Deliverable 4.4

Strategic Innovation Agenda

DISSEMINATION LEVEL		
PU	Public	**X**
CO	Confidential, only for members of the consortium (including the Commission Services)	

COVER AND CONTROL PAGE OF DOCUMENT	
Project Acronym:	CPSELabs
Project Full Name:	CPS Engineering Labs - expediting and accelerating the realization of cyber-physical systems
Grant Agreement No.:	644400
Programme	ICT-1: Cyber-Physical Systems
Instrument:	Innovation Action
Start date of project:	01.02.2015
Duration:	36 months
Deliverable No.:	D4.4
Document name:	Strategic Innovation Agenda
Work Package	WP4
Associated Task	Task 4.5
Nature [1]	R
Dissemination Level [2]	PU
Version:	1.0
Actual Submission Date:	2015-12-23
Contractual Submission Date	2015-10-01
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The CPSELabs project is co-funded by the European Community's Horizon 2020 Programme under grant agreement nº 644400.

[1] **R**=Report, **DEC**= Websites, patents filling, etc., **O**=Other
[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services)

Change Control

Document History

Version	Date	Change History	Author(s)	Organization(s)
0.1	2015-09-06	Draft structure	H. Pfeifer	FOR
0.2	2015-10-30	Document drafted	H. Pfeifer	FOR
0.4	2015-11-19	Partner contributions integrated	H. Pfeifer	FOR
0.6	2015-11-26	KPI targets	H. Pfeifer	FOR
0.8	2015-12-11	Complete draft for internal review	H. Pfeifer	FOR
1.0	2015-12-22	Document finalised	H. Pfeifer	FOR

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Executive Summary

The CPSE Labs Strategic Innovation Agenda (SIA) is part of the project's Innovation Management and serves as an important instrument to maximize the impact of CPSE Labs. The main purposes of the SIA are to provide a foundation for the planning of topics for the Open Calls for Experiments, to support the alignment of the plans of the individual design centres, and to identify needs and opportunities for collaboration across centres. In this first iteration, the SIA mainly focuses on providing guidance for the development of the portfolio of innovation experiments.

The CPSE Labs Design Centres provide technologies and expertise in various CPS application domains, including automotive, industrial automation, Smart Cities and urban sustainability, autonomous systems, and maritime systems. For each design centre, their specific competencies in CPS Engineering are described together with the relevant technologies and platforms supported by the Centre. Current needs experienced by businesses and barriers to innovation are identified. Based on these needs and barriers strategic measures are derived that are needed to support businesses and to accelerate innovation in CPS Engineering. At the core of these measures is the execution of collaborative experiments with businesses, and the centres identify the areas in which our Open Calls need to offer experiment topics with high priority.

Complementary to the centre-specific strategies, the SIA also outlines the measures that CPSE Labs undertakes to integrate these activities, relating to the project goals of fostering cross-centre activities, development of CPS eco-systems, and provision of professional training.

Finally, we list the set of key performance indicators (KPIs) with which CPSE Labs measures its progress and impact, together with the individual Design Centre's target values for the three years of the project life-time.

1 Introduction

The CPSE Labs aim at *expediting and accelerating the realisation of trustworthy CPS* by addressing bottlenecks in the innovation system and by creating and strengthening synergies among relevant stakeholders and efforts. They are fostering Pan-European ecosystems, where industrial technology leaders and academic researchers play a complementary role for an efficient innovation and value creation process. SMEs and mid-caps, in particular, bring adaptability, reactivity and innovation, and academia bring long term and disruptive ideas for future innovations. The innovation objectives of the CPSE Labs are summarized as follows:

- Foster an open, Pan-European network of design centres committed to transitioning science and technology for engineering trustworthy and dependable CPS into the marketplace;
- Identify, define, and execute focussed and fast-track experiments with a specific innovation focus.
- Spread best CPS engineering practices and promote cross-regional and cross-sectorial learning among industry and academia;
- Establish a marketplace for CPS engineering assets.

As one of the tasks within the Innovation Management, CPSE Labs develops and maintains a Strategic Innovation Agenda (SIA). The SIA serves as an important instrument to maximize the impact of CPSE Labs by providing a strategic guidance for the work to be performed by the design centres within WP4 after the first project year, and forming the basis for evolving the portfolio of experiments that has been developed during the first round of open calls.

This document constitutes deliverable D4.4 of work package 4, the “Strategic Innovation Agenda”. The SIA is based on the state-of-the art in CPS engineering with a focus on the competencies of each of the CPSE Labs design centres. It takes into account perceived industrial needs and potential barriers to innovation in the engineering of trustworthy cyber-physical systems to identify corresponding innovation opportunities and to develop a roadmap of concrete actions addressing these opportunities.

The main purposes of the SIA are:

- to provide a foundation for the planning of the upcoming rounds of open calls, including the identification and prioritization of call topics;
- to guide the process of selecting experiments proposed by third parties in response to the open calls;
- to support the alignment of the plans of the individual design centres in order to identify needs and opportunities for collaboration across centres and to define corresponding cross-centre experiments.

Besides impacting the definition of the portfolio of centre experiments, the SIA will also influence further CPSE Labs activities such as innovation eco-system development, e.g. by identifying potential gaps in value chains and important stakeholders relevant to achieve the innovation objectives of experiments.

There will be two iterations of the Strategic Innovation Agenda. In this first iteration, the SIA mainly focuses on providing guidance for the development of the open call topics and a portfolio of innovation experiments. For various CPS domains we analyse the needs of businesses that aim at adopting CPS Engineering technology and potential barriers to innovation in the field. Based on their specific competencies and supported technologies, the CPSE Labs Design Centres define measures that need to be taken in order to address those needs, and to which the centres will give particular priority and emphasis.

The second iteration of the SIA may then include strategies and prioritization relevant to other tasks in WP4. Particularly, initial findings from marketplaces and professional training investigations can provide relevant input.

The document is structured as follows: the main part of this SIA is provided in Section 2, where we present the individual strategies of the various Design Centres of the CPSE Labs network. Complementary to this, Section 3 outlines the measures that CPSE Labs undertakes to integrate the centre-specific activities. Finally, the set of performance indicators with which CPSE Labs measures its progress and impact are listed in Section 4 together with each Centre's target values.

