelling directly from the Vienna Development Method (VDM) with communication and concurrency constructs derived from Circus and Communicating Sequential processes (CSP).

In COMPASS, the Overture tools platform for VDM was extended to form the core of the Symphony CDE. Symphony links tools addressing SysML modelling, formal CML model-based analysis, and test automation as well as additional external tools. Construction, maintenance and analysis of CML models is supported by the Symphony tools implemented on Overture. Test automation is supported by the RT-Tester tool which identifies test cases, traces them to requirements and generates concrete test data by means of an integrated constraint solver.

The range and depth of the analyses that can be accomplished using this tools framework was demonstrated through industry case studies in audio/video streaming networks and emergency response.

4.10 CONSERN
( Cooperative and Self growing Energy aware Networks)

Low energy communication between one or multiple networked devices is envisioned to be fundamental in future systems. One of the aims of the CONSERN project is to develop solutions for such systems through autonomic and cooperative approaches. CONSERN is introducing a novel paradigm for dedicated, purpose-driven small scale wireless networks characterized by a service-centric evolutionary approach, referred here as an energy-aware self-growing network and system. In the context of CONSERN, the Self-Growing network paradigm considers (i) mechanisms for energy efficient interaction of the wireless network elements and (ii) mechanisms for the reliable and efficient evolvement towards later lifecycle phases. A Self-Growing network is set up on-demand and is initially dedicated to a single purpose such monitoring and/or control. Self-growing can be applied on large scale, distributed and cooperative systems, including, for example, construction sites, and delivering wireless services within a complex home/office environment requiring network parameter negotiation with a multitude of neighbouring networks, etc. In the course of its lifecycle, it may coexist and cooperate with other wireless networks of distinct owners and interest groups evolving in the
deployment area using or augmenting existing capacity in order to either serve additional purposes (e.g. in case of an emergency) or optimising under a specific purpose. CONSERN facilitates the emergence of mechanisms achieving energy efficient, robust, predictable and self-adaptive operation for future networked systems by considering mechanisms and methods for autonomic (design- and run-time) energy optimisations as well as cooperative energy aware behaviour of the distributed system nodes.

Project Website: [http://cordis.europa.eu/project/rcn/95373_en.html](http://cordis.europa.eu/project/rcn/95373_en.html)

4.10.1 DESIGN OF ENERGY-AWARE NETWORKING AND COOPERATION MECHANISMS (CASE STUDIES)

In an indoor environment relays can be used to mitigate interference between co-located femto base stations using the same frequency band. Cooperative relay communication and network coding is proposed to be used, based on the information fusion mechanisms, to increase the network performance and reliability.

A Heterogeneous Network (HetNet) is a network consisting of a mix of network nodes of various types. In such a network environment, relays can be used to save energy by cooperating and thus lowering the total number of needed transmissions. Similar results can be obtained by using distributed antenna systems. OPEX is a big cost for network operators and, by switching of network nodes at times with low traffic demands, energy can be saved. All these HetNet use cases build on the idea to save energy by directing the transmitted energy and utilising nodes that are close to the user.

In Cognitive Radio using licensed bands, it’s of utmost importance that secondary users do not interfere with primary users. Cognitive Radio power control is thus seen as important and will be studied.

Today (Circa 2011), there exist many devices which make use of unlicensed bands for their communication, e.g., WiFi, Bluetooth, ZigBee and DECT. It is anticipated that as the number of devices grow the interference between them will increase. To this end, CONSERN will focus on detection of and cooperation between various co-located network devices.

Wireless sensor networks can be used to collect environment information and help other networks in their cooperation. However, sensor raw data is often unreliable so ideas information fusion will be used to improve the quality.

Interoperability:

6. Semantics: information & interoperability level

Domain:

1. Energy

Infrastructure:
Ubiquitous autonomy

4.10.2 ENERGY EFFICIENT COOPERATIVE DECISION AND CONTROL SCHEMES

Deliverable D3.3 presents the progress and the outcomes for each of the considered studies and focuses on the developed mechanism for energy efficient co-operative networked control systems. Specifically, for each working item the following are provided:

- Overview of the problem, the developed mechanisms and algorithms, and the corresponding studies and studies,
- Mathematical formulation of models, key parameters and values for each study,
- Identification of the evaluation metrics and the evaluation (e.g. simulation or/and prototyping) environment,
- Description of evaluation studies (scenarios and assumptions), as well as indicative results highlighting performance of the proposed mechanisms and energy gains,
- Mapping of the considered mechanisms onto the CONSERN functional architecture - this way, WP3 mechanisms and algorithms are presented as addressing the functionalities forming the Self-growing architecture.

Interoperability:

9. Physical interoperability level

Domain:

1. Energy

Infrastructure:

10. Design development of function(s) or device(s) or both

17. Interfaces and interoperability issues

4.11 COSSIM

(A Novel, Comprehensible, Ultra-Fast, Security-Aware CPS Simulator)

COSSIM will provide an open-source framework to simulate the networking and the processing parts of the CPS more accurately, faster and including security and CPS simulation. Challenges include performance and accuracy of the simulation and Use cases are smart Grids, visual search

This multi-national project which will provide an innovative comprehensible, ultra-Fast, security-Aware CPS Simulator (called COSSIM) that will seamlessly simulate both the networking and the processing parts of the Cyber Physical Systems (CPS) significantly faster and more accurately than any existing solution. In order to achieve that COSSIM will develop a novel simulator framework based on a processing simulation sub-system (i.e. a “full-system simulator”) which will be integrated with a novel network simulator. Furthermore, innovative power consumption and security measurement models will be developed and incorporated to the end framework. On top of that, COSSIM will also address another critical aspect of an accurate CPS simulation environment: the performance as measured in required simulation time. COSSIM will create a framework that is orders of magnitude faster, while
also being more accurate and reporting more CPS aspects, than existing solutions, by applying hardware acceleration through the use of field programmable gate arrays (FPGAs), which have been proven extremely efficient in relevant tasks.

Project/Paper Website: http://cordis.europa.eu/project/rcn/194141_en.html

Interoperability:
8. Network interoperability
9. Physical interoperability level

Domain:
5. Manufacturing

Infrastructure:
21. Tools (including Simulation)

4.12 CPSETIS
(Towards Cyber-Physical Systems Engineering Tools Interoperability Standardisation)
- Area: International Open Standard for development tool
- Challenges: to conceive and set up a sustainable organizational structure as a platform joining all stakeholders to coordinate and harmonise all Interoperability Specification (IOS) related activities
- Use cases: automotive, aerospace, rail, health

There is currently no other content associated with this project

4.13 CPS-SUMMIT
Cyber-physical systems (CPS) are a core enabling technology for securing economic leadership in embedded systems and ICT, having an enormous social and economic importance, and making decisive contributions to societal challenges. The EU and the US face common challenges to push forward the limits of the science for engineering CPS, creating a favorable environment for strategic and pre-competitive collaboration.

The Transatlantic CPS Summit is an ambitious 18-month support action with the goal of facilitating and creating an enduring and sustainable collaboration campaign on CPS research and development between Europe and the US. The support action achieves its overall aim by means of:
1. Identifying and evaluating possible R&D cooperations between Europe and the US;
2. Investigating and promoting implementation of opportunities for cooperation;
3. Preparing a roadmap for R&D cooperation on CPS engineering between the EU and US together with recommendations for action;
4. Presenting final results to interested stakeholders (e.g. public bodies, industry, academic researchers) on both sides of the Atlantic.
To achieve the above, the project mobilises an outstanding multidisciplinary consortium of 7 EU partners and 5 US partners and brings together recognized CPS researchers across the EU and the US in a series of CPS Summit Workshops.

4.14 CPSE-LABS
(Cyber-Physical Systems Engineering Laboratories)

CPSE-Labs is an Innovation Action that aims to provide funding and support to CPS businesses around Europe. Funding and technical support is available for businesses to carry out experiments using platforms previously developed by a number of CPS design centres. This will help to close the gap between research centre technologies and the technologies in use in industry, by allowing businesses to trial the various CPS platforms and develop them further.

Project website: www.cpse-labs.eu

Interoperability:
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level

Domain:
1. Energy
2. Environment and Agriculture
3. Health Care
4. IT&C
5. Manufacturing
7. Smart Community
8. Transport

Infrastructure:
2. Architectures
4. Modelling and Simulation
9. Resilience and Fault Tolerance
11. Safety
15. Human interfaces for control
16. Human / community / social issues
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.14.1 SMART CITIES

The developments at the Spanish design centre build on the SOFIA2 (Smart Objects for Intelligent Applications) architecture, communication protocol, and a set of open tools as developed in this Artemis project.

Interoperability:

2. Business objectives: strategy & policies level
3. Business context: aligned operations level
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level

Domain:

7. Smart Community

Infrastructure:

2. Architectures
3. Business models / Enterprise design
16. Human / community / social issues

4.14.2 SMART PRODUCTION SYSTEMS

4DIAC is intended for the programming of programmable logic controllers (PLCs). Therefore, 4DIAC provides an alternative programming based on the distributed control standard IEC 61499. It provided as open source software under EPL-1.0 and consists of two parts: FORTE (4DIAC_RTE) and 4DIAC-IDE. fortiss future factory (f++) is a setup comprising 13 different MPS production machines from Festo Didactic controlled via different types of programmable logic controllers (PLCs) and microcontrollers. The production machines have been modified to allow for an arbitrary arrangement of them in a production line. In addition to 13 production machines, f++ comprises one mobile Robotino transportation robot from Festo Didactic.

Interoperability:

2. Business objectives: strategy & policies level
5: Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability

Domain:
5. Manufacturing

Infrastructure:
2. Architectures
3. Business models/Enterprise design
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
15. Human interfaces for control
18. Methods / protocols / procedures

4.14.3 CRITICAL MARITIME SYSTEMS ENGINEERING

The work will be carried in close cooperation with the German Association for Maritime Technologies (GMT), the industry cluster MARISSA (maritime safety and security applications), the Maritime Cluster Northern Germany (MCNG) and regional industry and agencies. The German Center North will drive this incubation from the automotive and aerospace sector into the maritime sector, a new high-tech growth market.

Interoperability:
2. Business objectives: strategy & policies level

Domain:
8. Transport

Infrastructure:
2. Architectures
5. Privacy
11. Safety
15. Human interfaces for control
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
4.14.4 AUTONOMOUS VEHICLES

CPSE Labs France aims to make dependability affordable for companies that are developing autonomous vehicles ranging from car with advanced driver systems to ground mobile robot or unmanned aerial vehicle. This is a prerequisite to prove that such vehicles can be operated safely and can be more widely deployed.

Interoperability:
2. Business objectives: strategy & policies level

Domain:
2. Environment and Agriculture
5. Manufacturing
6. Security
7. Smart Community
8. Transport

Infrastructure:
1. Ubiquitous autonomy
2. Architectures
4. Modelling and Simulation
6. Security
9. Resilience and Fault Tolerance
11. Safety
17. Interfaces and interoperability issues

4.15 CPSoS
(Cyber-Physical Systems of Systems)

The aim of the CPSoS project is to build constituencies for a European research and innovation agenda on SoS. The project will provide a discussion and an exchange platform for SoS-related projects and communities and will focus on the challenges posed by the engineering and the operation of technical systems in which computing and communication systems interact with large complex physical systems. The approach of CPSoS aims on integration and knowledge building processes regarding different
communities, and application fields. The focus in terms of domains lies on transport and mobility, but also on physically connected domains as electric grids, buildings, infrastructure, and process industry.

Project Website: http://www.cpsos.eu

Interoperability:
1. Political/ Economic/ Regulatory/ Business Board level,
2. Business objectives: strategy & policies level,
3. Business context: aligned operations level,
4. Business context: aligned procedures level,
5. Semantics: knowledge & sharing of knowledge level,
6. Semantics: information & interoperability level,
7. Syntactic interoperability,
8. Network interoperability,
9. Physical interoperability level

Domain:
1. Energy,
4. IT&C,
5. Manufacturing,
7. Smart Community,
8. Transport

Infrastructure:
1. Ubiquitous autonomy,
2. Architectures,
3. Business models / Enterprise design,
4. Modelling and Simulation,
5. Privacy,
6. Security,
7. Big Data,
8. Contracts & financial arrangements,
9. Resilience and Fault Tolerance,
10. Design development of function(s) or device(s) or both,
11. Safety,
12. Education,
13. Skills & training,
14. Human and Machine Awareness,
15. Human interfaces for control,
16. Human / community / social issues,
17. Interfaces and interoperability issues,
18. Methods / protocols / procedures,
19. Regulations & Policies,
20. Standards & Codes of Practice,
21. Tools (including Simulation)

4.15.1 SoA IN TERMS OF RESEARCH
Currently model-based design methods and tools have been established in the last years in industrial practice for traditional embedded systems. For CPS a step further needs to be done to adapt the existing methodologies and tools for design, engineering, and validation. There is nowadays no sufficient solution, which could master the nature of typical CPS like permanent evolution, flexibility, heterogeneity, and partial autonomy for instance. The current software and tools do not address aspects that are necessary for CPS such as questions of integration of CPS in all stages of the life-cycle – methods for modelling, simulation, and optimization are required for instance. Present solutions in manufacturing and engineering are based on central controlled and top-down hierarchical decisions, which do not fit to the nature of CPS that are more distributed and do have local autonomy. This means that current decision structures, systems architectures, the degree of self-organization, emergence behavior, real-time monitoring and fault tolerance do not meet the requirements of future CPS. The present systems and components do not address the necessary level of cognitive capacity that is essential for situational awareness. This awareness is required due to large distributed systems with decentralized management and control.

4.15.2 SoA IN TERMS OF TRANSPORT DOMAINS
The situation in terms of advancement regarding the level of CPS is dependent on the specific transport domain. The aerospace sector is currently leading in terms of autonomous vehicles. This advancement is due to the pressure from the military for progressive systems and due to the highly controlled character of the civil aviation. Less modern is the automotive sector, but partly autonomous systems are already launched to the market and complete autonomous elements will introduced to the market in 2015. The railway industry in terms of autonomous systems is lagging behind due to a more conservative and less innovative system. The maritime sector is increasingly becoming more progressive regarding autonomy but completely autonomous ships are far away from being launched to the market. Communication aspects in terms of security of communication processes and
guaranteed levels of quality of communication processes are not well addressed by current systems. Apart from these issues future CPS also need to master increasing interconnectivity, situational awareness, and resilience issues. Due to the different levels of progress in the development of advanced CPS in the various domains huge chances for technology transfer and knowledge exchange processes arise. The logistics domain is for instance partly autonomous with a trend to more automatic delivery processes outside the warehouse.

4.16 CPS-SUMMIT

Cyber-physical systems (CPS) are a core enabling technology for securing economic leadership in embedded systems and ICT, having an enormous social and economic importance, and making decisive contributions to societal challenges. The EU and the US face common challenges to push forward the limits of the science for engineering CPS, creating a favorable environment for strategic and pre-competitive collaboration. The Transatlantic CPS Summit is an ambitious 18-month support action with the goal of facilitating and creating an enduring and sustainable collaboration campaign on CPS research and development between Europe and the US. The support action achieves its overall aim by means of:

- Identifying and evaluating possible R&D cooperations between Europe and the US;
- Investigating and promoting implementation of opportunities for cooperation;
- Preparing a roadmap for R&D cooperation on CPS engineering between the EU and US together with recommendations for action;
- Presenting final results to interested stakeholders (e.g. public bodies, industry, academic researchers) on both sides of the Atlantic.

PROJECT RECENTLY STARTED SO NO SOA ADVANCES TO REPORT

Project Website: http://cordis.europa.eu/project/rcn/194164_en.html

4.17 CYPHERS

(Cyber-Physical European Roadmap and Strategy)

The overall aim of the CyPhERS project is combining and expanding the competence of EU member states in embedded and mobile computing and in control of networked embedded systems. The main objective of the project is to develop a European strategic research and innovation agenda for cyber-physical systems (CPS) to ensure Europe’s competitiveness in this emerging field. Within the CyPhERS project the state of the art in terms of engineering and regarding the current societal context was analysed. Concerning engineering the focus of the analysis was on properties and capabilities of cyber-physical systems, technologies for CPS, engineering processes related to the CPS lifecycle, scientific foundations for CPS. In terms of functioning future CPS, some aspects are relevant and need to be taken into account such as real-time, fault tolerance, big data analysis, proactive maintenance, and emergency behaviour.

Interoperability:
2. Business objectives: strategy & policies level,
3. Business context: aligned operations level,
4. Business context: aligned procedures level,
5. Semantics: knowledge & sharing of knowledge level,
6. Semantics: information & interoperability level,
7. Syntactic interoperability,
8. Network interoperability,
9. Physical interoperability level

Domain:
1. Energy,
4. IT&C,
5. Manufacturing,
7. Smart Community,
8. Transport

Infrastructure:
1. Ubiquitous autonomy,
2. Architectures,
3. Business models / Enterprise design,
4. Modelling and Simulation,
5. Privacy,
6. Security,
7. Big Data,
8. Contracts & financial arrangements,
9. Resilience and Fault Tolerance,
10. Design development of function(s) or device(s) or both,
11. Safety,
12. Education,
13. Skills & training,
14. Human and Machine Awareness,
15. Human interfaces for control,
16. Human / community / social issues,
17. Interfaces and interoperability issues,
18. Methods / protocols / procedures,
19. Regulations & Policies,
20. Standards & Codes of Practice,
21. Tools (including Simulation)

Project Website: http://www.cyphers.eu/project

4.17.1 CYPHERS SOA REPORT

The state of the art of CPS was analysed within the project in terms of technology, science, economy, education, legal, and societal aspects. In the following paragraphs examples and main aspects are summarised.

- **SoA regarding technological aspects:** One of the main technological challenges concerning CPS is the complexity of the systems. Reasons for this are aspects like increasing size and heterogeneity of the systems and aspects such as self-configuration and self-optimization. Solutions to master interoperability, autonomy, privacy, security, safety and uncertainty need to be addressed appropriately. Basic properties that are essential for cypher-physical systems are context awareness, cognitive computation, and autonomy. Different technologies are needed for CPS in order to master the paradigm change. To achieve physical awareness currently available technologies can be used such as sensors fusion, pattern recognition and situation recognition via situation maps. Existing and future sensors can be combined into global sensor networks – but the question of trustworthiness of the sensor data, the specific features of the sensors and how to ensure that the decisions taken by cyber-physical systems are correct, are not answered by now. In order to master the challenge of pattern recognition tried-and tested algorithms already exist, but problems regarding the selection of the right data are still not solved. Autonomous behavior of CPS could be achieved by available multi-criteria situation assessment. Issues that still remain in this field are unclear or contradictory situations. Artificial intelligence approaches can also be used, but are currently not suitable in situations where unknown actors are involved. Technologies for human-machine interaction with regard to recognising the intention of users are available in the fields of HMI, intention recognition, and human modelling.