2 Centre Strategies

This section describes the individual strategies of the various Design Centres of the CPSE Labs network. For each design centre, their specific competencies in CPS Engineering are described together with the relevant technologies and platforms supported by the centre. Current needs experienced by businesses and barriers to innovation are identified. Based on these needs and barriers strategic measures are derived that are needed to support businesses and to accelerate innovation in CPS Engineering. At the core of these measures is the execution of collaborative experiments with businesses, and the centres identify the areas in which our Open Calls need to offer experiment topics with high priority.

2.1 Design Centre France

2.1.1 Field of competencies

CNRS-LAAS and ONERA have strong expertise in dependable computing and robotics. CNRS-LAAS has one of the largest research departments on robotic systems in France, and also a lead position in dependability research.

CNRS-LAAS has extensive expertise in Decisional and Planning issues in robotics including learning and adaptation. It will in particular be a supplier of navigation algorithms for mobile robotic platforms. It also has extensive expertise on run-time verification of autonomous systems, whether the monitoring is integrated to the control system or is an independent safety device. CNRS-LAAS also provides testing methods applied to a variety of embedded systems, including both conformance and robustness testing.

ONERA conducts multi-disciplinary researches in aeronautic, space and defence fields. In the CPSE Labs, ONERA gathers in a coherent framework research results and experimental means related to autonomous systems (developed initially for the defence) and to safety critical systems (developed initially for the aeronautic).

The following technologies and platforms are provided or supported by the design centre:

- HAZOP-UML is a model-based safety analysis method to identify operational risks due to human-robot or robot-robot interactions. https://www.laas.fr/projects/HAZOPUML/
- AltaRica based safety assessment is a model-based safety analysis method to assess robustness of concept of operation and system architecture, which has been deployed in the aeronautics domain. The Design Centre provides libraries of models and specific tools to check or allocate safety levels and budgets.
- SMOF is a Safety Monitoring Framework that starts from the results of a HAZOP-UML analysis to derive the specification of a set of safety monitors that launch safety interventions. SMOF relies on a high-level formalization of the target properties and of the available interventions (e.g., lock the robot wheels). It provides tool support for synthesis of strategies that trigger the interventions when needed, while minimizing impact on the functional activity of the system. https://www.laas.fr/projects/smof
- MORSE and MORSE-based test method. MORSE is a generic simulator for robotics based on the Blender Game Engine. MORSE may be used for prototyping purposes, or for carrying out principled test experiments. In the latter case, the MORSE-based test method provides a framework for generation of virtual worlds and missions, allowing robots to be tested in a variety of situations. https://www.openrobots.org/wiki/morse/

- MAUVE is a domain specific language and associated tools used to design robotics components. It enables generation of OROCOS components. It also enables static analysis of worst-case execution time of the module and model-checking of functional requirements. MAUVE has been already applied to OROCOS components embedded in ONERA robots. These components can be adapted to re-implement the case study in OROCOS if needed.
- GenoM is an open-source solution for implementing CPS. It is widely used in the robotics domain at LAAS and in other labs. The latest implementation (GenoM3) is template based, and provides an easy way to synthesize automatically any model, based on the specification of a particular module or a set of modules. The module specification is parsed by GenoM3 which can then use the specific template to produce the targeted formal model. For more information see https://git.openrobots.org/projects/genom3

2.1.2 Needs and barriers

We want more smart vehicles / robots. An obstacle is lack of trust in the use of such smart systems and easily available reliable solutions. A market with easy access to assurance methods and embedded technology is needed. We already have a strong eco-system for high integrity systems of big industries. The issue is to adapt this eco-system for other stakeholders that are not so big or familiar with dependability.

The French centre aims at making the dependability culture affordable for companies that are developing autonomous vehicles ranging from cars with advanced driver systems to ground mobile robots or unmanned aerial vehicles. This is a pre-requisite to prove that such vehicles can be operated safely and can be more widely deployed. Autonomous vehicles range from cars that integrate advanced driver systems (ADAS) to remotely piloted aircrafts fulfilling various missions (e.g. agriculture, rescue, surveillance). They often interact with a control station according to predefined procedures; they also have to deal with the environment uncertainties (e.g. because of human presence). One obstacle to their development for a wider application is the lack of guidance about the technologies and the design methods, which ensure that they can be operated with an acceptable level of risks. There is also a lack of safety culture (especially for robotics SME), and the experiments will provide an excellent means to train dependability newcomers and to help the formalisation of new needs. However, the deployment of the dependability and safety culture is slowed by several factors such as the versatility of the concepts of operation and the variety of applicable regulations and standards, the robustness of complex technologies or the cost of system validation.

In this context the centre will:

(1) Assist companies to clarify their dependability needs according to their concept of vehicles and operation;

(2) Provide a set of methods, tools and technologies to address efficiently dependability issues specifically raised by autonomous vehicles; and

(3) Teach companies the most appropriate safety practices.

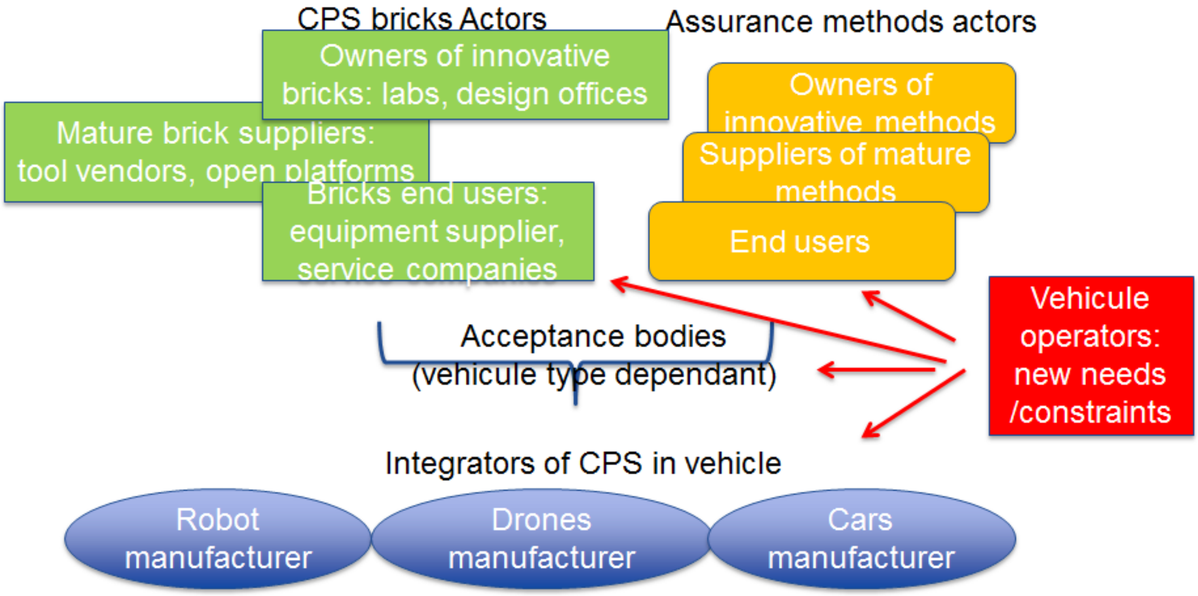
2.1.3 Strategic measures

The centre focusses on the following key strategic measure to reach its goals: strengthen use of formal methods and distributed artificial intelligence for safety critical robotic systems, i.e.

- Increase the Technology Readiness Level (TRL) of provided technologies of at least 1 point
- Plan technology transfer with relevant actors of the ecosystem
- Disseminate results at regional and European level:
    - One-day workshops targeting industrials of the ecosystem

- One-day workshops targeting academics (e.g., with a French research interest group on software engineering
- Workshop with proceedings as a satellite event of a dependability conference (e.g., Safecomp, EDCC, ERTS) or robotic conference (e.g., IROS, ICRA, ICAPS)
- Training: MSc and PhD levels, professional training (tutorials during conferences, or direct training of experiment partners, submission of courses to existing training structures like SEE or EUROSAE)

This measure can be decomposed/tuned according to the constituents of the value chain for autonomous vehicle or robots. This chain goes from the operators of the vehicles to the providers of technologies and tools used to build the system, without forgetting third parties like the accreditation bodies that assess the vehicle acceptability.



The French centre aims mainly at providing the actors of the chain with design and assessment methods that prevent the occurrence of system and software failures.

At the system level, such methods consist in assisting the specification of the relevant safety barriers and the assessment of the overall system architecture. For this level, CPSE Labs proposes to 1) adapt the aerospace methods, 2) mature methods specifically developed for autonomous vehicle and 3) train new comer to the dependability culture. To support these objectives, the centre will mainly carry out experiments to train end users and to mature the technology through its application to significant use cases.

At the software level, the focus is on the reliability of the key embedded technologies of autonomous vehicle. These key technologies encompass real time execution and communication platforms for cyber physical systems, navigation algorithm and decision making software used to ensure vehicle autonomy.

For this level, the centre proposes to provide 1) real time technologies based on formal models that prevent the occurrence or ease the removal of some design errors 2) decision making toolkit formerly validated 3) extensive test techniques for navigation modules. To support these objectives, the centre will not only carry out experiments to train end users and to mature its own technology through its application to significant use cases; it will also plan experiments to identify complementary sets of interesting technologies.

These activities planned in experiments will be coupled with complementary training and dissemination actions to reach the key centre objectives i.e. increase TRL of our own technologies, broadcast the dependability culture for autonomous vehicle and prepare technology transfers.

2.2 Design Centre Germany North

2.2.1 Field of competencies

OFFIS has a strong network of application partners from the automotive, aerospace, energy, production, and maritime domain including SMEs, large OEMs, end-users, research organisations, and universities with strong impact in the respective application sectors. OFFIS has broad vertical competencies for the development of standard compliant, certified embedded systems from CPS/SoS level down to component and chip level in the aerospace, automotive and maritime domain. This competence comprises among others:

- Development of mobile, intelligent and flexible systems: Design of safety-critical maritime systems of systems, co-simulation environments for safety analyses, development of system architectures as well as maritime test-beds and their architectures.
- Development of intuitively understandable and easy-to-use human-machine interfaces for assistance systems: Formal analysis of complex task sequences, modelling of human behaviour in traffic situations, Integration of driver, vehicle and assistance system models into a joint system simulation.
- Design methods, processes and tools for safety-critical systems: Methods for ensuring completeness, correctness, and consistency of requirements, supporting architectural views compliant to safety and security standards, formalization of operational, functional and technical requirements and formalization of hazards, attacks and failures.
- Analysis methods for efficient safety & security assessment of architectures and systems: Seamless model based safety and security analysis, quantification of perception uncertainties in cyber-physical systems, requirements analysis checking for consistency, correctness, and completeness, and early V&V of components and systems, and design space exploration.
- Architecture engineering and interoperability: Development of architectures and architecture frameworks for interoperable complex systems, enterprise application integration, domain specific models, and standardization of syntax and semantics

One of the challenges in the design and development of new maritime CPS technologies (e-Navigation and e-Maritime systems) is the test environment: these technologies are used in harsh environments (on sea), in which real world testing is not always possible and very costly. OFFIS is actively involved in the simulation- and test-platform eMIR (eMaritime Integrated Reference Platform). eMIR is an open initiative for improving safety and efficiency in maritime transportation systems:

- eMIR contains technology bricks such as a mobile bridge system, a mobile VTS system, mobile communication technology, sensors etc. that are used as building blocks to set up physical test environments for new systems
- eMIR provides a framework for engineering, validation, verification, and demonstration of technological innovations as for new cooperation and process models.
- eMIR supports user integration into the design process.
- eMIR provides practical and empirical foundation for the development of international regulations and standards.

- eMIR fosters a sustainable market position for vendors of maritime safety systems and components.

Providing a generic, open technology, communication and service platform, eMIR connects industry strengths in surveillance and control technology to a smart demonstration platform. Furthermore, it allows research for better understanding of maritime systems and offers a powerful virtual and physical testbed for system/component development, verification and validation. Polymorphic, adoptable interfaces guarantee a fast configuration of demonstration environments and testbeds. Furthermore, eMIR provides methods and tools to discuss, align, handle and design existing and upcoming systems, from architectural point of view but also from testing, validation and verification perspective. eMIR combines the following platforms:

- **LABSKAUS**: A physical platform for research in better understanding of maritime transportation systems and e-Navigation, a testbed for design, development and testing of new surveillance and assistance systems and a demonstration environment to present the power and capabilities of new products and services. It provides services accessible by eMIR polymorphic interface concepts: a reference waterway from the mouth of the river Elbe to the Port of Hamburg, an experimental VTS-System, a mobile bridge system, the Research Port Bremerhaven.
- **HAGGIS**: A modelling and open co-simulation platform to build virtual e-Navigation testbeds. Its purpose is rapid testing of new eMaritime technologies without the need to have equipment on high seas. To realize this for the whole diversity of eMaritime applications, HAGGIS consists of a number of modules that can be orchestrated for different applications. HAGGIS comes with a number of simulators: Maritime Traffic Simulation, Sensor Simulators, Environment Simulators, a cognitive human behaviour simulator.