- **SoA regarding scientific aspects:** Most disciplines stay in their established scientific field without or only linking to few neighborhood fields and so resulting in scientific silos. The lack of multidisciplinarity is based on missing instruments for collaboration regarding technological methods and organisational methods. The societal aspects such as capabilities and limitations of humans being part of CPS are not well analysed nowadays. The aspect human in the loop needs to be focused more in future approaches. Due to the cross-domain and cross-discipline approach of CPS, foundational theories in the field of CPS must be developed. Models of CPS and all aspects of the systems and elements are by now not adequately created – for instance methodical guidelines are missing.
SoA regarding educational aspects: In the current situation training and education is focused on one specific discipline. CPS are by nature cross-disciplinary and due to its innovative character disruptive and evolutionary. This should be taken into consideration in order to adapt the education system to the requirements of cyber-physical systems. For a successful implementation of a new CPS education discipline aspects like better exchange processes between theory and practice should be supported. In those days there is still a lack of cross-fertilization between academia and industry that should be overcome for optimized knowledge transfer processes.

SoA regarding economic aspects: The traditional domains like manufacturing have strong established and sometimes over embedded systems and networks which could hinder further developments and generation of new business relations between traditional firms and arising companies that are innovative and adapted to CPS. Internet firms such as Google, Amazon will increasingly enter the market of established firms, which have currently only well-known, over decades developed, competitors. Current business models in the relevant domains as engineering are more product-orientated. In terms of CPS service-orientated business opportunities will become more important.

SoA regarding societal aspects: Today’s European industrial system is often penetrated by risk-averse stakeholders from politics, industry, and the public sector, which hinder the successful fast and sophisticated implementation towards a future CPS. Awareness building processes need to be encouraged in order to show significant chances and also real risks. There is currently a lack of knowledge in the population and in the industry as well as academia about the potentials of CPS.

SoA regarding legal aspects: The current legal system is not completely adapted to the nature of upcoming cypher-physical systems. CPS need a legal framework that is adjusted to disruptive, innovative, and risk-taking characters of the new emerging systems – otherwise the legislation would act as a barrier for these kinds of innovations. The inherent characters of CPS like unclear situations and thus unclear interpretations of the cypher-physical machines will result in situations that can lead to judicial claim. Accidents of autonomous cars, for instance, need to base on a legal framework that do not inhibit the further development of CPS. Furthermore, certificates for the emerging CPS, that are necessary to secure certain quality of products and processes within the different CPS domains, are currently not adapted to the new paradigm. The current situation in terms of regulation of for example data protection, security, and safety is characterized by a huge fragmentation of different guidelines and laws and need a process of harmonization in order to reduce uncertainty for entrepreneurs, innovators, investors and established firms.

4.18 DANSE
(Designing for Adaptability and evolutionN in System of systems Engineering)

Systems of Systems consist of collections of (possibly independent, pre-existing, geographically distributed and following their own goals) constituent systems whose behaviours are coordinated to provide services and additional value with respect to their original intended operations. This kind of entity offers severe technical, management, and political challenges as witnessed by energy blackouts such as the one experienced by Italy in 2003 and the emergency management disaster in response to the hurricane Katrina in 2005. DANSE aims at developing new approaches to the design and management of the operation of SoS based on: advanced methodologies based on a new evolutionary, adaptive and iterative SoS life-cycle model; semantically sound models based on the notion of contracts; innovative architectures that provide the infrastructure to allow the dynamic affiliation of
components so that the behaviour of the ensemble is not disturbed; novel supporting tools for analysis, simulation, and optimisation; organised in an integrated environment. DANSE will develop training material and classes that help advance the knowledge base of European industry and government to allow the creation of new services and to substantially improve existing ones to levels of efficiency that are unthinkable today. Three Test Cases – Air Traffic Management, Autonomous Ground Transport and Integrated Water Treatment and Supply— which are real industrial problems planned for commercial development, have been identified to validate DANSE approach. The last case is a full-fledged industrial project used for the demonstration of the DANSE paradigm.

Project Website: [http://danse-ip.eu/home/](http://danse-ip.eu/home/)

4.18.1 DANSE TECHNOLOGY DEMONSTRATION PACKAGE

This document describes a demonstration of the DANSE methodology when applied to a Water Treatment scenario.


The presentation seems to be a description of a real world use case. It is therefore a useful statement of the current state of the art.

Interoperability:

5. Semantics: knowledge & sharing of knowledge level

6. Semantics: information & interoperability level

Domain:

2. Environment and Agriculture

4. IT&C

Infrastructure:

4. Modelling and Simulation

4.18.2 RELATIONS TO EXISTING WORLD STANDARDS AND PRACTICES

Several DANSE partners are actively contributing to standardisation bodies, which are relevant to promote important innovations developed in the course of the project. These innovations include systems engineering methodologies, languages, and tool interfaces.
This report summarizes the work done in the area of standardisation, as required by the DANSE DOW (Task T4.5 - http://danse-ip.eu/home/images/deliverables/danse_d4.5_standardisation.pdf) It consists of a review of existing relevant standards and details participation in the international forums that promote standards for systems engineering, to promote DANSE results in the future versions of their standards.

Interoperability:
1. Political/ Economic/ Regulatory/ Business Board level

Domain:
1. Energy
2. Environment and Agriculture
3. Health Care
4. IT&C
5. Manufacturing
6. Security
7. Smart Community
8. Transport

Infrastructure:
20. Standards & Codes of Practice

4.19 DYMASOS
(Dynamic Management of Physically Coupled Systems of Systems)

The DYMASOS project work on new management methods to better control and optimise the behaviour of large interconnected systems of systems, which are essential for the future well-being of the citizens of Europe. The project will develop new methods for the distributed management of large physically connected systems with distributed autonomous management and global coordination. The research will be driven by case studies in electrical grid management and control, including the charging of electric vehicles, and industrial production management.

The methods that will be investigated for the management of large physically coupled systems of systems are:
Population-control techniques that are motivated by the behavior of biological systems;
Market-like mechanisms that try to achieve global optimality by the iterative setting of prices or resource utilization constraints.

Coalition games, where agents group dynamically to pursue common goals.

Management of large distributed production and distribution systems.

The DYMASOS project will develop new management methods to better control and optimise the behaviour of large interconnected systems of systems, which are essential for the future well-being of the citizens of Europe.

Project Website: http://www.dymasos.eu/

Interoperability:
3. Business context: aligned operations level
4. Business context: aligned procedures level

Domain:
1. Energy
5. Manufacturing

Infrastructure:
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.20 EC-SAFEMOBIL

(Estimation & Control For Safe Wireless High Mobility Cooperative Industrial Systems)

Autonomous systems and unmanned aerial vehicles (UAVs), can play an important role in many applications including disaster management, and the monitoring and measurement of events, such as the volcano ash cloud of April 2010. Currently, many missions cannot be accomplished or imply a high level of risk for the people involved (pilots and drivers), as unmanned vehicles are not available or not permitted. This also applies to search and rescue missions, particularly in stormy conditions, where pilots need to risk their lives. These missions could be performed or facilitated by using autonomous helicopters with accurate positioning and the ability to land on mobile platforms such as ship decks. These applications strongly depend on the UAV reliability to react in a predictable and controllable manner.
manner in spite of perturbations, such as wind gusts. On the other hand, the cooperation, coordination and traffic control of many mobile entities are relevant issues for applications such as automation of industrial warehousing, surveillance by using aerial and ground vehicles, and transportation systems. EC-SAFEMOBIL is devoted to the development of sufficiently accurate common motion estimation and control methods and technologies in order to reach levels of reliability and safety to facilitate unmanned vehicle deployment in a broad range of applications. It also includes the development of a secure architecture and the middleware to support the implementation.

This development will be validated in two scenarios: industrial warehousing involving a large number of autonomous vehicles and surveillance also involving many mobile entities.

Interoperability:
7. Syntactic interoperability
8. Network interoperability

Domain:
4. IT&C
5. Manufacturing
6. Security

Infrastructure:
1. Ubiquitous autonomy
6. Security
10. Design development of function(s) or device(s) or both
11. Safety
15. Human interfaces for control
16. Human / community / social issues
17. Interfaces and interoperability issues

Project Website: http://www.ec-safemobil-project.eu

4.20.1 MODELLING AND CONTROL OF UNMANNED HELICOPTERS

This paper extends previous contributions of the authors regarding the use of tethered configurations for improving performance in hovering manoeuvres performed by unmanned helicopters. More
precisely, this work presents a more elaborate strategy for controlling the helicopter, while adopting the same control paradigm of operation with a constant tether tension by means of the ground device. The aim was to take better account of the complex and nonlinear nature of the system. To this end, instead of the basic linear scheme used for the first concept proof, a combination of classical PID control laws together with model inversion blocks constitutes the basis of the new controller. Additionally, feed-forward action for counteracting rotational couplings is also accounted for. Benefits emerging show that the response of the state variables directly related to the perturbation signals is better than in the linear controller. In order to endorse the validity of the conclusions obtained in these simulations, the next step will be carrying out field experiments.

Interoperability:
8. Network interoperability
9. Physical interoperability level

Domain:
4. IT&C

Infrastructure:
1. Ubiquitous autonomy
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
21. Tools (including Simulation)

4.20.2 EC-SAFEMOBIL ASSESSMENT OF BEST PRACTICES - MAY 2013
The Deliverable (D10.1 Compilation of Best Practices in S?W Dev processes) is devoted to the Compilation of best practices to be used in the design and development of software systems in the EC-SAFEMOBIL project. It first deals with general concepts and then reviews the current state of the best practice assessment in EC-SAFEMOBIL including software development, particular aspects related to middleware development, research on estimation and control, and industrial consideration.

The key elements of this deliverable are what the project considers to be Best Practice and SoA in terms of methods and processes to be adopted to develop the software systems for the UVs in question. It is useful in that is gives examples of why certain methods are believed to work better in innovative research environments than others.

Interoperability:
2. Business objectives: strategy & policies level
4. Business context: aligned procedures level
4.20.3 INNOVATION IN TECHNICAL APPROACH

New state estimation/prediction methods will be implemented for both very accurate coupled motion control and large scale systems composed of many mobile entities. Novel prediction methods will be developed for systems with real-time constraints. These methods will be able to cope with network delays and bandwidth limitations. Additionally, new decentralised state estimation algorithms, able to cope with different sources of uncertainty and to scale to many mobile entities, will be developed. For estimation purposes, data from monocular and stereo cameras as well as from IMU and GPS sensors will be fused. The project will also develop new, range-only, Simultaneous Localization and Mapping Techniques using the radio signals present in the networked devices, as well as cooperation techniques for intelligent estimation strategies (Active Sensing).

With respect to cooperation, coordination and control techniques, the project will apply in real-time new optimization techniques for scalable and dynamic multi-vehicle route and trajectory planning. The resulting decentralised decision/control algorithms should be able to cope with different sources of uncertainty while, at the same time, scale to a large number of entities. For dynamic routing and trajectory planning, new trajectory optimization techniques will be explored. Furthermore, the above results in distributed estimation/prediction will be used by distributed decision algorithms.

Both estimation and control techniques will be integrated through efficient middleware and communication protocols adapted to satisfy reliability, safety and security for industrial-grade operations. This middleware will integrate both data-centric and network-centric paradigms, and will address the safety challenges by ensuring that synchronisation and temporal constraints in distributed systems for high mobility applications are satisfied. The security of Mobile Ad Hoc Networks for estimation and control will also be considered.

Interoperability:

7. Syntactic interoperability
8. Network interoperability
There is enormous economic potential for the application of embedded optimization technologies in embedded systems design. Recent advances in the performance of embedded hardware platforms, in combination with fundamental improvements in optimization theory and algorithms, have opened the door to widespread applications over the next decade. Embedded optimization will enable huge energy and resource savings, increased safety, and improved fault detection across a wide range of industrial applications.

The project objectives:

- The EMBOCON consortium will enable widespread application of real-time optimization in embedded systems through:
  - Tailoring of customized numerical algorithms to increase their robustness and efficiency on embedded systems,
  - Enabling real-time optimization on cheap industry-standard hardware platforms,
  - Defining a common user interface for optimization technologies to facilitate technology transfer to industry, and
  - Performing challenging case studies in cooperation with industrial partners to demonstrate technological maturity.

Project Wiki
4.21.1 THE EMBOCON SOFTWARE PLATFORM
This platform offers a set of standardized software interfaces used for the rapid design of embedded systems. The software platform has been released as open source using a MIT licence. This is a tightly focused highly technical project with the objective of making a tool to increase the industrial accessibility of embedded systems. The publication of the EMBOCON platform may be taken as the state of the art at the time of release in 2014. Its impact would appear to cross all domains.

Interoperability:
9. Physical interoperability level

Domain:
1. Energy
2. Environment and Agriculture
3. Health Care
4. IT&C
5. Manufacturing
6. Smart Community
7. Transport

Infrastructure:
10. Design development of function(s) or device(s) or both
21. Tools (including Simulation)

4.22 ENOSYS
(IntEgrated ModelliNg and Synthesis tOol flow for Embedded SYStems Design)

To provide an integrated workbench that will increase productivity of embedded system development and shorten time-to-market for SoC (System on Chip) systems. Today, SoC vendors realize that critical decisions must be made long before development teams engage in the hardware and software design for new SoC and programmable SoC-based products. It is becoming clear that hardware-software design and verification must form part of a single, unified effort, whereas the methodologies currently available were intended to aid either hardware-only or software-only development. That these tools are no longer adequate for modern SoC designs is confirmed by the recent emergence of new concepts that are disrupting the traditional design flow; these include system-level specification (specification capture), functional and architectural analysis, and high-level estimation, partitioning and software synthesis. ENOSYS will provide an integrated workbench combining MARTE and FalconML. The OMG MARTE will be evaluated and extended to address end-user demands and requirements for integration. The
approach and the tool flow will be evaluated and validated with representative scenarios from the telecoms domain. The results will be reported and presented at OMG in order to influence standardization and improve opportunities for adoption.


### 4.22.1 ENOSYS METHOD DEMONSTRATED IN AN INDUSTRIAL CONTEXT

This paper describes the use of the ENOSYS flow by the Thales group on a small project. The conclusion of the study is that "As a general conclusion from these evaluations, end-users believe that adopting the ENOSYS flow could shorten the time to market of their current system development processes. The evaluation performed also demonstrated that the initial of the integrated tool set version is a strong base for the further development efforts planned within the project."

Interoperability:

4. Business context: aligned procedures level

**Domain:**

4. IT&C
5. Manufacturing

**Infrastructure:**

2. Architectures
10. Design development of function(s) or device(s) or both
18. Methods / protocols / procedures
21. Tools (including Simulation)

### 4.22.2 THE DESIGN SPACE EXPLORATION METHODOLOGY

Taken from the ENOSYS project deliverable D2.4 “The Design Space Explorer Methodology” which describes the approach for Design Space Explorer (DSE) for automated partitioning and co-design. Also included are aspects of FalconML, scheduling multi-level simulations (TLM, TLM-CA, RTL), collection of the data and re-tagging the UML description of the system with software/hardware stereotypes. Finally, a preliminary demonstrator case study is investigated for the software flow, hardware flow exploration around LE1 processor using Jink and ENOSYS flow."

Interoperability:
4. Business context: aligned procedures level

Domain:
4. IT&C
5. Manufacturing

Infrastructure:
2. Architectures
10. Design development of function(s) or device(s) or both
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.22.3 METHODOLOGY FOR SOURCE CODE OPTIMISATION USING TRANSFORMATIONS

Taken from the ENOSYS project deliverable D2.3 “Methodology for Source Code Optimization using Transformations” which records and provides sufficient details on both the methodological aspects and the implementation of the UPEL optimization tool, under the name ACOT (Application Code Optimization Tool). This methodology targets the optimization of the memory data transfers that happens during the program operation between the processing units (programmable processor, hardware accelerator) and memory system. By taking the following factors into account:

- most of the time the program operates on data resident in memory;
- memory responds in a much slower rate than the processor;
- a large amount of power is consumed in memories;
- memories have special addressing modes for efficient operation under specific memory access patterns;
- memories consume a significant amount when integrated on the same chip with the data path.

it can be concluded that optimizing the memory operation can give a high benefit in the overall system’s performance cost, and power consumption.

ACOT is presented as a compiler framework consisting of multiple tools that provide analysis and automatic transformation of the application’s source code. ACOT’s input originates from the C back-end emitter of the FalconML tool, while the output is partitioned into two parts: 1) the first one targeting to LE1 processor and 2) the second one targeting to the hardware synthesis.

ACOT gives flesh to the overall source code transformation methodology by automating most of its parts. Analysis of the source code is applied both prior and after the optimization to identify optimization opportunities and quantify the improvement by a transformation, respectively. The transformation module of ACOT provides automation for the most important transformations that have been identified in the literature for their benefits to memory operation. The whole process is steered by the designer which has full control over the optimization strategy (order and type of
transformations applied) followed to optimize the application.

Infrastructure

2. Architectures

10. Design development of function(s) or device(s) or both

18. Methods / protocols / procedures

21. Tools (including Simulation)

4.22.4 THE ENOSYS DESIGN FLOW FOR THE MODELLING AND SYNTHESIS OF EMBEDDED SYSTEMS

This document refers to the ENOSYS project deliverable D2.2 “The ENOSYS design flow for the modelling and synthesis of embedded systems (preliminary version)”

This deliverable is the initial document detailing the full design flow, from UML design entry all the way to silicon. The preliminary version provides outline flows, tool exchange points and the programmers’ model of the LE1 multicore engine. Outline descriptions silicon platform and the Design Space Explorer are given.

Interoperability:

4. Business context: aligned procedures level

Domain:

4. IT&C

5. Manufacturing

Infrastructure:

2. Architectures

10. Design development of function(s) or device(s) or both

18. Methods / protocols / procedures

21. Tools (including Simulation)

4.22.5 STATE-OF-ART-ART ANALYSIS FOR EMBEDDED SYSTEMS DESIGN

This document refers to the ENOSYS project deliverable D2.1 “State-of-Art Analysis for Embedded Systems design”. The work in this deliverable records and categorizes contemporary embedded system design practices and tools. It first classifies the existing embedded system design methodologies strategies as they have evolved by many years of design practice. These categories are primarily
distinguished by the path followed from the application’s high level definition to its realization on silicon.