2.2.2 Needs and barriers

Seafaring is and always was a joint undertaking between humans and their technology. Taking into account the impact of nature, such as wind, waves, etc. the dependability of technical equipment and its correct usage are essential for safe voyaging. This still holds true for the implementation of e-Navigation technology. “Safe and efficient voyage from berth to berth” is the goal of all e-Navigation strains, driven by new technologies, new infrastructures and new organizational structures on board, on shore as well as in the cloud. E-Navigation technology comes with numerous technical requirements. They are derived from aforementioned perspectives. For example communication channels reach, bandwidth, latency, integrity, reliability, safety, and security are a set of typical requirements. Maintainability and extensibility are also technical requirements from the development and maintenance perspective. To facilitate system development suitable engineering and safety/risk assessment methods are required. Understanding maritime transportation as a socio-technical system allows the usage of cyber-physical system engineering methods. Safety and security measures in the development phase of equipment is still based on old standards and regulations that are amended in an incremental way to cover new developments. However, no overarching structure of safety assessment including security measures, which would be necessary due to cooperative nature of e-Navigation, is available. Concepts like Safety Integrity Levels as defined in ISO 61508 are currently missing in the discussion on e-Navigation. The main overarching needs on supporting development of e-Navigation compliant CPS architectures are:

- Testing and demonstration of maritime CPS innovations using existing technology bricks
- Standardisation of architecture concepts and development processes
- Certification of new maritime systems, and
- Accelerated time-to-market for new maritime systems.

2.2.3 Strategic measures

To support CPS innovation across industry sectors the German Centre North derives incubation from the automotive, aerospace and energy sector into the maritime sector. The maritime sector is a new high-tech growth market. Coming from paper based navigation, in the last years the sector experiences growing electronic system integration of components and technologies from ship and shore side - enabling the development of innovative new products and services. To support companies in the development of a maritime CPS-architecture for integration of heterogeneous systems of the maritime transportation domain, the Design Centre North provides an infrastructure for rapid prototyping in simulation environments - co-simulated verification of safety and efficiency of systems for:

- Testing of concepts and software systems
- Optimization regarding factors like performance and risks of shipping lanes
- Analysis of the occurrence of rare events
- Error induction, e.g. sensors failures, and
- Model validation.

Testing in real environments - physical testbed for new approaches and technologies for

- Testing of concepts and software systems
- R&D
- Demonstration
- Scientific grounding

However, the maritime domain suffers from a huge amount of legacy systems. Lots of approaches, systems, architectures, stakeholders with their relationship to each other and rules and recommendations exist. Dealing with similar circumstances, other domains started to handle such a heterogeneous and fragmented technology landscape by developing and standardizing domain specific reference architecture models. In 2008, an initiative in the energy domain introduced the Smart Grid Architecture Model (SGAM). It includes appropriate methods, processes and tools in order to divide tasks and processes of CPS into manageable parts and describe complex system specifications and interactions between those systems in view of aspects such as common data models, common interfaces, normalization, interoperability and standardization. Following these fundamentals the Maritime Architecture Framework (MAF) is oriented towards the design principles of SGAM, provides a consistent terminology and takes into account IMO’s e-Navigation Strategy Implementation Plan and e-Navigation implementation process. The main objective of MAF is a stakeholder-oriented conceptual basis for existing and future services and (reference) architectures. MAF provides methods and tools to document, discuss, align, design and handle existing or future system architectures and architectural reference models within the maritime domain:

- Techniques for identification of existing standards as well as closure of gaps and loopholes in standards
- Framework to support interoperability, normalization and standardization of cyber-physical systems
- Tools for specification of use cases and systems
- Methodology to manage existing CPS architectures
- Techniques and tools supporting the development of new framework-compliant CPS architectures

The envisioned goal of MAF is to compare different maritime architectures and systems including related regulations to set them in context to each other in a consistent and harmonized way. This leads to the possibility of identifying gaps, overlaps and interoperability issues between different maritime concepts and technologies.

The main tasks of the centre will be 1) to align and drive the development of maritime CPS architectures – leveraging concept and technology transfer from the energy sector, 2) to adapt and deploy CPS engineering processes and analysis techniques to the maritime industry, and 3) to stimulate technology integration into eMIR along value chains. The MAF is a key enabling approach for the interoperability of cyber-physical systems as well as for the development of test environments for these systems. Therefore, eMIR as an environment for the development, integration testing and demonstration for e-Navigation systems must take into account and support the design aspects of the MAF.

2.3 Design Centre Germany South

2.3.1 Field of competencies

As a research and transfer institute for software-intensive systems, fortiss focusses on application-driven research for engineering open, cooperative and trustworthy CPS for the market-place. fortiss takes a holistic view of CPS and covers the complete value chain from business processes and business models by way of engineering methodology and integrated service, system, and architectures to engineering tools. In close collaboration with industrial partners, fortiss conducts R&D projects in various application domains such as automotive, robotics and automation, avionics, and business IT and cloud systems. As a CPSE Labs Design Centre fortiss provides expertise in a range of fields including model-based software and systems engineering, model-based synthesis, design space exploration, analysis and design of dependable systems, adaptive automation architectures, and software engineering for industrial automation. In the context of CPSE Labs fortiss builds on technical CPS platforms and engineering assets, with a specific focus on adaptive production systems ("Industrie 4.0") and virtual co-simulation of CPS.

With those focus topics, the following technologies and platforms are provided or supported by the design centre:

- **4DIAC** is an open-source solution for programmable logic controllers (PLCs) of the next generation. It implements the IEC 61499 standard and therefore enables the development and management of platform-independent, distributed control applications in industrial automation as well as their real-time capable execution on any platform.
- The **fortiss future factory (f++)** is an adaptable production model plant for demonstrating and validating Industrie 4.0 technologies. It is composed of standardized subsystems and a modular structure in hard- and software. Machine-to-machine communication is based on OPC UA, control systems are designed in 4DIAC and automatically deployed on the machines of the model plant. f++ automatically detects the machines and the plant topology including the possible material flow and schedules production operations accordingly. This allows responding to changing production requirements quickly, since plant subsystems can be rearranged easily.
- **OPC UA:** The Open Platform Communications Unified Architecture (OPC UA) is a platform independent service-oriented architecture and the interoperability standard for industrial automation. It provides the necessary specifications and protocols to exchange data between manufacturing execution systems (MES) and machines, as well as for horizontal communication between machines.