Interoperability:
4. Business context: aligned procedures level

Domain:
4. IT&C
5. Manufacturing

Infrastructure:
2. Architectures
10. Design development of function(s) or device(s) or both
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.23 EOT
(Eyes of Things)
A vision platform that will allow maximizing inferred information per milliwatt

The objective of this project is to build an optimized core vision platform that can work independently and also embedded into all types of artefacts. The envisioned open hardware must be combined with carefully designed APIs that maximize inferred information per milliwatt and adapt the quality of inferred results to each particular application.

The “Eyes of Things” project aims at developing a ground-breaking platform that combines:
A need for more intelligence in future embedded systems.
Computer vision moving rapidly beyond academic research and factory automation.
The phenomenal technological advances in mobile processing power.

Project Website: http://eyesofthings.eu/

Interoperability:
9. Physical interoperability level
ERA aims at investigating and developing new methodologies in both tools and hardware designs to break through current power and memory walls for the next-generation embedded systems platforms. The proposed strategy is to utilize adaptive hardware to provide the highest possible performance for given power budgets for a (set of) targeted application(s). This is a departure from utilizing fixed designs that limit their use to their intended application(s) and that require additional design effort to target new applications.

Project Website: http://www.era-project.eu/

Interoperability:
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level
4.25 EUROCPs

EuroCPS is working on enabling SMEs building innovative CPS products. The project main goals can be summarized as follows:

- Strengthen the position of European industry along the value chain
- Promote innovative CPS products using existing EU chips
- Promote the optimization of CPS products with new EU chips at SMEs

These objectives will be achieved by taking innovative embedded ICT from any sectors to SMEs thus facilitating user-supplier partnerships across value-chains and regions.

Project Website: https://www.eurocps.org/

Interoperability:
- 4. Business context: aligned procedures level
- 7. Syntactic interoperability
- 8. Network interoperability
- 9. Physical interoperability level

Domain:
- 4. IT&C
- 7. Smart Community

Infrastructure:
- 3. Business models / Enterprise design
- 17. Interfaces and interoperability issues
- 18. Methods / protocols / procedures

4.26 GENESI

(Green sEnsor NEtworks for Structural monitoring)

The background for the project is the number of dramatic events involving public structures and private buildings collapsing and the need to investigate whether anything can be done to mitigate their effects or avoid them and save the lives taken as a result of their occurrence. Wireless sensor network
(WSN)-based systems for structural health monitoring are seen as the answer to this crucial question if they are able to provide long lasting monitoring and robust and reliable data delivery on request.

The aim of GENESI is to fill the gap for long lasting or perpetual sensing systems, by designing and implementing a novel generation of “green wireless sensor networks” which can be embedded in buildings and infrastructures at the time of construction and be able to provide a monitoring and control intelligence over the whole structure lifetime.

Project Website: http://genesi.di.uniroma1.it

4.26.1 ROME UNDERGROUND TEST BED

The goal of Rome B1 Underground test-bed was to monitor the construction of the 700m tunnel connecting the Conca d’Oro and Jonio new metro stations. The construction involved the use of a 9m diameter Tunnel Boring Machine (TBM) long 70 meters. The excavation started at the end of November 2011 and finished in mid February 2012. GENESI system was deployed to monitor 4 concrete sections instrumented with vibrating-wire strain gauges to monitor the concrete and steel deformations that are a critical parameter to evaluate the forces which act over the structure. The sampling period has been set to 5 minutes for system stress tests, and then to 1 hour as requested by the construction works companies. Specifically, according to the requirements of the construction project the Conca D’Oro-Piazzale Jonio tunnel is monitored through no.4 instrumented sections, each having three concrete segments equipped with one commercial data loggers and six Sisgeo vibrating strain gauges. Commercial data loggers are connected to the remote centre through a cabled network, while the same type of monitoring system has been replicated interleaving the commercial instrumented sections envisioned for monitoring the tunnel with four GENESI instrumented sections.

Interoperability:

9. Physical interoperability level

Domain:

1. Energy

5. Manufacturing

8. Transport

Infrastructure:

10. Design development of function(s) or device(s) or both

4.26.2 LONG-LIFE SENSORS EMBEDDED IN THE BUILT ENVIRONMENT FOR USE ON CPSOS

To achieve the objectives of the project GENESI combines advanced HW components (low power, flexible sensing platform equipped with a smart power unit and wake up radio capabilities) with novel energy efficient, energy harvesting and wake up radio aware communication paradigms, in-network distributed processing and reasoning mechanisms. The resulting system provides the core of the next
generation of systems for structural health monitoring that are long lasting, pervasive, totally distributed and autonomous.

Interoperability:
9. Physical interoperability level

Domain:
1. Energy
7. Smart Community

Infrastructure:
2. Architectures
10. Design development of function(s) or device(s) or both

4.27 GREENERBUILDINGS
Buildings account for more than 40% of energy consumption and are the largest CO2 producers in many world regions. Thus, making efficient use of energy in buildings is paramount to the conservation of energy and reduction greenhouse effects. To date, automated control and adaptation in buildings is often limited to occupant commodity changes of indoor climate depending on room temperature, CO2, and lights operated through motion detectors.

GreenerBuildings aims to realise an integrated solution that addresses the challenge of energy-aware adaptation from basic (energy harvesting) sensors and actuators, up to an embedded software for coordinating thousands of smart objects with the goals of energy saving and user support.

“GreenerBuildings will investigate how buildings can dynamically adapt their operations according to actual use, aiming at substantial energy savings.”
Their vision is that buildings can respond to their actual use and changes in their environment; interact with their occupants through novel ubiquitous sensing and occupant behaviour inference techniques and that can transparently adapt a building’s function and operation.

Project Website: http://www.greenerbuildings.eu

4.27.1 LIVING LAB
A 'living-lab' assessment exercise was run for several months [no public deliverable about this]. The project got as far as prototyping, and was well-publicised. A description of this living lab is below, taken from a project newsletter (no 5):
"The living-lab consists of two installations: one in the Potentiaal building at TU Eindhoven campus, and another one at the neighboring MetaForum building. The living lab installation currently comprises the following sensors:

- Passive Infrared (PIR) sensors for motion detection and counting number of people
- Ultrasound rangers (USR) in order to measure distances and detect presence
- Microphones to recognize office activities
- Light, temperature, humidity and CO2 sensors for detection of environmental conditions
- Magnetic contact switches to recognize use of windows and doors
- Plug-in power meters to measure consumption of appliances
- In order to allow acting towards reduced energy consumption, the installation is completed by the following actuators:
  - Light switches to activate and dime lights
  - Plug-in power meters to be able to activate and deactivate appliances
  - Blinds motor/controller for controlling angle and height of window blinds
  - Portable air conditioner to control and adjust temperature, humidity and CO2 level"

Interoperability:
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
1. Energy
7. Smart Community

Infrastructure:
2. Architectures
7. Big Data
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
17. Interfaces and interoperability issues
18. Methods / protocols / procedures

4.27.2 ENERGY-EFFICIENT CONTROL OF SENSORS AND ACTUATORS IN LARGE BUILDINGS - CENTRALISED CONTROL APPROACH

No access yet to final report; instead, this information is based on Deliverable D2.1 "Architecture Design" which outlines the project plans.
Note also allied projects SCUBA, Local4Global, AGILE, all exploring built environment management and control.

The architecture (as intended) has three layers:

- **Physical Layer**: They envisage a very large number of sensors to detect human occupancy and characteristics (e.g. person identification by heat maps and differences in these; thermopiles everywhere to generate these heat maps and record activity, movement, etc [note privacy, security aspects of this]. Also actuators of various kinds/classes. These are connected to the upper layers through a Sensors/Actuators Gateway, which accommodates heterogeneity in all these physical entities. There is also an Interconnection to a smart grid via a Smart Meter, to take advantage of pricing fluctuations, and of any alternative sources such as solar panels on roof of the building.

- **Ubiquitous Layer**: This is a real-time operations layer. It receives input from the Physical Layer below it, and using AI it generates a real-time context picture (or common operating picture), which is fed into a Repository. This picture tracks Occupant Location, Occupant activity, Thermofluid Analysis of the state of the building, and the building context (e.g. which windows are open, outside environment, etc.) It controls the actuators through Orchestration and Scheduling modules; Orchestration works out which actuators in what sequence will deliver optimal building performance w.r.t. human, device occupancy, and Scheduling controls the timing and activity of the actuators, with diagnostic feedback about what is happening.

- **Composition Layer**: Sits above the Ubiquitous Layer; receives input from the Context generator (the real-time context) and the Repository (real-time context trends), both in the Ubiquitous Layer. Other inputs are direct user goals and the (adaptive) Building configuration. A Control then creates a 'desired automation description' as an input to Composition module. Its function is to produce an AI-based plan, with the aid of computational fluid dynamics and a set of rules, which can then be delivered to the Orchestrator in the Ubiquitous layer.

**Interoperability:**

6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

**Domain:**

1. Energy
7. Smart Community

**Infrastructure:**

2. Architectures
7. Big Data
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
17. Interfaces and interoperability issues
18. Methods / protocols / procedures

4.28 HYCON2
(Highly-complex and networked control systems)

ICT developments both enable and also enforce large-scale, highly-connected systems in society and industry. Knowledge to cope with these emerging systems is lacking. HYCON2 will stimulate and establish the long-term integration of the European research community, leading institutions and industry in the strategic field of control of complex, large-scale, and networked dynamical systems. It will interconnect scattered groups to create critical mass and complementarity, and will provide the necessary visibility and communication with the European industries. HYCON2 will assess and coordinate basic and applied research, from fundamental analytical properties of complex systems to control design methodologies with networking, self-organizing and system-wide coordination. HYCON2 has identified several applications domains to motivate, integrate, and evaluate research in networked control. These domains are ground and aerospace transportation, electrical power networks, process industries, and biological and medical systems. Benchmarking will serve as a tool for testing and evaluating the technologies developed in HYCON2 and for stimulating and enforcing excellence by the identification and adoption of best practices. In particular, two show-case applications corresponding to real-world problems have been selected in order to demonstrate the applicability of networked control and the need for research in control. As no substantial technological breakthrough can be achieved without preparing the proper cultural background, a further important objective of HYCON2 is to spread and disseminate excellence through multi-disciplinary education at the graduate and undergraduate level.

Project Website: [http://www.hycon2.eu](http://www.hycon2.eu)

4.28.1 MATHEMATICAL ANALYSIS OF INTERACTION TOPOLOGY

A highly mathematical model of the behavior of complex network interaction as the physical level. The principle focus is the modelling of consensus based systems. This work is difficult for the non mathematician to understand. However, this does not imply that it is not important. Mathematical models of this type are likely to become more important as the number of components or agents in a networked system increases. While the ordinary user is unlikely to be aware of the underlying mathematics, the architects of such systems will no doubt find this useful.

Interoperability:
8. Network interoperability
4.29 HYDROBIONETS
(Autonomous Control of Large-scale Water Treatment Plants based on Self-Organized Wireless BioMEM Sensor and Actuator Networks)

The HYDROBIONETS project focuses on the research and development of Self-Organized Wireless BioMEM Networks (WBNs) and their integration in a global system to monitor the complete water cycle in large-scale water treatment and desalination plants.

The key feature is the integration of BioMEM sensors and actuators in motes and the adaptation of the network function to the specific requirements that this type of application imposes. The WBNs will achieve a distributed monitoring of critical parameters, representing a novel instrument that can be successfully applied in a short term to the great challenge that represents the dense wireless networked control of microbiological parameters of water in the different stages of process in these plants.

Project Website: [http://www.hydrobionets.eu](http://www.hydrobionets.eu)

4.29.1 REAL-TIME MICROBIOLOGICAL WIRELESS NETWORKED CONTROL SYSTEM

This project is motivated by the grand challenge of providing:

- a fundamental understanding of the performance bounds of large-scale Self-Organized Wireless BioMEM Networks (WBNs);
- concrete design guidelines, algorithms, software and hardware architectures to assure the required robustness, fault-tolerance, power efficiency, autonomy and adaptation;
- implementation and deployment of a large-scale and reactive WBN for microbiological autonomous monitoring and decentralized control of water quality in industrial environments.

HYDROBIONETS will address:

- the distributed acquisition of spatio-temporal biological signals, including the specific design of BioMEMs and their stable integration to motes;
- in-network cooperative processing and distributed intelligence to achieve essential tasks such as inference, detection, and decision-making;
- networked dense control to ensure adequate water quality, productivity and energy efficiency of water treatment plants. The results of this project will be demonstrated in real large-scale industrial water treatment and desalination plants, provided directly by partner ACCIONA, a worldwide leader in the water industry.
This project focusses on the application of SoS in a single targeted domain water, which is taken to be included within the Environment and Agriculture tag.

Interoperability:
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
2. Environment and Agriculture

Infrastructure:
1. Ubiquitous autonomy
10. Design development of function(s) or device(s) or both

4.30 IMC-AESOP
(Architecture for Service-Oriented Process - Monitoring and Control)

IMC-AESOP will investigate a Service-oriented Architecture approach for monitoring and control of Process Control applications (batch and continuous process). Large process industry systems are a complex set of multi-disciplinary, connected, heterogeneous systems that function as a complex system of which the components are themselves systems. They link many components from individual groups of sensors to e.g. whole control, monitoring, supervisory control systems, performing SCADA and DCS functions.

The future "Perfect Plant" will enable monitoring and control information flow in a cross-layer way. Components can be dynamically added or removed and dynamic discovery enables the on-demand information combination and collaboration. All systems will collaborate in an enterprise-wide system of systems, dynamically evolving based on business needs.

IMC-AESOP deals with several key challenges that arise such as real-time web services, interoperability, plug and play, self-adaptation, reliability, cost-effectiveness, energy-awareness, high-level cross-layer integration and cooperation, event propagation, aggregation and management. Using SOA the project will go to complex infrastructures linked in a cross-layer way from devices to enterprise systems. Transition from legacy systems will be studied for existing ones. The SOA-based approach proposed by IMC-AESOP will simplify the integration of monitoring and control systems on application layer.

IMC-AESOP will demonstrate the application feasibility in pilots. The use cases provided from several end-users will be demonstrated in pilot applications.
The synopsis below is clipped from Local4Global deliverable D2.2:

The project embraces:

- A network of next-generation, linked, SCADA/DCS controllers for a large-scale process,
- Linked to these are:
  - ERP, CRM, etc applications
  - SCADA control software
  - PLCs, also linked to the SCADA control software
  - DCS software
  - MES applications
  - Other devices, also linked to MES applications
  - GW/ Mediators for legacy systems
  - Ubiquitous HMI devices and software.

Interoperability:

3. Business context: aligned operations level
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:

1. Energy
5. Manufacturing

Infrastructure:

2. Architectures
6. Security
9. Resilience and Fault Tolerance
15. Human interfaces for control
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
4.31 IMMORTAL
(Integrated Modelling, Fault Management, Verification and Reliable Design Environment for Cyber-
Physical Systems)

This project focuses on reliable design and real time fault management in multi core CPS. A feature of
the project is cross-layer modelling to facilitate fault management, verification and reliable design.
Key challenges are: minimisation of verification efforts; speeding up fault detection; and maintaining
system stability with part of the resources failing. The project will be evaluated using an aerospace use
case (satellite control). Other potential use cases include avionics, automotive and telecommunication.

Interoperability:
5. Semantics: knowledge & sharing of knowledge level;
6. Semantics: information & interoperability level;
7. Syntactic interoperability;
8. Network interoperability;
9. Physical interoperability level

Domain:
4. IT&C;
8. Transport Infrastructure:
4. Modelling and Simulation;
9. Resilience and Fault Tolerance;
10. Design development of function(s) or device(s) or both;
21. Tools (including Simulation)

4.32 INTO-CPS
(INTO-CPS: INtegrated TOol chain for model-based design of CPSs)
Area: Integrated tool chain for comprehensive model-based design of CPS.
Challenges: support for co-model construction and co-simulation: model, software, hardware in the
loop
Use cases: automotive, agricultural, railway and building automation

Project Website: http://into-cps.au.dk

4.32.1 PROJECT CASE STUDIES
The project has industry partners providing case studies in four diverse domains:
* Railways - Addressing the development of safety-critical, distributed track segment interlock controllers.

* Building Automation - This case study is aimed at developing a CPS supporting a heating, ventilation and air-conditioning in a building.

* Agriculture - Here the study focuses on developing high efficiency tilling equipment that has the potential to greatly increase crop yields by controlling weeds.

Interoperability:
4. Business context: aligned procedures level

Domain:
1. Energy,
2. Environment and Agriculture
5. Manufacturing
8. Transport

Infrastructure:
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.32.2 INTEGRATED TOOL CHAIN FOR MODELLING CPS
The aim of INTO-CPS is to create an integrated “tool chain” for comprehensive Model-Based Design (MBD) of Cyber-Physical Systems (CPSs). The tool chain will support the multidisciplinary, collaborative modelling of CPSs from requirements, through design, down to realisation in hardware and software. This will enable traceability at all stages of the development. INTO-CPS will support the holistic modelling of CPSs, allowing system models to be built and analysed that would otherwise not be possible using standalone tools.

Interoperability:
4. Business context: aligned procedures level

Domain:
2. Environment and Agriculture
4. IT&C
8. Transport

Infrastructure:
4. Modelling and Simulation
10. Design development of function(s) or device(s) or both
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.33 KARYON
(Kernel-based ARchitecture for safetY-critical cONtrol)

The project focuses on the development of technologies for safety-critical autonomous mobile systems. Prototype systems and simulation-based demonstrations are also developed as part of the project. Key challenges include: facilitating cooperation with other mobile systems via unreliable wireless communications; safety provision and assurance; approximation of global state; and handling and evaluating uncertainty in sensor data. The project results were exploited by two large enterprises in aeronautics and by an SME in automotive.

Interoperability:
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability;

Domain:
8. Transport

Infrastructure:
2. Architectures
4. Modelling and Simulation
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
20. Standards & Codes of Practice
21. Tools (including Simulation)

Project website: http://www.karyon-project.eu/

4.33.1 FACILITATING COMMUNICATION AND COOPERATION BETWEEN VEHICLES
A body of research that aims at facilitating communication and cooperation between autonomous vehicles has been developed and includes:

- A novel architecture to provide resilient real-time communications over wireless networks
- Approaches to providing temporal guarantees in wireless communications and protocols that facilitate good performance characteristics and predictability for dynamic wireless networks
- Adaptive middleware to handle quality of service heterogeneity issues that are inherent in distributed control
- Environment models facilitate filtering and sharing of environmental data between cooperating vehicles
- Approaches to establishing a consistent global view
- Diagnostic support for cooperative systems is addressed via a tool developed to provide distributed logging and deterministic replay

Interoperability:
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability

Domain:
8. Transport

Infrastructure:
2. Architectures
4. Modelling and Simulation
9. Resilience and Fault Tolerance
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.33.2 DEVELOPING RESILIENT SAFETY-CRITICAL AUTONOMOUS SYSTEMS

A number of technologies were identified and/or developed to support safety assurance of autonomous systems:

- Architectural patterns were devised that provide separation of safety-critical and complex functionality, in order for the system to tolerate faults and preserve safety
- Failure semantics and failure modes for distributed sensor systems were established that enable external sensors to communicate the trustworthiness of their outputs along with the data
- A failure algebra was constructed to enable system level assessments of trustworthiness to be derived from the failure metadata of the components
- A conceptual framework, models, methods and tools were identified for handling and evaluating uncertainty aspects of communications
- A safety kernel was developed to balance time critical and non-time critical computations and to provide suitable level of service based on safety constraints and trustworthiness of inputs

An analysis of the impact of cooperative functionality on safety requirements and assurance was also provided. The project identified areas in which further investigation is needed to determine how existing procedures for assuring safety should be adapted for cooperative systems.

Interoperability:

4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability

Domain:

8. Transport

Infrastructure:

2. Architectures
4. Modelling and Simulation
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
20. Standards & Codes of Practice
21. Tools (including Simulation)

4.33.3 APPROXIMATING GLOBAL STATE

KARYON technology uses global state to dynamically determine what level of cooperation can be supported. As such, the project examined approaches to approximating the global state of cooperative systems and of evaluating and handling uncertainty:

- Consensus protocols were exploited to decide on the cooperative level of service that can be provided
- A conceptual framework, models, methods and tools were identified for handling and evaluating uncertainty aspects of communications

Interoperability:

6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability

Domain:
8. Transport

Infrastructure:

4. Modelling and Simulation
9. Resilience and Fault Tolerance
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
21. Tools (including Simulation)
4.33.4 AUTOMOTIVE AND AVIATION APPLICATIONS

Two use cases provided requirements for, and evaluation of, the technologies developed by the KARYON project. The focus is on autonomous vehicles, so both use cases come from the transportation domain. The first is on an unmanned aerial system that shares airspace with piloted vehicles. The second is on a driver support system for cooperating automobiles, providing functionality such as coordinated intersection negotiation and lane changing.

Interoperability:

4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability

Domain:

8. Transport

Infrastructure:

2. Architectures
4. Modelling and Simulation
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
20. Standards & Codes of Practice
21. Tools (including Simulation)

4.34 LOCAL4GLOBAL

(Systems of Systems that act locally for optimizing globally)

Today’s Technical Systems of Systems (TSoS) such as transport, traffic and energy management systems require the deployment of an expensive-to-deploy and operate sensor and communication infrastructure. Moreover, they need a very time/effort-consuming modelling, analysis and control design procedures in order to achieve an efficient performance. On the contrary, Natural Systems of
Systems (NSoS) such as the human brain, animal herds (swarms), teams of interacting/cooperating humans or animals achieve a highly efficient, elegant and supreme functionality without the need of an expensive infrastructure as they primarily rely on local information between neighbouring systems and, most importantly, they do not need any modelling, analysis or control design tools to achieve such a functionality. If the powerful attributes of NSoS were possible to be transferred and embedded into TSoS, this would lead not only to more efficient TSoS operations but, most importantly, to TSoS that are significantly easier, safer and more economical to design, deploy and operate. This is the main objective of Local4Global: to develop, test and evaluate a new groundbreaking, generic and fully-functional methodology/system for controlling TSoS which - as in the NSoS case - optimizes the TSoS performance at the global level without the need of deployment and operation of an expensive sensor and communication infrastructure and, most importantly, without the need for the use of elaborate and time/effort consuming modelling, analysis and control design tools. The economic and societal impact and consequences of the availability of such a system will be tremendous in literally any activity of everyday life: for instance, drivers/travellers will spent significantly less time for commuting, building occupants will see their energy bills significantly reduced and, most importantly, energy consumption and pollution will be substantially reduced. This system will be deployed and extensively tested in 2 real-life TSoS Use Cases, a Traffic TSoS Use Case and a Building TSoS Use Case.

Project Website: http://local4global-fp7.eu

4.34.1 LOCAL4GLOBAL, SOS CONTROL PROJECT - DISTRIBUTED, 'SWARM' APPROACH

Two use cases; traffic and smart building. In traffic case, they explore component systems that interoperate; the vehicles travelling on a traffic-controlled road network, and the network operation system involving traffic lights. These components talk to each other in real time, including informing the vehicle drivers who make decisions (i.e we have a smart traffic system). Note, the traffic light system is fixed, while the vehicles are non-stationary & variable.

Note, they rely on findings of 2 previous projects, AGILE and HYCON2.

This approach is in marked contrast to 2 other control projects, UnCoVerCPS and GreenerBuildings, both of which are predicated on centralised control. This one is all about distributed control, where each component has its own controller that is somewhat aware of overall SoS state, and can do local learning. The easy extensibility and substitutability of this approach is certainly appealing.

From D2.1 TSoS modelling & Analysis requirements (this is a very informative document on the technical aspects and associated problems) the project claims that they will develop and extensively test and evaluate in real-life TSoS, a generic, integrated and fully-functional methodology/system for TSoS with the following attributes:

- The TSoS constituent systems are operating as fully autonomous units that react and interact depending only on their local environment in order to optimise the TSoS emerging performance at the global level.
- There will be no need for an elaborate and tedious effort to deploy the Local4Global system or to re-design/re-configure it in cases of changes in the topology, environment or hierarchy of the TSoS. In essence, the Local4Global methodology will provide a plug-and-play control mechanism.
for the constituent systems with the ability to fully exploit each constituent system’s abilities by embedding within it learning, evolving and self-organising capabilities.

- There will be no need for an elaborate, expensive infrastructure that provides each and every constituent system with information coming from all over the TSoS.
- The Local4Global methodology/system will be applicable to generic TSoS that comprise highly heterogeneous TSoS. Moreover, it will, by its very nature, be totally scalable and computationally efficient.

Interoperability:

4. Business context: aligned procedures level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
7. Smart Community
8. Transport

Infrastructure:
1. Ubiquitous autonomy
2. Architectures
10. Design development of function(s) or device(s) or both
11. Safety
15. Human interfaces for control
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.35 MADNESS
(Methods for predictAble Design of heterogeNeous Embedded System with adaptivity and reliability Support)

The MADNESS project aims at the definition of innovative system-level design methodologies for embedded systems, able to drive the optimal composition of a heterogeneous MPSoC architecture, according to the requirements and the features of a given target application field. The proposed methodologies will extend the classic concept of design space exploration, to cope with high heterogeneity, technology scaling, system reliability and multi-application demands, pursuing the following objectives: Improved design predictability of highly heterogeneous embedded systems, bridging the so called "implementation gap", i.e. the gap between the results that can be predicted
during the system-level design phase and those eventually obtained after the on-silicon implementation.

Project Website: http://www.madnessproject.org/

4.35.1 IDENTIFICATION OF KEY ISSUES
Modern embedded systems usually integrate components provided by different parties, very often yielding a high level of design complexity to be handled by the designer. Different computational tasks to be executed often offer different kinds and degrees of parallelism, thus optimally fitting to a specific kind of processing elements. In order to improve the overall productivity, an effective system-level design should be handled in a novel manner, taking into account, at its early stages, a bigger number of variables as well as more complex IP cores inside the design space available to the designer. Moreover, the efficient “static approach” to the design of embedded processors needs to be extended to MPSoC design, and in certain cases needs to include dynamic behaviour. This is particularly the case when multiple applications are executed at the same time, unpredictably interfering with each other at runtime and posing the need for the assurance of a given level of Quality of Service. In addition, given the increasing complexity of the systems, a certain degree of fault tolerance must be guaranteed, but constraints presented by embedded systems design make approaches involving massive redundancy hardly adoptable. Both these issues require the support inside modern MPSoCs of a certain degree of adaptivity. To take meaningful system-level decisions, moreover, the designer must deal with several problems related to modern technology nodes and rely on accurate estimations of the hardware costs of each candidate architectural solution.

Interoperability:
2. Business objectives: strategy & policies level

Domain:
1. Energy
2. Environment and Agriculture
3. Health Care
4. IT&C
5. Manufacturing
6. Security
8. Transport

Infrastructure:
2. Architectures
10. Design development of function(s) or device(s) or both

4.36 MAKESENSE
(Easy Programming of Integrated Wireless Sensor Networks)

Wireless sensor networks (WSNs) are expected to play a critical role in the next computing revolution of cooperating objects and smart embedded devices, yet industry adoption is below expectations. makesense will lower the barrier for using WSNs by simplifying programming and creating a direct, technical link to business processes. This will allow e.g. more intelligent facility or supply chain management, resulting in better insight, energy efficiency and comfort.

Currently, total cost of deployment of a sensor network is not dominated by hardware (a few 100 to a few 1,000 €) but by the cost of programming an application that carries out the task of sensing (10,000s of €). This task requires highly skilled and paid embedded software engineers who know details of the used sensors and system platform. This also affects total cost of ownership as re-configuration requires the same skills. The tool chain developed by makeSense will reduce this need by providing a macro language that allows a skilled developer without explicit WSN knowledge to build such an application using a set of pre-defined abstractions. On top of this, makeSense will provide a modelling layer that allows business process modellers to effectively model processes that interact with the real world, as sensed by the WSN, with unprecedented integration.

By re-using concrete abstractions across scenarios, we expect the WSN development cost to be reduced by 50%. Our approach requires some additional cost for process modelling, however overall, this could still reduce the cost compared to other systems currently used (such as SCADA) by around 30%.

By substantially reducing the cost of deployment and ownership of sensor networks, makeSense will help to make many applications economically feasible, that are beneficial for society and individuals that would not be available if their development was cumbersome and hence time-consuming and expensive, e.g. to implement energy saving in facility management or optimization of supply chains, leading to a greener, more competitive European economy.

While SAP expects to integrate the findings of makeSense in commercial tools for business process automation, ACCIONA will include makeSense technologies in their technology portfolio and expects to increase the amount of building projects by about 15% in 5 years.

Project Website: http://www.project-makesense.eu/

Interoperability:
4. Business context: aligned procedures level
9. Physical interoperability level
Domain:
4. IT&C 5. Manufacturing

Infrastructure:
2. Architectures
4. Modelling and Simulation
18. Methods / protocols / procedures
20. Standards & Codes of Practice
21. Tools (including Simulation)

4.36.1 COMPREHENSIVE MACRO PROGRAMMING
The core contribution of makeSense is a comprehensive macro programming system that enables the integration of WSNs into business processes. The programming platform is supported by a complete tool-chain starting from business processes down to the code running on the individual nodes, including tools to assist the developer in the programming activity and the compiler technology required to bridge the gap between the application and the WSN hardware.

Interoperability:
4. Business context: aligned procedures level
9. Physical interoperability level

Domain:
4. IT&C
5. Manufacturing

Infrastructure:
2. Architectures
4. Modelling and Simulation
18. Methods / protocols / procedures
20. Standards & Codes of Practice
21. Tools (including Simulation)
4.36.2 CHEAP DEVELOPMENT OF SENSOR NETWORKS

makeSense aims at lowering the barrier for adoption of WSNs in real-world applications, notably business processes. In making this vision a reality, the makeSense approach must be sufficiently expressive to specify a range of different business applications, and be easy to use with no need for specialised training for domain-experts. The name of the project reflects both the purpose and the ambition level of the project. The first part of the name, make, refers to the make tool, the seminal software development utility that relieves the developer of low-level software development details.

Interoperability:
4. Business context: aligned procedures level
9. Physical interoperability level

Domain:
4. IT&C
5. Manufacturing

Infrastructure:
2. Architectures
4. Modelling and Simulation
18. Methods / protocols / procedures
20. Standards & Codes of Practice
21. Tools (including Simulation)

4.37 MOVES
(Modeling, verification and control of complex systems: From foundations to power network applications)

The problem as seen from the project perspective is as follows:

"Stable operation of the electric power system is crucial to any advanced society. And yet the safety, stability and efficiency of our power networks are affected by many uncertainties, including fluctuating demands, unforeseen events such as natural failures or acts of malice, and, more recently, uncertainty in power production due to the push to integrate renewable sources of energy and distributed generation into existing grids.

This combination of continuous dynamics (e.g. the evolution of voltages, frequencies), discrete dynamics (e.g. changes in network topology), and probability (e.g. uncertainty about power demand and supply) make power systems an ideal testing ground for stochastic hybrid systems methods."

© Road2CPS Consortium
The objectives for the project state the following:

We propose novel methods for modelling, analysis and control of complex, large scale systems. Fundamental research is motivated by applied problems in power networks. We adopt the framework of stochastic hybrid systems (SHS), which allows one to capture the interaction between continuous dynamics, discrete dynamics and probabilistic uncertainty. In the context of power networks, SHS arise naturally: continuous dynamics model the evolution of voltages, frequencies, etc. discrete dynamics changes in network topology, and probability the uncertainty about power demand and (with the advent of renewables) power supply. More generally, because of their versatility, SHS are recognized as an ideal framework for capturing the intricacies of complex, large scale systems. Motivated by this, considerable research effort has been devoted to the development of modelling, analysis and control methods for SHS, in computer science (giving rise to theorem proving and model checking methods) and in control engineering (giving rise to optimal control and randomized methods).

Project Website: http://www.movesproject.eu/index.html

4.37.1 MICROGRID CASE STUDY

The project deliverable “Final report on modeling, analysis, impact and potential exploitation” which may be found at http://www.movesproject.eu/deliverables/WP4/D4.3woExploitation.pdf

This deliverable reports on the application of the project in the control of microgrids.

Interoperability:
8. Network interoperability
9. Physical interoperability level

Domain:
1. Energy

Infrastructure:
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.38 OPENCOSS

Open Platform for EviutioNary Certification Of Safety-critical Systems
Safety assurance and certification are amongst the most expensive and time-consuming tasks in the development of safety-critical embedded systems. European innovation and productivity in this market is curtailed by the lack of affordable (re)certification approaches. Major problems arise when evolutions to a system entail reconstruction of the entire body of certification arguments and evidence. Further, market trends strongly suggest that many future embedded systems will be comprised of heterogeneous, dynamic coalitions of systems of systems. As such, they will have to be built and assessed according to numerous standards and regulations. Current certification practices will be prohibitively costly to apply to this kind of embedded systems. OPENCOSS will devise a common certification framework that spans different vertical markets for railway, avionics and automotive industries, and establish an open-source safety certification infrastructure. The strategy is to focus on a compositional and evolutionary certification approach with the capability to reuse safety arguments, safety evidence, and contextual information about system components, in a way that makes certification more cost-effective, precise, and scalable. OPENCOSS will define a common certification language by unifying the requirements and terminology of different industries and building a common approach to certification activities. A fully-fledged tool infrastructure will be developed for managing certification information and performing safety assurance activities. The infrastructure will be realised as a tightly integrated solution, supporting interoperability with existing development and assurance tools. Within this infrastructure, systematic and auditable processes will be developed to reduce uncertainty and (re)certification costs. To have long-lasting industrial impact, we will pursue standardisation of the conceptual framework and the open-source tool infrastructure resulting from the project.

"This deliverable presents a conceptual framework for compositional certification, establishing principles and ideas. Our aim is to help support re-use of component level assurance data, thus improving the time taken to produce a system, and reduce the costs associated with development. Three fundamental aspects of compositional certification are presented:

1. Composition of assurance arguments via:
   a. Argumentation patterns - in which we separate concerns between systems and components, and further sub-divide these into functionality, backing arguments and compliance.
   b. Language and expression - looking at both syntax and semantics of assurance claims, and the compliance, confidence and safety vocabulary we required to express and compare them.

2. Composition of evidence - which presents the results of a survey of industrial practitioners on assessing sets of evidence, and how their overall consistency and quality can be assessed.

3. A meta-model for argumentation - merging the Goal Structuring Notation (GSN) and Structured Assurance Case Metamodel (SACM)."

Web Reference:

Infrastructure:
10. Design development of function(s) or device(s) or both
4.38.1 COMPOSITIONAL CERTIFICATION FRAMEWORK

"This deliverable presents a conceptual framework for compositional certification, establishing principles and ideas. Our aim is to help support re-use of component level assurance data, thus improving the time taken to produce a system, and reduce the costs associated with development. Three fundamental aspects of compositional certification are presented:

1. Composition of assurance arguments via:
   a. Argumentation patterns - in which we separate concerns between systems and components, and further sub-divide these into functionality, backing arguments and compliance.
   b. Language and expression - looking at both syntax and semantics of assurance claims, and the compliance, confidence and safety vocabulary we required to express and compare them.
2. Composition of evidence - which presents the results of a survey of industrial practitioners on assessing sets of evidence, and how their overall consistency and quality can be assessed.
3. A meta-model for argumentation - merging the Goal Structuring Notation (GSN) and Structured Assurance Case Metamodel (SACM)."

Web Reference:

Infrastructure:
10. Design development of function(s) or device(s) or both
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures

4.38.2 COMMON CERTIFICATION LANGUAGE

"The CCL (Common Certification Language) provides a common language for both safety case and standards-based approaches for certification, enabling a structured way for argumentative reasoning about safety requirements and constraints across multiple schemes. The CCL contains conceptual
models which address key aspects of the technical challenges of assurance for safety-critical systems - process assurance, safety argumentation, evidence characterisation and compliance management. These models can be characterised for each standard, domain or organisation. Next to that the CCL contains a vocabulary which provides a means for the harmonisation and comparison of terminology from different domains.

The CCL can be implemented through usage scenarios, aimed at specific user groups in safety assurance and certification. To support this implementation a toolset is developed for the CCL. The governance of the CCL is fully integrated in the governance of the OPENCOSS platform."

4.45 Web Reference:

Infrastructure:
11. Safety
18. Methods / protocols / procedures
21. Tools (including Simulation)

4.39 PAPYRUS
The development of complex systems is often a problematic endeavour, mainly due to the scope and complexity of solution, spanning multiple disciplines. One of the disciplines affected by this complexity is the development of software-intensive systems and, especially, that of real-time embedded systems.

Papyrus-RT will provide user documentation describing how to model UML-RT systems and how to generate code and execute from the model and toolsmith documentation describing how the modeling user interface, code generator and runtime services libraries can be augmented or modified.

Papyrus-RT will also provide a library of sample models demonstrating aspects of tool usage.

Papyrus-RT is an industrial-grade, complete modeling environment for the development of complex, software intensive, real-time, embedded, cyber-physical systems.

The initial version of Papyrus-RT is based on the UML-RT approach, so the discussion below is representative of this decision. This decision was made from feedback from active interested parties, sponsors, and experience of the development team.