- **FMI**, the Functional Mock-up Interface, is a tool-independent standard to support both model exchange and co-simulation of dynamic models between various simulation tools. System simulation gains importance in different phases of product development and replaces real testing in order to develop products faster and to reduce development cost.

2.3.2 Needs and barriers

The field of production systems is becoming more interdisciplinary as IT is entering the scene. The Industrie 4.0 trend comes with a shift in the automation industry towards software solutions allowing for the establishment of adaptive production systems. Introducing such new technology is, however, challenging in a field that is generally very change-resistant. For instance, while IT technology evolves in cycles of 3 to 5 years, the lifetime of machines is very long, up to 30 years. Moreover, production industries have high requirements with respect to operation times of machines.

Currently existing Industrie 4.0 solutions are often vendor-specific, not interchangeable, and difficult to be integrated with each other. Consequently, the strong vendor lock-in in the domain and the limited interoperability constitute major barriers to broader adoption. Furthermore, the base technologies are not yet mature, and standards are still evolving.

The technologies used in industry target the support of mechanical and electrical engineers in the creation of automation systems. With the new requirements of seamless integration and communication of automation systems with the business IT and the support of adaptability new challenges arise. Existing technologies and approaches are not well suited for supporting these upcoming challenges. Therefore new approaches are necessary for the incorporation of automation systems with IT. The application of those approaches is hard for small and mid-sized enterprises (SMEs) with a strong background only in mechanical and electrical engineering.

Industrie 4.0 technology and corresponding standardization efforts are mainly driven by large companies in the field. For SMEs it is difficult to keep up with the new developments, as often they lack access to base technologies for adaptive production systems. SMEs need to be able to establish relevant knowledge in the technologies fields required for the creation of Industrie 4.0 capable applications. A key challenge is to incorporate SMEs into the Industrie 4.0 eco-system and enable them to use upcoming Industrie 4.0 technologies, such as OPC UA for machine-to-machine communication, IEC 61499 for flexible distributed control, or FMI for virtual co-simulation.

Hence, from a higher-level perspective, the main needs are

- To enable SMEs to participate in future value chains to build adaptive production systems;
- To validate emerging technologies and standards for adaptive production systems and to suggest necessary extensions;
- To provide the relevant knowledge for using the technologies in future products and services developments.

At a more technical level, we perceive obstacles when it comes to taking aspects of time into account in both standards OPC UA and FMI:

- Though OPC UA has been well embraced in industrial automation, the main applications are with respect to monitoring and visualization. It has been advocated that OPC UA allows one to elegantly describe machines with their capabilities in a structured manner. This eases the discovery process of other machines. Yet of great interest is to be able to not just browse existing capabilities within production systems, but also to (re)configure them. However, when it comes to real time (re)-configuration, OPC UA provides little help. Consequently, to avoid ad-hoc solutions, effort is needed in order to add real time features at the level at the standard itself.

- As for FMI, it has recently been drawn to attention that the standard as it is does not cover the case of composing discrete and continuous simulators. Most of existing tools offering support for FMI are composing only continuous simulators. However, especially in industrial automation where safety plays a crucial role, it is important to be able to simulate both the controllers and the dynamic behaviour of system components, such as sensors for instance.

2.3.3 Strategic measures

For SMEs to successfully master the challenges posed by Industrie 4.0, they need to be supported in evaluating, adopting, and evolving base Industrie 4.0 technologies in real-life environments and experiments. The results gained from these evaluations will also have to be analysed with respect to necessary extensions to the relevant standards. The Centre Germany South will provide technologies and expertise to support SMEs to execute such evaluation experiments that are tailored to their specific business needs to realize Industrie 4.0 capable applications.

The Centre Germany South will specifically perform experiments with SMEs on selected technologies like model-driven engineering methods, OPC UA, or virtual co-simulation, in order to support SMEs in the integration of such technologies into their development activities. Such projects are very important in the domain of industrial automation to raise acceptance for new technologies, and to be able to convince companies to adopt them within their business. SMEs will also receive guidance from the Centre on how to further improve their solution with respect to needs of Industrie 4.0. This may be helpful for the companies to update their future product roadmaps.

Furthermore, the centre will offer suitable trainings on the supported technologies to SMEs and other stakeholders. With respect to the more technical challenges, the Design Centre will run activities to

- Raise interest in collaboration with companies already investigating real-time extensions of OPC UA;
- Build the bridge between companies needing solutions for hybrid simulation and academia by promoting already existing academic results about new requirements for FMI;
- Organize seminars bringing together researchers and professionals to advocate existing good practice in the application of OPC UA, and to analyse the current weaknesses of FMI and possible solutions;
- Encourage collaboration among the centres themselves on common topics such as hybrid simulation.

2.4 Design Centre Spain

2.4.1 Field of competencies

The Spanish Design Centre will be physically located in the facilities of Universidad Politécnica de Madrid. The Centre will have hardware to implement the developments of CPSE Labs. This hardware includes sensors, such as those incorporated in buildings, and servers in virtual machines.

These machines will be used, among other purposes, to deploy SOFIA2. The Spanish Design Centre will have a stable development environment based on SOFIA2, allowing both the use of SOFIA2 as an interoperability platform for developments, and the evolution of the SOFIA2 technology to adapt to these technologies.

The Spanish partners have scheduled the technological implementation for the last quarter of 2015, when technical experts will work on-location for installation, deployment and/or training purposes. The specifics of technologies provided and supported by the Spanish Centre will be detailed after the publication of the second Open Call, as the Centre may adapt to accommodate particular hardware or software required for an experiment.

The Spanish Centre is expected to be used to deploy demonstrators for the experiments. As the Spanish Centre will be in an open, public ecosystem, the sheer movement of students and staff may be used to provide input to the experiments, depending on the situation.

2.4.2 Needs and barriers

The domain of Smart Cities is the focus of the Spanish Design Centre. Smart Cities' stakeholders are in a sense the Public Administrations, but always taking into account that these are only representatives of the citizens. The citizens, real stakeholders of the Smart Cities, have specific demands, including the ability to participate and act in the decisions taken in their city; a more efficient use of the resources to improve their supplies, the infrastructures, the public services (e.g. health, security, environmental aspects); and a quality environment along with a good social integration.

Several clear objectives go toward experimental research literally on top of existing infrastructure, some of which may be experimental themselves. Updates, extensions and new set-up will be required for this. The Smart City paradigm breaks the isolation of services to citizens, to provide a dynamic, transversal view of the city and an efficient decision-making and constant learning system. This is achieved by sharing the available information. Due to the market fragmentation leading to a number of legacy systems, Smart Cities are filled with heterogeneous platforms. Integrations of existing facilities is of foremost importance to get a reliable, diversified infrastructure. Advanced networking is clearly implied here. H2020 and other authorities have devoted effort in this sense. Scalability in platform integration, which is another barrier, is expected to lead to economies of scale.

Technological difficulties may arise in the implementation of experiments. To solve this, experts on that technology will be contacted to provide support and training if needed. Management issues will be solved following the procedures approved by the CPSE Labs project; the cooperation, high qualification and good working environment within the Spanish Consortium, however, suggests that a problem here is unlikely. Any risk general to all the Design Centres will be solved using the project-level measures, and considering what has been learned from other Centres. Already available specialized teams will deal with the hindrances related to dealing with Public Administration-related final users including, for instance, periodic government changes. Corrective actions can be taken within the project considering that the Spanish Design Centre has access to other CPSE Labs partners.

The opportunities in the Smart City domain overweight of course all those troubles, considering that the developments can reach whole populations.

2.4.3 Strategic measures

The innovation objectives are directed toward the Smart City domain, preferably in ecological experiments (e.g. related to flora and fauna, smart agriculture, etc.). Town halls are either the final users or very related with them, and SMEs are expected to participate in the experiments.

The experiments will have a well-defined business plan to create new business opportunities, employment and products. SOFIA2 technology, already in use in real scenarios, will evolve during the experiments, and the changes on it will be extended to other users of SOFIA2 even outside the project.

An important asset to contribute to progress beyond the state-of-the-art is the direct contact of specialized partners with the expertise in CPS and the support of other partners in a European innovation project, with specific goals and procedures aimed to the innovation.

Impact

Considering that the Spanish Design Centre is focused in technological developments within their domains, those developments are the basis of the impact both during the CPSE Labs project's lifespan and after that.

The choice of Smart City domain provides a first layer of impact where the developments are introduced in wide environments (cities, with their whole populations and visitors as potential users) within the development of CPSE Labs. After the end of the project, the developments become products that can be incorporated in other smart cities, reaching even more citizens as final users. In a third layer, the developments are not necessarily restricted to the use in smart cities, thus reaching more potential users. The developments are thus particularly widespread.

The experiment proposals are required to focus on the impact of the developments to generate employment and new business opportunities. Besides, the experiments will also include important stakeholders with the involvement of town halls.

Beyond the open calls, the CPSE Labs is building the Spanish Design Centre, which will outlive the project's completion to keep on with CPS-related developments in the relationship between the Spanish partners. Other developments made within the Design Centre, such as the evolution of technologies, will improve the quality of products already prevalent for several final users, thus allowing for a greater impact of the CPSE Labs' results.

2.5 Design Centre Sweden

2.5.1 Field of competencies

The following describes the competencies and technologies of the Swedish Design Centre. The highlighted topics are those which the centre intends to connect more closely to CPSE Labs, i.e. the list is not exhaustive.

1. Data and tool integration. The development of Cyber-Physicals Systems is inherently multidisciplinary and faces the challenge of coordinating among multiple experts, concepts, models and tools. The main direction proposed by KTH and partners is to provide explicit modelling and tool support for tailorable integration and architecting of federated engineering environments. KTH provides methodological expertise in this area and moreover develops an open source tool which, based on a model, generates required integration code for data integration. The integration approach is based on OSLC (Open Services for Life-Cycle Collaboration), an open standard (http://www.oasis-oslc.org/). For more information, see: http://wiki.eclipse.org/Lyo/AdaptorCodeGeneratorWorkshop
2. Model based engineering of CPS. While this theme is closely related to the previous one, we here refer specifically to model-based engineering of safety critical systems and also to MBSE languages. KTH provides competence in the following areas:
    a. Safety life-cycle management. KTH provides competence in both best practices and state-of-the-art techniques with regard to processes, standards, hazard analysis and safety assessment for functional and system safety, especially in (but not limited to) the automotive domain.
    b. Modelling languages for MBSE. KTH is one of the contributors to EAST-ADL (http://www.east-adl.info/). We are also evaluating the ARCADIA/CAPELLA MBSE approach from Thales (https://www.polarsys.org/capella/arcadia.html)
3. Platforms for autonomous systems and safety critical systems: As part of the Integrated Transport Research Lab (https://www.kth.se/en/itrl), KTH with partners are developing a number of platforms of interest in the context of CPSE Labs. The Research Concept Vehicle (RCV) (https://www.itrl.kth.se/projects/kth-rcv/kth-research-concept-vehicle-1.476469) is a modular x-by-wire car platform which is currently being made autonomous. Value chain completion is in particular focus in the context of CPSE Labs, specifically w.r.t. software, electronics and tool support platforms.

2.5.2 Needs and barriers

As general challenges we would like to point to findings from the CyPhERS project (www.cyphers.eu) encompassing Scientific, Technological, Economic, Education, Legal and societal challenges. Many of these challenges have to do with "integration" and the bridging of gaps between technologies, domains, and disciplines.

Challenges specific to the targeted experiments and competence areas are elaborated in the following:

- Data and tool integration in the context of CPS development and engineering.
    - Challenges: In general, there is lack of a methodology to support cost-efficient integration and maintenance. The root causes are due to the complexity of the problem stemming among other things from heterogeneity of scenarios and users, dependencies among integration aspects (data, control, presentation etc.), and interoperability facets (from technology to semantics). Interoperability moreover faces lock-in and legacy problems. The problems faced are similar across multiple CPS industrial domains (for example regarding efficient model and information management, and with respect to traceability and impact analysis).
    - Offering: The design centre is pursuing the development of methodologies, open standards, and communities to deal with these challenges. CPSE Labs contributes to this through the experiments and through the marketplaces effort. A standards based and open-innovation approach makes it easier for new entrants (such as SMEs) to contribute solutions.
- Open platforms for safety critical systems and autonomous vehicles.
    - Challenges: The development of safety-critical CPS in areas such as self-driving vehicles and wearable medical devices requires mature, highly reliable platforms (hardware, software, and communication stacks). Traditionally, the platforms used for such purposes are more conservative in nature, and lag the state of the art when it comes to both performance and incorporating rapidly evolving research results. Simultaneously, researchers in these areas often use specific prototyping platforms to demonstrate "proof-of-concept" results. This necessitates a longer transition phase between research results and commercial, "certifiable" products (the current practices in the automotive industry provide an example of this). The long turn-around time from model-based design to embedded systems verification provides an obstacle to innovation and potentially provides competitive advantages for those companies that will be able to significantly reduce the time to market while guaranteeing trustworthiness of their autonomous systems. There is therefore a need to create high maturity, reliable, certifiable platforms for safety-critical CPS that conform to existing industrial best practices, while leaving room for experimentation and improvement in accordance with latest theoretical research results in systems architecting, design methodology, and modelling tools.
    - Offering: The specific emphasis by the design centre is to develop an open platform for safety-critical CPS that contributes towards an end-to-end design flow for such systems. CPSE Labs experiments will be used for this purpose by making sure the missing technological bricks are made available ("value-chain completion"). The KTH research concept vehicle provides a basic platform for proof of concept realization and evaluation.
- Safety life-cycle management.
    - Challenges: Current best practices rely on identifying all relevant risks during design time and ensuring, through extra effort during development and/or installation of

extra safety mechanisms, that these risks are unlikely (enough) to lead to accidents. Such "Predetermined Risk Assessment Strategies" (PRAS) are likely to be insufficient (e.g. in terms of inefficiency and risks) for the highly dynamic systems that many emerging Systems of Systems (SoS) belong to (an example would e.g. be the currently emerging collaborative transportation systems with a mix of autonomously and manually driven vehicles).

  - Safety engineering favours conservative approaches to engineering, which according to theory should result in a reduced amount of radical innovation. However, this is not evident when one studies the high-end engineering companies that deliver complex CPS products with high requirements on safety, cost, etc. Unfortunately, the mechanisms that allow these companies to combine successful high-end engineering with radical innovation are largely unknown.
  - Current safety standards heavily impact the costs of those that implement them. However, whether these costs actually lead to gains, or if it is rather the organisational factors related to accepting the deployment of these standards that are beneficial, is largely unknown.

- Offering: Various ways of approaching these challenges are being proposed by researchers in a variety of different research field. KTH (Mechatronics) has a multidisciplinary approach that brings together research into CPS, systems engineering, mechatronics and embedded systems, safety engineering, organizations and innovation from both within and outside KTH. Through this approach KTH (Mechatronics) is in a unique position to leverage on these proposals (e.g. STAMP, dynamics safety cases, belief theory, etc.) and cross-fertilize different domains.

2.5.3 Strategic measures

The CyPhERS project developed recommendations for action to deal with CPS challenges and opportunities. The recommendations address general and overall barriers for CPS that were found to be common across multiple application domains. The recommendations include advice to (1) Strengthen cross-disciplinary research collaboration, (2) Foster CPS education and training, (3) Stimulate public-private partnerships for CPS technology experimentation and to ensure dependable ICT infrastructure, (4) Promote interoperability of CPS technology, (5) Anticipate new business models and supporting open innovation, (6) Ensure trustworthiness including safety and security, and (7) Favouring human centred approaches to CPS.

The specific needs and barriers highlighted by CPSE Labs Sweden refer in particular to recommendations (4) – Interoperability for data integration, (3) – value chain completion for safety critical CPS platforms, and (6) – trustworthiness w.r.t. safety engineering methodology. On a more general level, the networking and catalyst activities of the centre address recommendations (1), (2) and (5).

Concretely, CPSE Labs Sweden is, and will be, performing the following actions for the focused platforms and methodologies:

- Performing experiments for the purposes of value-chain completion and industrial validation
- Performing experiments for purposes of domain cross-fertilization (we are e.g. interested in evaluating safety engineering approaches from the aerospace domain and to see if they can be transferred to other domains such as road transport systems)
- Developing case studies and examples
- Carrying out training through tutorials and professional training

- Providing access to on-line information
- Strengthening the centre competence network to stimulate cross-domain exchange of best practices, with the goal towards community and eco-system development
- Investigating suitable marketplace forums, in particular for data integration (which may serve as a role model for other areas later on)

Concrete actions undertaken by the KTH design centre so far are as follows:

- Training and education: During the fall 2015, KTH provides a tutorial on OSLC based data integration as well as a course on Safety to Swedish industry. KTH is also part of organizing a number of interoperability related European events.
- Community building and exchange of best practices: KTH conducts a number of workshops related to marketplaces for data integration, business opportunities for autonomous driving, and architecture and safety for autonomous systems (fall 2015, spring 2016)
- Investigation of best practices and stakeholder needs for marketplaces.
- Conducting and initiating experiments in the targeted areas (see first subsection).

The expected contribution to CPSE Labs KPIs are described in Sect. 4. In general these KPI contributions serve to

- Extend the network/eco-system
- Enhance activities and exchange levels referring to collaboration, coordination, co-creation and industry-academia exchange
- Stimulate innovation and creating value through technology platforms and technology maturation.

CPSE Labs is suitable for these measures because it provides a broad, holistic view on CPS engineering, thereby helping to integrate dispersed efforts regionally and across Europe. CPSE Labs also addresses technology maturation as well as many of the above mentioned areas, pointed out as important for strengthening innovation.

2.6 Design Centre UK

2.6.1 Field of competencies

The competencies of the UK Design Centre (University of Newcastle) include:

- Expertise in model-based engineering of systems of systems, contractual approaches to system interface modelling, and the formal verification of emerging system behaviour
- Co-modelling, collaborative modelling and co-simulation for embedded systems, particularly using formal approaches to facilitate collaborative use of modelling tools based on discrete event and continuous-time formalisms.
- Industry application of formal techniques (notably model-based formalisms including Event-B and VDM).
- Empirical studies of software engineering, using real-world data from case studies to suggest improvements to best practice.
- Background in dependability and fault tolerance including at architectural level in SoSs with independent constituents

- Digitally enabled urban sustainability, with cross-disciplinary integrated research into improved sustainability for future cities, particularly in the fields of: big data and cloud computing; digital civics; transport and mobility; smart buildings and smart cities; smart grids

Newcastle offers several platforms supporting system analysis and modelling; this includes tools and also associated guidelines and methods to support their use.