Interoperability:
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level

Domain:
4. IT&C
5. Manufacturing

Infrastructure:

2. Architectures

4. Modelling and Simulation

21. Tools (including Simulation)

Project Website: http://projects.eclipse.org/projects/modeling.papyrus-rt

4.40 PLANET

(PLAtform for the deployment and operation of heterogeneous NETworked cooperating objects)

Efficient deployment and management has been identified as one of the main problems for the acceptance of new technologies based on Cooperating Objects (COs). The goal of PLANET is to provide an integrated planning and maintenance platform that enables the deployment, operation and maintenance of heterogeneous networked COs in an efficient way. The main objective of the project particularly emphasizes the capability of the platform to support deployment and operation strategies for large-scale systems composed of unmanned ground and aerial vehicles cooperating with wireless sensor/actuator networks.

PLANET addresses the design methodology and development of the platform as well as the algorithms required to support the deployment and maintenance of heterogeneous systems with mobile and static nodes. The most challenging algorithms that will form the core functionality of the PLANET platform are: optimal planning to achieve optimal coverage; network-centric, cooperative sensing/actuation; cooperative transportation and retrieval of nodes; data mulling techniques; secure, non-intrusive monitoring of the network for failures and possible threats; synthetic network simulation; user interface algorithms for the efficient usage of the platform by non-experts.

Project Website: http://www.planet-ict.eu

4.40.1 PLANET - WIRELESS-BASED CONTROL OF ECOLOGY-TYPE NETWORKS OF COOPERATING OBJECTS CASE STUDIES

The key objective of PLANET project was the design, development and validation of an integrated platform to enable the deployment, operation and maintenance of large-scale/complex systems of heterogeneous networked Cooperating Objects, including Wireless Sensor and Actuator Networks and mobile objects. The platform will support optimal and adaptive deployment and operation by means of mobile cooperating objects, i.e. vehicles, networked with static nodes. The platform was validated in two complementary scenarios: the monitoring of the Donyana Biological Reserve with very high ecological value and very sensitive to the impact of pollution, and a highly automated airfield scenario in which security plays an important role and where wireless communication and cooperative techniques pose significant challenges.

Key elements include

- Integrated wireless-based platform
Adaptive network deployment (vehicles change in numbers, location, activity)
- Expectation that vehicles may be autonomous
- Network-centric computing (dynamic resource discovery and management, distributed mission planning and task allocation, data capture and conservation)
- Security of wireless network and large numbers of heterogeneous co-operating nodes; authentication, key management, distributed algorithms for anomalous behaviour detection

No publicly available deliverables at the time of publication.

Interoperability:
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
2. Environment and Agriculture
8. Transport

Infrastructure:
1. Ubiquitous autonomy
2. Architectures
6. Security
9. Resilience and Fault Tolerance
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures

4.41 ROAD2CPS
(‘Strategic action for future CPS through roadmaps, impact multiplication and constituency building’)

The Road2CPS project has been conceived to respond to the current situation in terms of CPS by analysing impact from past and ongoing projects, identifying gaps, and bridging efforts towards impact multiplication. Furthermore, the project aims to develop technology, application and innovation
strategy roadmaps for CPS to serve as a catalyst for early adoption of CPS technologies as well as enhancing CPS implementation and exposing exploitation opportunities via case studies. Within the project recommendations for future research priorities and implementation strategies will be developed and a CPS constituency will be build. As a result of this key players will be brought together into targeted task forces in order to contribute to the Road2CPS action plan. The state of the art of the merging of cyber and physical systems is characterized by fragmentation across disciplines, domains and value chains, the gap between academia and industry (concepts and applications) as well as the missing alignments between research and application side. Furthermore, the emerging CPS technologies and approaches remain underexploited and the achievements and impact of past and ongoing projects lack visibility, knowledge has to be brought together and gaps to be closed. Constituencies (of a critical mass) in the field of CPS are not yet built to discuss and solve the manifold technological and non-technological challenges. At present, there is still a lack of a clear picture of the domain and an assessment of ongoing activities as well as the urgent need for a look forward.

Interoperability:
1. Political/ Economic/ Regulatory/ Business Board level
2. Business objectives: strategy & policies level
3. Business context: aligned operations level
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
1. Energy
3. Health Care
4. IT&C
5. Manufacturing
7. Smart Community
8. Transport

Infrastructure
1. Ubiquitous autonomy
2. Architectures
3. Business models / Enterprise design
4. Modelling and Simulation
5. Privacy
6. Security
7. Big Data
8. Contracts & financial arrangements
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
11. Safety
12. Education
13. Skills & training
14. Human and Machine Awareness
15. Human interfaces for control
16. Human / community / social issues
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
19. Regulations & Policies
20. Standards & Codes of Practic
21. Tools (including Simulation)

Project Website: www.road2cps.eu

4.42 ROAD2SOS
(Roadmaps for Systems of Systems Engineering)

Road2SoS aimed to develop research and engineering roadmaps to identify future RTD and Innovation strategies for Europe in the field of SoS engineering in four key domains. These four domains are multimodal traffic control, emergency and crisis management, distributed energy generation and smart grids, and multi-site industrial production. The impact of Road2SoS are delivering insights on new solutions for SoS engineering, pushing forward the limits of SoS engineering via roadmaps and case studies, transferring SoS engineering research, development, and innovation results to relevant stakeholders, identifying of roadmap trends in research, development and innovation and link them to future possible products and applications, and understanding of technical, social and economical enablers and barriers as well as identifying of effects of SoS implementation.

Interoperability:
1. Political/ Economic/ Regulatory/ Business Board level
2. Business objectives: strategy & policies level
3. Business context: aligned operations level
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
1. Energy
4. IT&C
5. Manufacturing
8. Transport

Infrastructure:
1. Ubiquitous autonomy
2. Architectures
3. Business models / Enterprise design
4. Modelling and Simulation
5. Privacy
6. Security
7. Big Data
8. Contracts & financial arrangements
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
11. Safety
12. Education
13. Skills & training
14. Human and Machine Awareness
15. Human interfaces for control
16. Human / community / social issues
17. Interfaces and interoperability issues
4.42.1 SOA OF SOS/CPS IN DIFFERENT APPLICATION DOMAINS: MANUFACTURING

The vision of multi-site manufacturing is the interacting of interoperable factories within a global network, allowing the dynamic allocation of manufacturing. In such a scenario, manufacturing enterprises will be able to assign production to available capability and capacity, wherever it may be. In order to achieve the above mentioned scenario increasing interoperability across factories, adaptability, higher level of integration, management of complexity, and increasing control of product changes across supply chain will be necessary and is not currently appropriately available. Today, the supply networks are relatively static and allow little changes or need huge efforts for quick changes. This kind of re-configuration outside the factory goes hand in hand with limited capabilities for re-configurations within production sites. Currently, a lack of standards is one big issue – different information and communication software and standards are widely spread within the manufacturing industry. Especially SMEs face significant barriers for entering the market of manufacturing products.

4.42.2 SOA OF SOS/CPS IN DIFFERENT APPLICATION DOMAINS: TRAFFIC

At present transportation systems such as individual traffic, rail, tram, or aviation are not sufficiently interconnected to ensure an optimal usage of the infrastructures and natural resources. A closer interconnection can now be envisioned thanks to the advance of networking and information technologies. The vision for multimodal traffic control based on SoS and CPS is a global transportation infrastructure, operated as a whole without administrative and technological boundaries. Service to end-users for the right transportation demand will be more important than nowadays and the different transportation systems will be more easy to access and flexible in times of usage. State of the art is regarding traffic systems negative aspects that hinder the above mentioned vision like the existence of different operators for different types of roads, locations and for different transport modes as car, tram, train or plane. Only few communications systems are available to satisfy a certain amount of information for multi-modal traffic. One further issue, which is typical for the state of the art, is the independency of car traffic, tramways, buses and trains.

4.42.3 SOA OF SOS/CPS IN DIFFERENT APPLICATION DOMAINS: EMERGENCY AND CRISIS MANAGEMENT

The vision of advanced emergency and crisis management considers smart information management before, during, and after an emergency incident. The management system would be also supported by a network of interactive sensors that assess risk information. Real-time decision making and a complete coverage with secure and reliable communication networks is part of the visionary goal, too. Currently insufficient communication between emergency bodies and personnel is state of the art in the field of emergency. Too many hierarchical levels are hindering decision-making procedures at
present and slow coordination processes to assess the emergency situation are resulting in delays. Furthermore, the forecast of emergency situations are nowadays not precise enough.

4.42.4 SOA OF SOS/CPS IN DIFFERENT APPLICATION DOMAINS: ENERGY

The vision for the future energy system can be described as the shift to decentralized, emission-free generation of renewable energies. The energy generation will change from being concentrated to a few main power plant stations to decentralized production from renewables by a large number of generators. Furthermore, the number of active stakeholders in the energy grid is expected to greatly increase, as many of today’s consumers may turn into so-called ‘prosumers’, who act as producers in the energy grid at times. Security of supply needs to be achieved despite the volatility of the renewable sources as wind and sun, and simultaneously controlling of a large number of energy producers. Energy flow in the future energy grid will have to be accompanied by a flow of information to master the vision. Currently decentral structures for energy generation are increasing and thus the share of renewable energies in total. At present the energy market become more liberalized and accompanied by a lack of business models. Due to the before mentioned changes the legislation of the energy market needs to be adapted. For the time being standards are missing and as well as suitable regulations.

4.43 SAFURE

(SAFety and securiRity by design for interconnected mixed-critical cyber-physical systems)

SAFURE targets the design of cyber-physical systems by implementing a methodology that ensures safety and security "by construction". This methodology is enabled by a framework developed to extend system capabilities so as to control the concurrent effects of security threats on system behaviour. The current approach for security on safety-critical embedded systems is generally to keep subsystems separated, but this approach is now being challenged by technological evolution towards openness, increased communications and use of multi-core architectures.

The goals of the SAFURE project are to

- implement a holistic approach to safety and security of embedded dependable systems,
- preventing and detecting potential attacks,
- to empower designers and developers with analysis methods, development tools and execution capabilities that jointly consider security and safety
- to set the ground for the development of SAFURE-compliant mixed-critical embedded products.

The results of SAFURE will be

- a framework with the capability to detect, prevent and protect from security threats on safety,
- the ability to monitor system integrity from application level down to the hardware level
- including time, energy, temperature and data integrity;
- a methodology that supports the joint design of safety and security of embedded systems,
- assisting the designers and developers with tools and modeling language extensions;
- proof of concept through 3 industrial use cases in automotive and telecommunications;
- recommendations for extensions of standards to integrate security on safety-critical systems;
Interoperability:
5. Semantics: knowledge & sharing of knowledge level

Domain:
6. Security

Infrastructure:
5. Privacy
6. Security

PROJECT ONLY RECENTLY STARTED – NO WEBSITE AND NO DELIVERABLES YET

4.44 SCUBA
(Self-organising, Cooperative, and robUst Building Automation)

Large scale embedded Monitoring and Control (M&C) systems in energy management, transportation, security and safety often co-exist alongside each other with little cooperation within and among heterogeneous systems which hampers the increasing demand to operate the whole system optimally. A good example is building management, a market worth in excess of $36 billion annually by 2015, where a wide range of vendor specific, heterogeneous M&C systems for HVAC, access control, fire and safety, etc. are in use. This "stove pipe" system approach limits optimal solutions to energy-efficiency, occupant comfort, or fire safety, especially as most systems need to evolve over time and have to deal with unexpected or unpredictable dynamics such as fire. SCUBA will create a novel architecture, services, and engineering methodologies for robust, adaptive, self-organising, and cooperating monitoring and control systems to address the current problems of heterogeneity and interoperability, installation and commissioning complexity, and adaptability and robustness in the building monitoring and control space. SCUBA will develop semantic models for devices, systems and building management applications and will contribute to their standardisation to improve interoperability. SCUBA will provide a proof of concept of this approach by demonstrating how self-organisation will lead to simpler engineering, commissioning, and maintenance and how cooperation among heterogeneous, multi-vendor building monitoring and control systems will make the system more adaptive and robust in real building management applications.

Project Website http://www.aws.cit.ie/scuba
4.44.1 ENERGY SAVING RESULTS OF PILOT STUDIES ON SYSTEMS CO-ORDINATION AND
CONTROL IN LARGE BUILDINGS

Synopsis below clipped from D6.1:

"This document summarizes SCUBA experiments conducted in WP6 on various demo-sites. Among these experiments, a better cooperation among Building Automation Systems (namely anti-intrusion system and air conditioning units) has provided a high energy gain of 20% on the LAMA building located near Chambéry, France. The demand-Response scenario adapts the lighting level depending on the energy cost. It demonstrates how the strategy manager (WP4) takes decision and reacts on Building Automation Systems (lighting) through the self-X LINC middleware. This has been demonstrated and the La-T12 platform in CEA premises, Grenoble, France. Then the whole tool chain is evaluated on the NIMBUS building located in Cork, Ireland. Lastly the fire emergency evacuation scenario is reported. Indeed the Rescue Worker Interface is evaluated by fire wardens."

The project ran a series of 7 scenarios at different sites, to test their implementation. Conclusions indicate:

- System seems to work; tool chain is indeed a tool chain and would enable energy savings if the plan is implemented
- Where real-world evaluations could be undertaken, energy savings of about 25% were achieved.
- Co-ordination across systems (e.g. anti-intrusion, HVAC, lighting, etc.) was accomplished.
- Rescue worker interface was deemed OK by Fire Wardens.

However, the whole SCUBA system is designed to be operated by a Facilities Manager (or equivalent); no direct input by building occupants is envisaged. So all internal operational rules are long-term, not necessarily aligned with user's states, needs and intentions.

Interoperability:

2. Business objectives: strategy & policies level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
1. Energy
7. Smart Community

Infrastructure:
2. Architectures
6. Security
10. Design development of function(s) or device(s) or both
12. Education
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
19. Regulations & Policies
21. Tools (including Simulation)

4.44.2 ARCHITECTURE FOR BUILT ENVIRONMENT MONITORING AND CONTROL

Note similar projects, GreenerBuildings, AGILE, Local4Global, UnCoVaerCPS, all in same area of control of the built environment.

Deliverable D1.1 describes the requirements, the use cases, the architecture and the semantic specifications to be considered for the SCUBA solution development

System architecture appears to be centralised, in 3 layers.

- At the bottom is a device layer, which can accept devices on different protocols: LON, KNX, BACNET, OPC, 6LOWAPAN, etc.
- Above this is a middleware layer. This has 3 components;
  - Building Automation System Ontology (BASont). This has constructed rules to deal with what device for what purpose where, how to mitigate device faults, etc. It is a knowledge source for other components.
  - Self-X Middleware, acting as a gateway to the device layer. It applies the bindings between the devices in the device layer, minimising the constraints between the protocols, other constraints, and also provides fault-tolerance. It comprises 3 sub-components; Device adapter (takes care of the different protocols, and any legacy subsystems), Binding engine (provides mappings between physical devices and their representations in SCUBA), which together link to the Chaski co-ordinator, which realises the implementation plan that coordinates the devices in producing the required building state.
  - Strategy and co-operation manager. This contains 'scenarios' (e.g. a 'Fire' scenario, or a 'detected device failure'). The component recognises the occurrence of a scenario, calls on the BASont for rules, generates an implementation plan, and passes it on.
- Above this is Tool Layer, with which the stakeholders interact. This has 3 components:
  - Systematic engineering tools, to capture the building layout, relevant devices, templates and develop the HMI instantiation.
  - Wireless deployment planning tool
  - Co-ordination scheme editor develops binding and co-operation rules for the Chaski co-ordinator

4.45 SPRINT

(System software platform for integration of engineering and things)

Systems Engineering has impact on VERY large markets, e.g., electronics embedded in products such as automobiles has a market size 100x the size of the desktop market. Improving its efficiency and
competitiveness can be of fundamental importance for the European industry as the functional and nonfunctional requirements on future generation products become gradually unmanageable due to their ever increasing complexity. Industries such as Telco service providers, Retail and Financial Services exploit the Internet in new and creative ways that dramatically increase efficiency and revenues. The system engineering industry has not been able to unleash this potential in the design and test of its products. The project proposes to leverage the concept of Internet of Things, establishing the foundation for the Internet of System Engineering.

Based on an Internet-like service infrastructure the SPRINT Networked Environment will provide the virtual blending via Internet of all "things" pertaining to a complex system: sensors, actuators, processing elements, system design tools and models and design teams that are in general spread over different geographical locations. The platform will include novel early verification approaches that involve virtual integration of mathematical models of components to alleviate the problem of late error discovery while supporting the entire cycle of product development: design, integration, verification and deployment. This research will open a new vista on the use of Internet of Things that may change radically the way in which systems are designed and tested.

Project Website: http://www.sprint-iot.eu

4.45.1 SYSTEM MODELLING

Sprint has produced a series of public papers describing lower level simulation challenges. Higher level application descriptions relating to autonomy are not listed, perhaps because of sensitivity. It is difficult to find advances other than in the area of low level simulation.

Interoperability:
8. Network interoperability
9. Physical interoperability level

Domain:
7. Smart Community
8. Transport

Infrastructure:
17. Interfaces and interoperability issues
18. Methods / protocols / procedures

4.46 T-AREA-SOS
(Trans-Atlantic Research and Education Agenda in System of Systems)
The T-AREA-SoS Support Action addressed ICT-2011.3.3, target outcome g) "to analyse international research agendas to prepare concrete joint R&D initiatives for international collaboration, particularly with the USA in the area of System of systems (SoS)". The concept for this proposal is to exploit the established networks of the participants and associates (based in EU and US) including the extant activities they lead within the IEEE and INCOSE in the area of SoS to explore and evolve SoS R & D themes and priorities for FP7/FP8 and other international programmes that will lead to outcomes that address societal needs, with exemplars across a wide variety of sectors including non-traditional aspects of Energy, Transport, and Production, using Engineering of SoS (i.e. SoSE) as a mainstream discipline for the management of large complex systems.

SoSE is an emerging discipline that deals with ultra large systems that include many heterogeneous systems that may be independently owned and/or operated, distributed, evolutionary in nature and which exhibit emergent behaviours. The outputs from this Support Action included a strategic research agenda that will create the environment for the development of concrete research initiatives through which the EU and the US will collaborate to enhance existing research programmes and set the scene for future programmes. These outputs were supported by an analysis of the state of the art and high level definition of research requirements in SoSE, and a thesaurus to enable concepts to be shared across industrial sectors and technical disciplines.

Project Website: https://www.tareasos.eu

4.46.1 SOSE STRATEGIC RESEARCH AGENDA

The Strategic Research Agenda (SRA) was the most important output of the project; it provided to the Commission a focused agenda for SoSE research that had consensus among researchers active in this field and users (in the sense of industry and government technical staff). To the SoS community at large it has provided coherence for future research activities. Although conceived as a project that would support European collaboration with the US, in fact there is evidence that the SRA is having an impact in other parts of the world and among the international SoS community.

A consultative approach was used to develop the SRA and its content includes a description of specific research within twelve themes:

- Characterisation and Description of SoS
- Theoretical Foundations for SoS
- Emergence
- Multi-level Modelling of SoS
- Measurement and Metrics for SoS
- Evaluation of SoS
- Definition & Evolution of SoS Architecture
- Prototyping SoS
- Trade-off in SoS
• Security in SoS
• Human Aspects of SoS
• Energy Efficient SoS

Opportunities for developing appropriate research in these themes are also discussed.

Interoperability:
1. Political/ Economic/ Regulatory/ Business Board level
2. Business objectives: strategy & policies level
3. Business context: aligned operations level

Domain:
1. Energy
2. Environment and Agriculture
3. Health Care
4. IT&C
5. Manufacturing
6. Security
7. Smart Community
8. Transport

Infrastructure:
2. Architectures
3. Business models / Enterprise design
10. Design development of function(s) or device(s) or both
16. Human / community / social issues
17. Interfaces and interoperability issues
21. Tools (including Simulation)

4.47 TAMS4CPS
(Trans-Atlantic research in Modelling and Simulation for Cyber-Physical Systems)
The TAMS4CPS project is a coordination and support action (CSA) funded by the European Commission and running from February 2015 to January 2017. Its overall aim is to lay the foundations for concrete EU-US collaboration in modelling and simulation for CPS and to develop:

- A Strategic Research Agenda for Collaboration (SRAC), based on a comprehensive roadmapping process and endorsed by researchers in the EU and US,
- A set of openly available test cases for model developers which can be used for collaborative evaluation,
- A web-based report on the state-of-the-art in M&S for CPS to provide the context for the SRAC and to act as a baseline for future collaborative research activities.

The project directly addresses European priorities in CPS: the focus is on the following themes, which are derived from those elaborated by ARTEMIS, the European Industry Association in Embedded & Cyber-Physical Systems:

- Architectures principles and models for autonomous safe secure Cyber-Physical Systems,
- Systems design, modelling and virtual engineering for Cyber-Physical Systems,
- Real time modelling for autonomous adaptive and cooperative Cyber-Physical Systems,
- MBSE applied to computing platforms and energy management for Cyber-Physical Systems,

To these is added a fifth theme of:

- Integration of socio/legal/governance models within modelling frameworks.

Interoperability:

1. Political/ Economic/ Regulatory/ Business Board level

Domain:

7. Smart Community

Infrastructure:

19. Regulations & Policies
20. Standards & Codes of Practice

Project Website: [http://www.tams4cps.eu](http://www.tams4cps.eu)

4.48 TAPPS

(Trusted Apps for open CPS)

TAPPS will design, implement and validate a separate, dedicated, real-time Trusted Execution Environment (TEE) for highly-trusted CPS Apps. The TEE is located inside the system control units and uses TAPPS’ processor- and network-centric security mechanisms and a hypervisor for virtualization. TAPPS will also provide and validate an end-to-end solution for development and deployment of
trusted Apps, and validate the multi-level trusted Apps platform and tool chain in several application domains using industrial, realistic use cases and to develop domain-specific exploitation plans.


### 4.48.1 EXTENDING AND CUSTOMISING CPS DEVICES

Today, the trend goes towards open CPS devices and we see a strong request for open platforms, which act as computational basis that can be extended during operation. In this area, the focus is on the functional extension provided by Apps, as it is already common for mobile and other consumer devices. The main goal is to extend and customize CPS devices with new 3rd party services and features in an Apps platform in an efficient, secure and trusted way. This extensibility is an important differentiator that enables new market extensions to keep pace with user expectations and latest technology. For instance, current Apps for vehicles provide infotainment functionality or control basic settings, both of which are not safety critical.

**Domain:**
- 2. Environment and Agriculture
- 3. Health Care
- 4. IT&C
- 8. Transport

**Infrastructure:**
- 2. Architectures
- 3. Business models/Enterprise design
- 5. Privacy
- 6. Security
- 11. Safety
- 17. Interfaces and interoperability issues

### 4.49 TERESA

*(Trusted Computing Engineering for Resource Constrained Embedded Systems Applications)*

The objective of the project is to provide guidelines for the specification of sector-specific RCES trusted computing engineering. Software process engineers in a given sector will use the guidelines to define a trusted computing engineering process that is integrated with the software engineering process used in the RCES sector. The objective of TERESA is to define, demonstrate and validate an engineering discipline for trust that is adapted to resource constrained embedded systems. Trust is defined as the degree with which
security and dependability requirements are met. Resource constrained embedded systems are characterized as follows:

- They belong to different application sectors.
- Computing resource are mostly statically determined and allocated through a process consisting of a configuration phase and a build phase.
- They are generally high integrity systems with strong assurance requirements.
- They therefore use advanced engineering disciplines.

This trusted computing engineering approach should be suited to the following sectors: automotive, home control, industrial control, and metering. The proposed approach is to use a model-based repository of security and dependability patterns: Application sector trust models are defined as profiles (e.g. UML, SysML profiles), based on a common trust meta-model. Security and dependability patterns, platform independent are identified and defined for each application sectors (some patterns could be used by several application sectors). Formal properties on security and dependability are defined and validated for patterns used in application sectors requiring this level of assurance. Platform dependent implementation of the patterns are guided with very precise requirements. The engineering process for resource constrained embedded systems will be validated in four application sectors: automotive systems, home control systems, industry control, and metering.

Interoperability:

2. Business objectives: strategy & policies level

Domain:

1. Energy
2. Environment and Agriculture
4. IT&C
5. Manufacturing
6. Security
8. Transport

Infrastructure:

18. Methods / protocols / procedures
19. Regulations & Policies
20. Standards & Codes of Practice

Project Website: http://www.teresa-project.org/
4.50 U-TEST
(Testing Cyber-Physical Systems under Uncertainty)

No dedicated website for this project since only recently started. Content below clipped from a partner's website:

"Dealing with uncertainty at an acceptable cost is vital to avoid posing undue threats to the system users and the environment. Reliability, robustness, efficiency, safety, and security in CPSs are facets of a more general property often known as “dependability”. Improving system dependability first and foremost relies on the ability to verify and validate CPSs in a cost-effective manner. One way of achieving this is via systematic and automated testing such as Model-based Testing (MBT).

U-Test will aim to improve dependability of CPSs by defining extensible MBT frameworks supporting holistic testing of the systems under uncertainty in a cost-effective manner through:

- providing a comprehensive and extensible taxonomy of uncertainties, classifying uncertainties, their properties, and their relationships;
- creating an Uncertainty Modeling Framework (UMF) to support modeling uncertainties at various levels (relying on exiting modeling/testing standards);
- defining an intelligent way to evolve uncertainty models developed using UMF towards realistic unknown uncertainty models using search algorithms; and
- generating cost-effective test cases from uncertainty and evolved models.

2 interesting case studies have been chosen to assess the cost-effectiveness of U-Test: handling systems and geo sports. The solutions will be integrated into two key commercial tools available on the market. Solutions will also be deployed within logistics, geo sports, and healthcare domains to achieve a wider impact, and facilitate interoperability among tools and technologies."

Interoperability:
3. Business context: aligned operations level
4. Business context: aligned procedures level
5. Semantics: knowledge & sharing of knowledge level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
4. IT&C

Infrastructure:
2. Architectures
4. Modelling and Simulation
9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
11. Safety
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
21. Tools (including Simulation)

No Project Website available.

4.51 UNCOVERCPS
(Unifying Control and Verification of Cyber-Physical Systems)

Mission from Project Website:

“Cyber-physical systems are very hard to control and verify because of the mix of discrete dynamics (originating from computing elements) and continuous dynamics (originating from physical elements). We present completely new methods for deverticalisation of the development processes by a generic and holistic approach towards reliable cyber-physical systems development with formal guarantees. In order to guarantee that specifications are met in unknown environments and in unanticipated situations, we synthesise and verify controllers on-the-fly during system execution. This requires to unify control and verification approaches, which were previously considered separately by developers. For instance, each action of an automated car (e.g. lane change) is verified before execution, guaranteeing safety of the passengers.

We will develop completely new methods, which are integrated in tools for modelling, control design, verification, and code generation that will leverage the development towards reliable and at the same time open cyber-physical systems.”

Objectives/deliverables of the project include:

- Novel on-the-fly control and verification concepts.
- Ground-breaking methods for unifying control and verification to quickly react to changing environments.
- Seamless integration of modelling and conformance testing.
- A unique tool chain that makes it possible to integrate modelling, control design, formal verification, and automatic code generation.
- Prototypical realisations of the novel methods in automated vehicles and human-robot collaborative manufacturing.
- Analysis of the benefits of formal methods on wind turbines and smart grids case studies.
- A new development process that reduces development time and costs for critical cyber-physical systems to strengthen European companies which design or produce cyber-physical systems.
A set of Use cases have been identified: automotive (self driving cars), smart grids, wind turbines, manufacturing with robots

Project Website:  http://cps-vo.org/group/UnCoVerCPS

4.51.1 CONTROLLING DYNAMIC NETWORKS BY DEVELOPING SPARSE REPRESENTATIONS OF THE FUNCTIONALITY OF THE NODES

This appears to be an alternative way to exercise control over CPS-based SoS, compared to approaches of Local4Global and GreenerBuildings.

Project is about developing tools and procedures for modelling and simulating networked CPS (i.e. SoS where component systems are CPS). It seems that the output from this project would be most useful for operational control of a SoS, particularly when you might be swapping components (see use cases). Methods/tools seem to find abstract of new component, fit this into existing model network, and control operations thereafter.

Interoperability:
4. Business context: aligned procedures level
6. Semantics: information & interoperability level
7. Syntactic interoperability
8. Network interoperability
9. Physical interoperability level

Domain:
1. Energy
5. Manufacturing
8. Transport

Infrastructure:
2. Architectures
10. Design development of function(s) or device(s) or both
11. Safety
15. Human interfaces for control
16. Human / community / social issues
17. Interfaces and interoperability issues
18. Methods / protocols / procedures
21. Tools (including Simulation)
4.52 VERDI
(Verification for heterogeneous Reliable Design and Integration)

Systems of Systems (SoS) are heterogeneous whereby the functionality more and more rely on the interaction and interoperability between the analogue/mixed-signal (AMS), digital electronics, software and other physical domains. To achieve the required reliability, robustness and quality of SoS, mastering the heterogeneous behaviour across domains is the most essential part during the development process. The traditional barriers between different design disciplines such as system design, verification and prototype validation should be removed, by introducing an integral system verification and validation methodology. Verdi aims at improving the design efficiency and quality by developing methods and tools to address the design challenges related to heterogeneous integration. It will link simulation-based, "pre-tape-out" system analysis and verification with system validation and analysis of the physical prototype using measurement equipment, by:

- Defining a unified system-level verification and validation methodology
- Specifying a reuse strategy for verification IP between and within companies and for different product generations
- Defining a path from verification IP to validation IP, to bridge the gap between verification and prototype validation

The unified system-level verification library developed in Verdi will provide new concepts to continuously validate the SoS throughout the product creation process. It will be based on methods to create and reuse verification components and IP such as stimuli, test-benches, analysis algorithms, etc. The Verdi methodology and library will demonstrate for safety critical automotive SoS applications: power-train, in-vehicle networking, and airbag. As the methodology and library will extend industry-recognized standards (Universal Verification Methodology, SystemC and IP-XACT) they will be actively brought to standardization (Accellera, OSCI), enabling promotion and wider adoption in the industry in other heterogeneous applications.

Project Website: https://wiki.eas.iis.fraunhofer.de/verdi/index.php/Public:Abstract

4.52.1 VERDI TECHNICAL APPROACH – OVERVIEW

Verdi will link simulation-based, “pre-tape-out” system analysis and verification with system validation and analysis of the physical prototype using measurement equipment, by:

- Defining a unified system-level verification and validation methodology
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Interoperability:

2. Business objectives: strategy & policies level

Domain:

1. Energy
2. Environment and Agriculture
3. Health Care
5. Manufacturing
6. Security
8. Transport

Infrastructure:

2. Architectures
18. Methods / protocols / procedures

4.53 VITRO
(Virtualized distributed plTaFoRms of smart Objects)

The quick growth of the Virtual Sensor Networking (VSN) domain has led to a highly dispersed gamut of technologies and approaches, which seriously jeopardize the long-term vision of an Internet of Things since very few of these solutions are able to mutually communicate. VITRO aims at providing this crucial but missing link between highly heterogeneous wireless sensors and actuators platforms and hence facilitate cooperative smart objects. This proposal is focused on developing architectures, algorithms and engineering methods, which will enable the realization of scalable, flexible, adaptive, energy-efficient and trust-aware VSN platforms. To achieve this objective, VITRO enabled platforms will:

- Provide a homogeneous abstract appearance to enable federated collaboration with external entities (from objects and systems to domains and networks) and thereby extending the networking degree by several orders of magnitudes.
- Simplify the discovery and management of the underlying hardware and software resources of large collections of heterogeneous smart objects (sensors, actuators and embedded processors).
- Achieve energy-efficiency, trust-awareness and seamless connectivity and communication in large-scale heterogeneous VSN deployments and thereby enable dependable, secure and scalable inter-objects collaboration.

The VITRO results will be packed in a VITRO toolbox, which will enable easy configuration and instant support for deploying VSN applications. Although VITRO aims to be application-neutral, the proposed architecture and protocol toolbox will be validated through extensive simulation testing and furthermore implemented in a large trial of sensor nodes and smart objects in smart home and building automation application domains.
Machine-to-machine networks are spreading over every sector of our society due to their self-organisation capabilities. In these networks, thousands of devices are left unattended for years of operation without the possibility of human intervention. In this sense, every step forward into avoiding early exhaustion of the network nodes is of paramount importance. Vitro has introduced a novel authentication scheme that is able to discard non-intended and/or non-legitimate packets just after the reception of the physical preamble. This proposal was shown to yield enormous energy saving with regard to both node exhaustion attacks and normal network operation. In a paper the authors extend that work with a novel synchronisation protocol that addresses previous desynchronisation issues and, in addition, analyse and propose more appropriate deployment parameters that maximise the overall energy savings. Also detailed are the necessary key generation and key updating processes required to manage the in use keying material and how to fit the proposed mechanism into the IEEE 802.15.4e amendment to the IEEE 802.15.4-2006 standard, as many companies have decide to go for this technology for the development of machine-to-machine networks.

Web Reference: Academic paper: Energy-efficient physical layer packet authenticator for machine-to-machine networks

Interoperability:

8. Network interoperability
9. Physical interoperability level

Domain:

6. Security
7. Smart Community

Infrastructure:

9. Resilience and Fault Tolerance
10. Design development of function(s) or device(s) or both
20. Standards & Codes of Practice

4.53.2 SECURITY OF DISTRIBUTED WIRELESS SYSTEMS

Wireless sensor networks are vulnerable to a wide set of security attacks, including those targeting the routing protocol functionality. The applicability of legacy security solutions is disputable (if not infeasible), due to severe restrictions in node and network resources.
Although confidentiality, integrity and authentication measures assist in preventing specific types of attacks, they come at high cost and, in most cases, cannot shield against routing attacks. To face this problem, Vitro have proposed a secure routing protocol which adopts the geographical routing principle to cope with the network dimensions, and relies on a distributed trust model for the detection and avoidance of malicious neighbours. A novel function which adaptively weights location, trust and energy information drives the routing decisions, allowing for shifting emphasis from security to path optimality.

The proposed trust model relies on both direct and indirect observations to derive the trustworthiness of each neighboring node, while it is capable of defending against an increased set of routing attacks including attacks targeting the indirect trust management scheme. Extensive simulation results reveal the advantages of the proposed model.


Note that it is not clear if the principles have been applied to real applications.

Interoperability:
8. Network interoperability

Domain:
6. Security

Infrastructure:
17. Interfaces and interoperability issues
11. Safety

4.54 WiBRATE
(Wireless, Self-Powered Vibration Monitoring and Control for Complex Industrial Systems)

Vibration is a daily occurrence in a wide range of machinery used in industries such as manufacturing, aerospace, petrochemical and building and construction. One of the major problems of vibration is that it causes wear and tear which in many instances can lead to equipment or structural failure. To prevent such occurrences, it is essential to not only monitor vibration levels but also to try and understand the underlying causes. This knowledge can subsequently be used to perform active vibration control which in turn improves the overall system's performance, efficiency, lifetime and safety.

WiBRATE explores new paradigms for developing innovative strategies for wirelessly monitoring and controlling vibration using a network of intelligent embedded devices that power themselves using harvested vibration energy. The project contributes directly to strengthening the European market in
several key sectors such as quality control systems, safety systems, wireless communication and industrial automation and control systems.

Project Website: http://wibrate.eu

4.54.1 WIRELESS, SELF-POWERED VIBRATION MONITORING AND CONTROL FOR COMPLEX INDUSTRIAL SYSTEMS

WiBRATE’s key innovation lies in the development of a self-powered, vibration monitoring and control platform. Unlike existing vibration monitoring devices available in the market that operate as individual entities, WiBRATE’s unique approach is based on individual intelligent sensor-actuator nodes that communicate wirelessly to collaboratively predict impending failures, perform fault diagnosis or provide real-time feedback. This feedback can then be used to further minimise vibration levels using distributed and autonomous micro-actuators that are capable of carrying out robust, distributed control. The use of robust wireless communication strategies ensures that the system is highly flexible and allows for a new class of monitoring and control applications that are not possible using traditional wired systems. Apart from measuring and controlling vibration levels, WiBRATE’s platform also harnesses the vibration itself thus resulting in a system that is both maintenance free and environment friendly.


Interoperability:
9. Physical interoperability level

Domain:
1. Energy
2. Environment and Agriculture
5. Manufacturing
8. Transport

Infrastructure:
1. Ubiquitous autonomy
9. Resilience and Fault Tolerance
5 PROJECT IMPACTS

5.1 METHOD ADOPTED

This section is built upon the analysis of the projects formally included in section 4 of this review and includes further literature review where that has been deemed appropriate by contributors. This reduces the possibility that relevant impacts have been omitted from this report because of constraints due to project choice.

Impacts have been collated using the Vulture Tool and impact categorisations applied: EC Expectations; Extent of Impact; and Maturity.

Impact - EC Expectations:
- Contributes to inclusion of SMEs in networked embedded ICT
- Improvements to collaboration along the supply chain (Enablers – Enhancers – Exploiters)
- Provision of platforms for collaboration (e.g. mbed, HyperKat, Homekit, etc)
- Contributes to development & uptake of architectures, etc.
- Contributes to development & uptake of business models
- Contributes to development & uptake of standards
- Improvements in Capability
- Reduction in Time to Market
- Reductions in Costs to Market

Impact - Extent of Impact:
- Not yet available
- Impact currently restricted to project partnership; at least some partners exploiting results
- Impact currently restricted to project partnership; some partners exploiting results; industrial community of interest created
- Evidence of wider exploitation within the domain of interest (e.g. ARTEMIS categories; IT&C, Agriculture, etc; companies outside project consortium are making use of results
- Evidence that SMEs within the domain are making use of results
- Evidence that results have been taken up more widely; e.g. across other domains, or standards interest, or professional societies and business associations are interested

Impact - Maturity
- Results supply a documented solution concept
- Results exist in prototype form
- Prototype tested, full system documented
- System validation and verification (V&V) completed, ready for production engineering
- Results are deployable, support available
It should be emphasised that there was difficulty in accessing information regarding impacts. The impact reports for many projects are (justifiably) restricted to consortium members only. The findings in this section should therefore be taken to be a conservative indication of project impacts.

5.2 POTENTIAL IMPACTS ANTICIPATED BY THE PROJECTS

The following table summarises the anticipated impact on a project by project basis:

Table 5.1 Potential Impacts

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Impact</th>
<th>Classification of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADVANCE</td>
<td>Unified tool-based framework for automated formal verification and simulation-based validation of cyber-physical systems.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>AGILE</td>
<td>Development and evaluation of an integrated LSCS-design methodology which reduces the initial design phase and the need for constant calibration and re-configuration of the control system throughout its lifetime.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>AMADEOS</td>
<td>Development of a conceptual model for information transfer in an SoS that takes account of dissimilar representations of the same semantic content in the diverse constituent systems.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>AXIOM</td>
<td>2 Use Cases: smart video surveillance (coordination of multiple cameras towards a single event), smart living/home (new, scalable, smart thermostat). Standardisation efforts may widen impact</td>
<td>Not yet classified as the project has just started.</td>
</tr>
<tr>
<td>AUTOPROFIT</td>
<td>Development of a model-based operation support technology that enables control and model calibration at a considerable higher level of autonomy than currently possible.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>Project</td>
<td>Description</td>
<td>Notes</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>BALCON</td>
<td>Research co-operation between academic and industrial communities from the EU and the Western Balkan Countries (that are active in the design, development and implementation of systems and applications for Monitoring and Control in Energy and Transport Management and Intelligent industrial production)</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>BEMO-COFRA</td>
<td>Linksmart – intelligent WSN management to facilitate more accurate decision making. Allows the integration of multiple modules that feeds the two main functional components of the product, the Network Manager and the Event detector. Focused on industrial environment Training information is available</td>
<td>Extent of impact: 4: Evidence of wider exploitation 6 Evidence that results have been taken up more widely (Training) Impact Expectation: 1. Contributes to networked embedded ICT, 2: Provision of platforms, 3: Contributes to development &amp; uptake of business models (Training) 4: Improvements in Capability Maturity of results: 4: System V&amp;V completed 5: Results are deployable (training)</td>
</tr>
<tr>
<td>CLAM</td>
<td>Development of a cooperative, flexible and robust underwater sensing, reasoning and communication platform for online surveillance of submarine environments accommodating pervasively deployed heterogeneous sensor nodes deployed at different water depths, enabling sensing and actuating devices to exchange data, autonomously network together, and collaboratively and locally assess their observation environment and act upon.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
</tbody>
</table>
| COMPASS | Model –based engineering for audio/video, home automation systems  
Evaluating by Bang & Olufsen (B&O) using a set of case study aspects representing the company’s development process challenges for SoS  
Case studies included models of AV data streaming, leader election and service discovery in networks.  
Test showed the Compass methods and tools met B&O’s SoS engineering needs and the semi-formal COMPASS technologies were adopted by B&O.  
Value in linking of refinements/methods/concepts between the stages of the development process  
Another selling point of the approach was the support for the development of project ontologies to enable consistent communication and reasoning about complex SoS domains. |
| --- | --- |
| Extent of impact:  
3: Impact restricted but community of interest created  
Impact Expectation:  
1. Contributes to networked embedded ICT, 3: Contributes to development & uptake of tools, methods, 4: Improvements in Capability  
Maturity of results:  
2: Results exist in prototype form, 3 Prototype tested, full system documented |
<p>| COSIM | Provision of an innovative comprehensible, ultra-Fast, security-Aware CPS Simulator (called COSSIM) that will seamlessly simulate both the networking and the processing parts of the Cyber Physical Systems (CPS) significantly faster and more accurately than any existing solution |
| Not yet classified due to lack of accurate impact estimates available through project website |</p>
<table>
<thead>
<tr>
<th>Project</th>
<th>Description</th>
<th>Extent of impact</th>
<th>Impact Expectation</th>
<th>Maturity of results</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSERN</td>
<td>Energy efficient SoS: scenarios and use cases for advanced techniques in energy efficiency and self growing network-based scalability management, Requirements and evaluation criteria for the deployment of energy efficiency system Identification of key future challenges for reducing energy wastage and energy consumption in these networks, Impact assessment of energy efficiency in self-growing systems on wider socio-economic, environmental and policy objectives, Standardisation monitoring and contribution</td>
<td>Extent of impact: 3: Impact restricted but community of interest created Impact Expectation: 3: Contributes to development &amp; uptake of standards Maturity of results: 2: Results exist in prototype form</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPSE-LABS</td>
<td>Funding and support to CPS businesses around Europe. Smart cities initiative built on SOFIA2 (Smart Objects for Intelligent Applications) architecture, communication protocol Smart Production Systems: improved programmable logic controllers Maritime Safety and Security applications Dependability of Autonomous Vehicles</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>CPSETIS</td>
<td>No detailed information available</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>CPSOS</td>
<td>Constituencies and integration/knowledge exchange for the creation of a European research and innovation agenda on SoS</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>CPS-SUMMIT</td>
<td>Enhancement of R &amp; D collaboration between EU and US</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>CYPHERS</td>
<td>Improved competence of EU member states in embedded and mobile computing and in control of networked embedded systems State of the Art Report</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>Project</td>
<td>Description</td>
<td>Impact &amp; Maturity</td>
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<tr>
<td>DANSE</td>
<td>DANSE technology demonstration package [Water Treatment Scenario] -- new approach to the design and management of the operation of SoS to avoid failures in operation</td>
<td>Contribution to standards; Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>EMBOCON</td>
<td>Software Platform: set of standardized software interfaces used for the rapid design of embedded systems - released as open source using a MIT licence - aimed at increasing the industrial accessibility of embedded systems</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>ENOSYS</td>
<td>An integrated workbench that will increase productivity of embedded system development and shorten time-to-market for SoC (System on Chip) systems. Short industrial use case backs up initial claims</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<td></td>
<td>Development of a new platform that combines: A need for more intelligence in future embedded systems. Computer vision moving rapidly beyond academic research and factory automation. Technological advances in mobile processing power.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>EOT</td>
<td>Extent of impact: 3: Impact restricted but community of interest created, 4: Evidence of wider exploitation Impact Expectation: 2: Provision of platforms, 3: Contributes to development &amp; uptake of architectures, 3: Contributes to development &amp; uptake of tools, methods Maturity of results: 3 Prototype tested, full system documented</td>
<td></td>
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<tr>
<td>ERA</td>
<td>Next generation, open source adaptive embedded systems platform with a dynamically reconfigurable parameterized processor core. To be used to enable faster design space exploration and prototyping of embedded systems</td>
<td></td>
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</tr>
<tr>
<td>EUROCP</td>
<td>Enabling SMEs to build innovative CPS products with the goal of strengthening the position of European industry along the value chain and to promote the development and optimisation of innovative CPS products using existing EU chips</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>GENESI</td>
<td>Remote condition monitoring system (cableless, long lasting operation, ability to provide data in critical situations when traditional systems fail, low maintenance etc) Use case in a tunnelling context.</td>
<td>Extent of impact: 4: Evidence of wider exploitation Impact Expectation: 1. Contributes to networked embedded ICT, 2: Provision of platforms, 3: Contributes to development &amp; uptake of architectures Maturity of results: 3 Prototype tested, full system documented</td>
<td></td>
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</tr>
<tr>
<td>Topic</td>
<td>Description</td>
<td>Extent of impact:</td>
<td>Impact Expectation</td>
<td>Maturity of results:</td>
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<tr>
<td>GREENER BUILDINGS</td>
<td>Living Lab: Sensor installation in buildings to identify dynamic usage patterns in occupants behaviour to minimise energy consumption</td>
<td>2: Impact restricted to partners</td>
<td>1. Contributes to networked embedded ICT, 2: Provision of platforms, 3: Contributes to development &amp; uptake of architectures, 4: Improvements in Capability</td>
<td>3 Prototype tested, full system documented</td>
</tr>
<tr>
<td>HYCON2</td>
<td>Control of complex, large-scale, and networked dynamical systems. Assessment and co-ordination of research and activities in this area Domains: ground and aerospace transportation, electrical power networks, process industries, and biological and medical systems. Multi-disciplinary education at the graduate and undergraduate level</td>
<td>2: Impact restricted to partners</td>
<td>1. Contributes to networked embedded ICT, 1: Contributes to inclusion of SMEs in networked embedded ICT, 2: Improvements to collaboration, 2: Provision of platforms, 3: Contributes to development &amp; uptake of architectures, 3: Contributes to development &amp; uptake of standards 4: Improvements in Capability 4: Reduction in Time to Market, 4: Reductions in Costs to Market</td>
<td>1: Results supply a documented solution concept</td>
</tr>
<tr>
<td>HYDROBIONETS</td>
<td>Development of Self-Organized Wireless BioMEM Networks (WBNs) and their integration in a global system to monitor the complete water cycle in large-scale water treatment and desalination plants.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td>IMC-AESOP</td>
<td>Service-oriented Architecture approach for monitoring and control of Process Control applications (batch and continuous process)</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
<td></td>
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<tr>
<td>Project</td>
<td>Description</td>
<td>Classification</td>
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<tr>
<td>IMMORTAL</td>
<td>An integrated, cross-layer modeling based tool framework for fault management, verification and reliable design of dependable Cyber-Physical Systems (CPS) – recently started.</td>
<td>Not yet classified as the project has just started.</td>
<td></td>
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</tr>
<tr>
<td>INTO-CPS</td>
<td>Integrated tool chain for comprehensive model-based design of CPS. Challenges: support for co-model construction and co-simulation: model, software, hardware in the loop Use cases: automotive, agricultural, railway and building automation</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
<td></td>
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</tr>
<tr>
<td>KARYON</td>
<td>Predictable and safe co-ordination of co-operating, smart, autonomous vehicles</td>
<td>Extent of impact: 2: Impact restricted to partners Impact Expectation: 1. Contributes to networked embedded ICT, 1: Contributes to inclusion of SMEs in networked embedded ICT, 3: Contributes to development &amp; uptake of standards Maturity of results: 2: Results exist in prototype form</td>
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<tr>
<td>LOCAL4GLOBAL</td>
<td>Provision of ready to use control system in Energy, Transport and Traffic Management systems based on self-learning Natural Systems of Systems in the shape of an embedded, web-based, &quot;plug-and-play&quot; software system This system will be deployed and extensively tested in 2 Use Cases in Traffic and Building.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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</tr>
</tbody>
</table>
| MADNESS | Advanced technology and specific tools for strengthening European excellence in the design of multi-processor heterogeneous embedded systems including:  
- Significantly increased productivity of embedded system development.  
- Improved competitiveness of European companies in this area by reducing design costs and time to market.  
- Emergence and growth of new companies that supply design tools and associated software.  
- Reinforced European scientific / technological leadership in the design of complex embedded systems. | Extent of impact:  
1: Not yet available  
Impact Expectation:  
3: Contributes to development & uptake of business models, 4: Reduction in Time to Market, 4: Reductions in Costs to Market  
Maturity of results:  
1: Results supply a documented solution concept |
| MAKESENSE | The makeSense tool chain allows easier programming of Wireless Sensor Network applications. For a typical building automation system comprising 30 sensors or actuators and some control logic makeSense technology would only require a 60.000€ investment compared with 180.000€ for a conventional system or 105.000€ for a state-of-the-art WSN system. | Extent of impact:  
3: Impact restricted but community of interest created  
Impact Expectation:  
1. Contributes to networked embedded ICT, 3: Contributes to development & uptake of architectures, 3: Contributes to development & uptake of tools, methods, 4: Reductions in Costs to Market  
Maturity of results:  
1: Results supply a documented solution concept |
<p>| MoVES | Novel methods for modelling, analysis and control of complex, large scale power systems using the framework of stochastic hybrid systems (SHS), | Not yet classified due to lack of accurate impact estimates available through project website |</p>
<table>
<thead>
<tr>
<th>Project</th>
<th>Description</th>
<th>Impact/Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPENCOSS</td>
<td>Addresses the lack of affordable (re)certification approaches particularly for evolving CPS and SoS by creating an open-source safety certification infrastructure and a common certification language. Aim is to help support re-use of component level assurance data, thus improving the time taken to produce a system, and reduce the costs associated with development.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>PAPYRUS</td>
<td>Methodology / Ontologies for multimedia data classification and a Digital Library Engine Accelerates and improves accuracy of searches Increases the value of the digital content archives through the semantic translation of content Simplified retrieval of information as user profile allows pre-filtering of results Definitions can be applied to other similar databases where this type of data is stored. Documentation is provided to show how it can be applied to different content type.</td>
<td>Extent of impact: 4: Evidence of wider exploitation Impact Expectation: 2: Provision of platforms, 2: Improvements to collaboration, 3: Contributes to development &amp; uptake of architectures, 3: Contributes to development &amp; uptake of tools, methods Maturity of results: 3 Prototype tested, full system documented</td>
</tr>
<tr>
<td>PLANET</td>
<td>Provision of an integrated planning and maintenance platform that enables the deployment, operation and maintenance of heterogeneous networked Co-operating Objects in an efficient way - unmanned ground and aerial vehicles cooperating with wireless sensor/actuator networks.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>ROAD2CPS</td>
<td>Just started: Roadmaps to create research agenda for CPS Community of interest</td>
<td>Impact Expectation: 2: Provision of platforms, 3: Contributes to development &amp; uptake of business models Maturity of results: Not yet known</td>
</tr>
</tbody>
</table>
| ROAD2SOS | Roadmaps to identify future RTD and Innovation strategies for Europe in the field of SoS engineering in 4 domains: multi-modal traffic control, emergency and crisis management, distributed energy generation and smart grids, and multi-site industrial production. Impact of roadmaps include: new solutions for SoS engineering, transferring SoS engineering research, development, and innovation results to relevant stakeholders, identifying of roadmap trends in research, development and innovation and link them to future possible products and applications, understanding of technical, social and economical enablers and barriers as well as identifying of effects of SoS implementation. | Impact Expectation: 2: Improvements to collaboration 3: Contributes to development & uptake of tools, methods 4: Improvements in Capability  
Extent of impact: 3: Impact restricted but community of interest created 4: Evidence of wider exploitation 6 Evidence that results have been taken up more widely 
Maturity of results: 1: Results supply a documented solution concept 5 Results are deployable |
| SAFURE | Only recently started no real impact information available | Extent of impact: 3: Impact restricted but community of interest created |
| SCUBA | Energy savings by centralised control of large buildings
A platform and associated tools to enable a Facilities Manager (or equivalent) to connect up sensors and actuators within the building, assess faults, move devices, introduce new devices etc
Enables co-ordination across different subsystems (e.g. anti-intrusion, HVAC, lighting, windows and doors, etc.) to optimise energy savings
Key feature: adjusting the building's energy consumption according to grid energy prices.
Maturity of results: 3 Prototype tested, full system documented |
<table>
<thead>
<tr>
<th>Road2CPS</th>
<th>1.1 Road2CPS State of Art Report</th>
<th>1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPRINT</strong></td>
<td>SPRINT Networked Environment which provides the virtual blending via Internet of all &quot;things&quot; pertaining to a complex system: sensors, actuators, processing elements, system design tools and models and design teams that are in general spread over different geographical locations. This research will open a new vista on the use of Internet of Things that may change radically the way in which systems are designed and tested.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td><strong>T-AREA-SOS</strong></td>
<td>State of the Art Report: influenced two research programs at the Australian Defence Systems Innovation Centre (DSIC); one of most downloaded documents from INCOSE website Gap Analysis Report: served as a basis for the production of a list of high-level requirements specifications for SoS Strategic Research Agenda Strategic Research Agenda: influenced H2020 research programme and referenced in a strategic agenda for Australian defence strategy.</td>
<td>Impact Expectation: 2: Improvements to collaboration 3: Contributes to development &amp; uptake of tools, methods 4: Improvements in Capability Extent of impact: 3: Impact restricted but community of interest created 4: Evidence of wider exploitation 6 Evidence that results have been taken up more widely Maturity of results: 1: Results supply a documented solution concept 5 Results are deployable</td>
</tr>
<tr>
<td><strong>TAMS4CPS</strong></td>
<td>Only recently started so no impact information available</td>
<td></td>
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<tr>
<td><strong>TAPPS</strong></td>
<td>Aim to extend and customize CPS devices with new 3rd party services and features in an Apps platform in an efficient, secure and trusted way. This will enable new market extensions to keep pace with user expectations and latest technology eg current Apps for vehicles provide infotainment functionality or control basic settings, both of which are not safety critical.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>TERESA</td>
<td>Aim is to define, demonstrate and validate an engineering discipline for trust that is adapted to resource constrained embedded systems where trust is defined as the degree with which security and dependability requirements are met. Validation planned in four application sectors: automotive systems, home control systems, industry control, and metering.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
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<tr>
<td><strong>U-TEST</strong></td>
<td>2 case studies of U-TEST handling system Solutions will be integrated into two key commercial tools available on the market: ModelBus/Fokus!MBT (Fraunhofer FOKUS) and Certifylt (Smartesting, France) Intent to deploy in logistics, geo sports and healthcare</td>
<td>Extent of impact: 4: Evidence of wider exploitation Impact Expectation: 1. Contributes to networked embedded ICT, 1: Contributes to inclusion of SMEs in networked embedded ICT, 3: Contributes to development &amp; uptake of architectures, 4: Improvements in Capability, 4: Reduction in Time to Market, 4: Reductions in Costs to Market Maturity of results: 2: Results exist in prototype form</td>
</tr>
<tr>
<td><strong>UnCoVerCPS</strong></td>
<td>4 Demonstrators for control of automated systems Robust and fault-tolerant control of smart grids and components Automated Driving Robots as co-workers in manufacturing Control and online verification of wind turbine</td>
<td>Extent of impact: 3: Impact restricted but community of interest created Impact Expectation: 1. Contributes to networked embedded ICT, 1: Contributes to inclusion of SMEs in networked embedded ICT, 2: Provision of platforms, 3: Contributes to development &amp; uptake of tools, methods, 4: Improvements in Capability, 4: Reduction in Time to Market, 4: Reductions in Costs to Market Maturity of results: 3 Prototype tested, full system documented</td>
</tr>
<tr>
<td>Project</td>
<td>Description</td>
<td>Impact Expectation</td>
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<tr>
<td>VITRO</td>
<td>VITRO toolbox, which will enable easy configuration and instant support for deploying VSN applications. Although VITRO aims to be application-neutral, the proposed architecture and protocol toolbox will be validated through extensive simulation testing and furthermore implemented in a large trial of sensor nodes and smart objects in smart home and building automation application domains.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>VERDI</td>
<td>Verification of heterogeneous SoS. The Verdi methodology and library will be demonstrated with safety critical automotive SoS applications: power-train, in-vehicle networking, and airbag. It will extend industry-recognized standards (Universal Verification Methodology, SystemC and IP-XACT) to enable the promotion and wider adoption among the industry of other heterogeneous applications.</td>
<td>Not yet classified due to lack of accurate impact estimates available through project website</td>
</tr>
<tr>
<td>WIBRATE</td>
<td>Wireless, self-powered sensors. Powered solely by energy harvested from vibrations themselves Awarded its first industrial contracts for the sensor system, from South Eastern Railways in the United Kingdom; this has allowed to further enhance the prototype and convert it into a product.</td>
<td>Extent of impact: 4: Evidence of wider exploitation Impact Expectation: 1. Contributes to networked embedded ICT Maturity of results: 3 Prototype tested, full system documented</td>
</tr>
<tr>
<td>IEEE-SA: IoT impact on Smart City</td>
<td>Big Data techniques for development of Pothole tracking system IOT to manage and track garbage cans and content</td>
<td>Extent of impact: 4: Evidence of wider exploitation Impact Expectation: 1. Contributes to networked embedded ICT, 2: Improvements to collaboration, 4: Improvements in Capability Maturity of results: 5 Results are deployable</td>
</tr>
</tbody>
</table>
6 CONCLUSIONS

6.1 APPROACH

This work has used a collaborative approach to categorise data relating to CPS projects. To facilitate this activity an online tool, the “Vulture Tool” was created and populated. A further feature of this tool is that it allows rapid *ad hoc* exploration of the data using the categories and user search facilities. In this respect it may well be easier to browse the data dynamically by using the tool, rather than in the static form of this report.

The summary charts in the sections that follow are condensed from the data collected from the Vulture tool.

6.2 STATE OF THE ART

Analysing the data collected using the Vulture Tool found evidence for four clusters of activity characterised by classification on the Interoperability and Infrastructure scales (See Figure 6.1). These clusters are independent of the Domain axis, and indicate the broad cross domain nature of the issues explored by the projects.

![Figure 6.1 Summary of the State of the Art: Cube 2.0](image)

An expanded Infrastructure axis was used for the categorisation of data. The sub-headings for the expanded terms are enclosed in light grey for clarity. Note that the boundaries of the clusters would be unaffected by compressing the Infrastructure axis, indicating robustness in this diagrammatic representation, called “Cube 2.0” for convenient reference.
Mapping projects, activities and impacts in turn on to the Cube 2.0 diagram offers effective visualisation of the CPS projects reviewed.

In figure 6.2, the projects reviewed have been mapped on to the Cube 2.0 diagram. While the individual project titles are not readable in this small version of the diagram, it is clear that project activity is not uniform. A bias is apparent towards Strategic Technology Research and Technology Implementation, especially towards the latter.

**Figure 6.2 Cube 2.0 Project overlay**

Mapping the project activity for each project or group of projects shown in Figure 6.2 facilitates a further useful summary.
Now summarising the activity overlay in Figure 6.4:
Figure 6.4 Cube 2.0 Summary overlay

From Figure 6.4, the analysis of the fifty-four projects suggests that the current state of the art may be summarised as being within the following areas (in approximate order of number of activities):

- **Technology Implementation:**
  - CPS Simulation Control & Validation;
  - Energy, Actuators & Sensors for CPS.

- **Strategic Technology Research:**
  - Building a CPS Research & Operational Community;
  - Enabling Technologies for CPS Design & Control.

- **CPS Support Ecosystems:**
  - Building, Training & Educating a Safe & Secure CPS Constituency;
  - Designing Safe & Secure CPS.

- **Systems of Systems:**
  - Regulation;
  - Control of Distributed CPS;
  - Designing Safe and Secure Systems.

### 6.3 IMPACTS

Making an assessment of project impacts proved problematic due to the limited amount of information available. Following the same approach of mapping projects with reported impacts on the Cube 2.0 visualisation supports a provisional view that impacts follow activity without any obvious
bias using the Infrastructure and Interoperability categorisations. It is also reasonable to assume impacts may not be reported publicly for legitimate reasons such as commercial sensitivity.

No attempt to validate extent of the impacts has been made due to the incomplete nature of the information. Many of the impacts noted suggest that many of the outputs of these projects are around NASA Technology Readiness Level 6 - “System/subsystem model or prototype demonstration in a relevant environment (ground or space)”. Section 5 contains a tabular summary of the information collected in the Vulture Tool.

![Figure 6.4 Cube 2.0 Impact overlay](image)

6.4 GAPS

When examining projects by their categorisations it is clear that “Contracts & financial arrangements” and “Education” are poorly represented in the coverage of projects. This observation is supported by Gap Snippets also entered into the Vulture Tool and will be the subject of additional investigation as a deeper gap analysis is performed as on going work.

6.5 DISCUSSION

By exporting the data into a suitable analysis tool, this work has found that CPS projects may be usefully grouped into clusters by their categorisations within the Infrastructure and Interoperability scales. This is not to say that the Domain scale is unimportant, but rather Domain categorisation is not useful when trying to group projects into clusters.
A potential application of this finding is the placement of information gathered at workshops, roadmaps and other sources into natural groups based on the Infrastructure and Interoperability axes.

This work also found evidence that there is a domain bias in projects within the technology implementation cluster: Environment and Agriculture; Healthcare; and Security are almost completely ignored. Further research will be required to understand this observation.

The cluster analysis has allowed for observation of large scale features within the dataset that may have been hard to find though other analytical approaches. No attempt has been made to apply a rigorous statistical analysis as only obvious findings have been included, but such an analysis might uncover other useful associations. In this context the raw dataset of CPS projects and associated categorisations may be a useful resource for other work packages and projects. However, anonymisation and removal of personally attributable remarks would be required.

Although many projects offer limited public access to impacts due to commercial sensitivities, descriptions of impacts have been described and categorised from nearly thirty projects.

6.6 FURTHER WORK

The Vulture Tool will be developed further to support the and Gap Analysis report (D1.2) and Impact assessment (D1.3).

Inputs will also be sought from FP7 projects as well as organisations such as the IEEE, INCOSE, standards bodies such as ISO, CEN, IEC, AFNOR, DIN, BSI, FP7-ICT.

There is also potential to use the dataset uncover other useful relationships relating to CPS projects.
7 REFERENCES


ADVANCE project description: http://cordis.europa.eu/project/rcn/104887_en.html

AGILE project website: http://www.agile-fp7.eu

AUTOPROFIT project description: http://cordis.europa.eu/project/rcn/95579_en.html

AXIOM project website: http://www.axiom-project.eu/axiom-an-introduction/

BALCON project website: http://www.balcon-project.eu/mainpage

BEMO-COFRA project website: http://bemo-cofra.eu/

COMPASS project website: http://www.compass-research.eu/


CONSERN project website: http://cordis.europa.eu/project/rcn/95373_en.html

COSSIM project website: http://cordis.europa.eu/project/rcn/194141_en.html

CPSE-LABS project website: http://www.cpse-labs.eu

CPSoS project website: http://www cpsos.eu

CPS-SUMMIT project website: http://cordis.europa.eu/project/rcn/194164_en.html

CYPHERS project website: http://www.cyphers.eu/project

DANSE project website: http://danse-ip.eu/home/

EC-SAFEMOBIL project website: http://www.ec-safemobil-project.eu

EMBOCON project description: http://cordis.europa.eu/project/rcn/93754_en.html

EMBOCON project wiki. – Website: http://www.embocon.org/index.php/Main_Page

ENOSYS project website: http://cordis.europa.eu/project/rcn/93274_en.html

EOT project website: http://eyesofthings.eu/

ERA project website: http://www.era-project.eu/

EUROCP5 project website: https://www.eurocps.org/

GENESI project website: http://genesi.di.uniroma1.it


GREENERBUILDINGS project website: http://www.greenerbuildings.eu


HYCON2 project website: http://www.hycon2.eu

HYDROBIONETS project website: http://www.hydrobionets.eu
IMC-AESOP project website: http://www.imc-aesop.eu

INTO-CPS project website: http://into-cps.au.dk

KARYON project website: http://www.karyon-project.eu/

LOCAL4GLOBAL project website: http://local4global-fp7.eu


MADNESS project website: http://www.madnessproject.org/

MAKESENSE project website: http://www.project-makesense.eu/


MOVES project website: http://www.movesproject.eu/index.html


PAPYRUS project website: http://projects.eclipse.org/projects/modeling.papyrus-rt

ROAD2CPS project website: www.road2cps.eu

ROAD2SOS project website: http://www.road2sos-project.eu/cms/front_content.php

SCUBA project website: http://www.aws.cit.ie/scuba

SPRINT project website: http://www.sprint-iot.eu

TAMS4CPS project website: http://www.tams4cps.eu

TAPPS project website: http://www.tapps.eservices4life.org/

T-AREA-SOS project website: https://www.tareasos.eu

TERESA project website: http://www.teresa-project.org/


UNCOVERCPS project website: http://cps-vo.org/group/UnCoVerCPS

VERDI project description: https://wiki.eas.iis.fraunhofer.de/verdi/index.php/Public:Abstract


VITRO project description: http://cordis.europa.eu/project/rcn/95468_en.html

Vulture Tool: Further references are included within the Vulture Tool covering on-line sources, academic publications and project publications.


WiBRATE project website: http://wibrate.eu
8 APPENDICES
8.1 CUBE 2.0 (HIGH RESOLUTION)
8.2 CUBE 2.0 PROJECT SUMMARY OVERLAY (HIGH RESOLUTION)
8.3 CUBE 2.0 PROJECT OVERLAY (HIGH RESOLUTION)
8.4 CUBE 2.0 PROJECT ACTIVITY OVERLAY (HIGH RESOLUTION)
8.5 CUBE 2.0 IMPACT OVERLAY (HIGH RESOLUTION)
8.6 PRINCIPLE R! CODE USED

# R script for processing output from Vulture tool
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#Heavily updated in June 2015
#Define a function to split the categorical data into a list
#This function uses a , to split the list so we cannot use a comma in categories
vulture_split <- function(x) {
  c(strsplit(toString(x),","))
}

#This is a test subset of data so can be ignored
NCOIC <- my.csv.datacube[4]
#Now we have a test function let's test it
NCOIC <- apply(NCOIC,1:2, vulture_split)
#Just keep ignoring above

#The raw csv data is effectively stored as a mixture of text and categories so force it to text with toString(x)
#Once we have it as text we can split any comma delimited string into a list using the custom function vulture_split
#What we really need to do is to convert the whole csv data frame into a list of lists
#This turns out to be easy using the apply function and specifying it to at upon the columns and rows with 1:2

data_list <- apply(my.csv.datacube,1:2, vulture_split)
#length_data_list <- length(data_list)
#The output can be checked using
#data_list
#data_list[2,]
#data_list[5,3]
or similar to verify the integrity of data
str(data_list[5,3])

We now need to produce a dataframe upon which to perform our analysis.
From each row in data_list we need to return one value for each column from the list that comprises each column.
We will do this randomly over data_list many times to produce a plottable dataframe.

cols <- as.numeric(ncol(data_list))
rows <- as.numeric(nrow(data_list))

To make life easier when extracting and plotting the metadata an index number has been assigned to each term.
We will need to extract the number out of the meta-data.
We'll do it like this:

grab_number <- function(x) {
  #grab the cell value
  input_value <- as.character(x)
  if (!is.null(input_value)) {
    list_value <- unique(na.omit(as.numeric(unlist(strsplit(unlist(input_value), "[^0-9]+")))))
    unlist(list_value)
  }
}

#now we need to randomly select a value from each column.

grab_value <- function(x) {

}
# grab the cell value
list_cell <- unlist(x)

list_cell_length <- length(list_cell)
# Now we know the length of the cell we'll grab the final value
# Some conditional actions
if (list_cell_length == 1) {
  the_cell <- list_cell
}
else {
  # As everything else depends upon a match this is the default action
  the_cell <- list_cell_length
}
# Now we can just add a series of self contained actions
if (list_cell_length < 1) {
  # If the cell is empty.......
  the_cell <- "No value"
}
if (list_cell_length > 1) {
  # Grab a random value from the list
  the_cell <- list_cell[sample(1:list_cell_length,1)]
}

# see if we have a number
is_a_number <- grab_number(the_cell)

# now lets check the number is reasonable and not a null
#if ( !is.null(is_a_number) && length(is_a_number) > 0 ) {
#  if ( as.numeric(is_a_number) > 0 ) {
#    the_cell <- unlist(is_a_number)
#  }
#}
#if (length(is_a_number) > 0) {
#the_cell <- is_a_number
#}

#R always returns the last calculated value as the result of the function
returnthisvalue <- the_cell
}

vulture_values <- NULL
for(i in 1:2000) {
  vulture_values_working.row <- list()
  length_data_list <- nrow(my.csv.datacube)
  random_row_number <- sample(1:length_data_list,1)
  #Use random_row to get a random row
  vulture_values_working.row <- my.csv.datacube[random_row_number,]
  #now we have our random row let's select a single value from each category
  #we need to do this for columns 3, 4 and 5
  vulture_values_working.row.3 <- vulture_split(vulture_values_working.row[,3])
  #now take a random row
  vulture_values_working.row.3.single <- grab_value(vulture_values_working.row.3)
  #and turn it into a number
  vulture_values_working.row.3.number <- grab_number(vulture_values_working.row.3.single)
  #and feed the value back to the working row
  vulture_values_working.row[,3] <- vulture_values_working.row.3.number
  # Do this the long way....

  vulture_values_working.row.4 <- vulture_split(vulture_values_working.row[,4])
  #now take a random row
  vulture_values_working.row.4.single <- grab_value(vulture_values_working.row.4)
#and turn it into a number
vulture_values_working.row.4.number <- grab_number(vulture_values_working.row.4.single)
#and feed the value back to the working row
vulture_values_working.row[,4] <- vulture_values_working.row.4.number
# Do this the long way....

vulture_values_working.row.5 <- vulture_split(vulture_values_working.row[,5])
#now take a random row
vulture_values_working.row.5.single <- grab_value(vulture_values_working.row.5)
#and turn it into a number
vulture_values_working.row.5.number <- grab_number(vulture_values_working.row.5.single)
#and feed the value back to the working row
vulture_values_working.row[,5] <- vulture_values_working.row.5.number
# Do this the long way....

#vulture_values_working <- apply(my.csv.datacube,2, grab_value)
vulture_values <- rbind(vulture_values, vulture_values_working.row)
#vulture_values <- rbind(vulture_values,vulture_values_1)
}

#Now output a file
write.csv(vulture_values,file ="/home/enpjp/Documents/vulture_data_out_random-1.csv", row.names=FALSE)

# Now to set up some graphics
#First lets load the library
library(rggobi)
# Now we need to convert the vulture values to a data frame for plotting
vulture_frame <- as.data.frame(vulture_values)
rownames(vulture_frame) <- NULL

# We need to set the factor columns to numeric
# Ha! This seems to coerce the column into numeric format by using the number in the string
# vulture_frame$Infrastructure <- as.numeric(vulture_frame$Infrastructure)
# vulture_frame$NCOIC <- as.numeric(vulture_frame$NCOIC)
# vulture_frame$Domain <- as.numeric(vulture_frame$Domain)
# Now let's get a couple of basic plots
# First let's create the ggobi object

# Make a dataframe
VV.sub <- vulture_values[, c(1,3,4,5)]

# Make the names in project.nae the rownames...
# row.names(VV.sub) <- VV.sub[,1]
row.names(VV.sub) <- NULL
VV.sub <- as.data.frame(VV.sub)

# test.sub <- data.frame( lapply(VV.sub[2:4], grab_number) )

VV.sub$Infrastructure <- as.numeric(VV.sub$Infrastructure)
VV.sub$NCOIC <- as.numeric(VV.sub$NCOIC)
VV.sub$Domain <- as.numeric(VV.sub$Domain)

VV.sub.dist <- dist(VV.sub)

VV.sub.dend <- hclust( VV.sub.dist, method="average" )

clust9 <- cutree(VV.sub.dend, k=6 )

# Now we have to add the cluster membership number
VV.sub.clustID <- cbind(VV.sub, clusterID=clust9)

#Lets see if we can do this to the original data
vulture_values.clustID <- cbind(vulture_values, clusterID=clust9)
#Yep it works!#Now to pull out the index numbers for the metadata

#vulture_values_numbers <- cbind(vulture_values[1:2], apply(vulture_values[3:5],2, grab_number))

#Some test cases
#data_list_cell <- unlist(data_list[5,4])

#length(data_list_cell)
#list_cell$data_list_cell[2]
#Now we have the cluster members let's print the file:

write.csv(vulture_values.clustID, file = "./home/enpjv/Documents/Vulture/FullData/cluster_members/vulture_cluster_members_full_updated.csv", row.names=FALSE)

plot(VV.sub.dend, labels=FALSE)

#(x <- identify(VV.sub.dend)) ## Terminate with 2nd mouse button !!

gd <- ggobi(VV.sub)[1]
display(gd, vars=list(X="Domain",Y="Infrastructure"))
#glyph_color(gd)[clust9==4] <- 8

#glyph_size(gd)[clust9==4] <- 5

# Now a few scatter plots by project
display(gd, vars=list(X="Project.Source",Y="Infrastructure"))
display(gd, vars=list(X="Project.Source",Y="Domain"))
display(gd, vars=list(X="Project.Source",Y="NCOIC"))

# now lets try a few permutations
display(gd, vars=list(X="Domain",Y="NCOIC"))
display(gd, vars=list(X="Infrastructure",Y="NCOIC"))
#display(gv[1], vars=list(X="Project.Source",Y="NCOIC"), position = position_jitter(w = 0.1, h = 0.1))