- Overture – an open-source tool for modelling in the formal method VDM (Vienna Development Method)
- Crescendo – an open-source co-simulation engine that supports collaborative simulations including models created in Overture and models created in Controllab 20-sim (together with methods designed to support design space exploration activities and collaborative cross-disciplinary modelling in dependable embedded systems)
- Symphony – a tool suite supporting models of systems of systems (SoSs) including guidelines and profiles for modelling in SysML, and tools and guidelines for translating these into a new notation CML, for formal analysis using a variety of proof obligation and model-checking analysis tools.

2.6.2 Needs and barriers

The UK Centre's expertise lies in formal modelling for software, particularly when deployed on cross-disciplinary projects such as embedded systems or systems of systems. Tools allowing designers to create models in different formalisms to work collaboratively on the design of a CPS can be useful for innovation goals. Allowing models of computational and physical elements of the system to be integrated at an early stage of development helps designers identify misunderstandings between the teams at an early stage, and can aid implementation and testing of highly complex behaviours, such as fault tolerance that requires input from both models. Experience on the DESTECS project suggested that incorporating aspects of formal software modelling can speed up the design process by allowing design teams to explore a variety of designs in a cost-effective way, receiving feedback quickly and testing implementations designed to deliver complex fault tolerant functionality at an early stage.

Collaborative modelling can be employed to refine complex behaviours that require co-operation between the cyber and physical aspects of a system as well as analysing and checking the correct require function of complex algorithms that straddle the hardware / software divide.

Key Barriers for CPS Innovators for the Modelling Standpoint

1. A lack of integrated, industry strength tool support. In order for collaborative modelling techniques to be widely adopted, there is a need for industrial tools that are intuitive, that integrate seamlessly with existing processes and tools, and which support current best practice such as traceability. There are challenges in developing tools to cross notations and disciplinary concepts effectively, although there are a number of large, long-term projects currently examining ways to aid this.
2. There is little in the way of recommended best practice or of guidelines to support the integration of software modelling techniques into a systems approach. Therefore it is difficult for practitioners to adapt to collaborative modelling since all lessons must be learned from scratch.
3. The potential ROI of formal software modelling is not particularly well understood, especially for non safety-critical systems. The perception is that formal modelling is expensive. There is little in the way of readily accessible case study or benchmarking information to show how collaborative modelling approaches that employ formal analysis and reasoning techniques can be beneficial in design space exploration or can results in a reduced time to market. As a result,

many teams are reluctant to experiment with the possibility of incorporating a formal modelling technique.

4. Formal modelling techniques are assumed to be difficult. Training is required to fully exploit formal modelling. There is a need for increasingly accessible formal methods to allow engineers from a wide variety of disciplines to interact with models, and a wider range of case studies that have demonstrated how to integrate formal modelling process into an overall design activity or systems approach.
5. Terminology, concepts, processes and training are different in the various disciplines. Due to CPS's inherent cross-disciplinary nature, CPSE projects have a high probability of misunderstandings between design teams. Concepts and notations used by each discipline vary and might be difficult to access without the benefit of specialist training. Concepts bases are beginning to be available, but there is a need to extend these via experiences in demonstrator and pilot projects, and should be disseminated to improve awareness.
6. Lack of marketplace and large-scale dissemination channels to reach SMEs involved in developing CPS products and services. Delivering information about CPS design tools to the SMEs which could benefit from them is difficult. Communication channels for reaching SMEs are disparate and diffused. This is a particular problem in CPS engineering, which spans a wide range of disciplines and application domains. Conferences and workshops organised by industry associations (e.g., ARTEMIS, INCOSE) or by academics tend not to attract large numbers of SMEs.

2.6.3 Strategic measures

To mitigate the key barriers for CPS innovators described above the following strategic measures can be taken:

1. Lack of Integrated Professional Quality Tool Support

Extend existing support in (some of the following ways)

- Improve the reliability of existing tools for collaborative modelling (Crescendo, Symphony etc.)
- Improve the usability and intuitiveness of the user interface of collaborative modelling tools, based on user input where possible.
- Test existing interoperability with third party tools, improving reliability where necessary.
- Identify third party tools that are candidates for interoperability with existing platforms.
- Identify potential problems caused by existing interoperability standards on demonstrator or pilot projects.
- Extend existing collaborative modelling platforms to work with new third party tools and standards where possible.
- Extend existing platforms and notations with new features designed to support user needs, such as extending modelling notations to support analysis of stochastic events or real-time information.

CPSE Labs experiments create a mechanism for carrying out some of these activities. Feedback from experimenters involved with the pilots and demonstrators can be sought on possible improvements or problematic areas of future development.

2. Little in the way of recommended best practice or guidelines

To resolve this we should carry out pilot projects and demonstrators using real-world development projects where possible, including structured plans for capturing data about the process used, potential problems and potential benefits. Experiments are the primary mechanism for this. For each experiment which meets the criteria of a pilot project or potential demonstrator, steps should be taken to develop a plan for collecting information about the development progress through lifecycle stages and any problems or positive experiences encountered during the experiment's lifetime. This could involve at least some of the following data:

- Lifecycle process, including data input into and collected from the design process. This information will be helpful for understanding how a design process is embedded into a general development effort and what the outputs from the design process are used for
- Benchmarks or metrics to assess performance of a tool or platform and the contributions it is capable of making towards the design process (e.g. metrics and benchmarks can be collected to examine system performance or design team performance). This also requires a plan for when and how to gather such data. This type of information may be more relevant for some pilot projects than others.
- Interviews conducted with developers, modellers and designers after the conclusion of the experiment, to gather their thoughts and inputs into suitable recommendations for similar future projects.

This information, once gathered, can be used as a basis for developing guidelines and recommendations for future projects.

CPSE Labs training provision is a mechanism for disseminating best practice in terms of systems approach, lifecycle structuring and information sharing. In the long term, training materials and courses delivered on this topic can draw upon an increasing evidence base composed of pilots and experiments.

3. Potential ROI of formal software modelling is not widely understood

See actions outlined above. Collecting information about the development process and developer impressions of the tools will be useful in building an evidence-led picture of how collaborative modelling techniques can improve (or degrade) ROI. Experiments acting as demonstrators or pilot projects will be the primary mechanism for collecting this information.

4. Formal modelling techniques are assumed to be difficult.

More work needs to be completed on making the formal methods (which underpin collaborative modelling) "accessible." This includes improvements to collaborative modelling tools, increased interoperability with other notations such as SysML or UML to improve a designer's ability to "visualise" how a system is analysed, and also improved understanding of how formal methods can be integrated into a systems approach.

Experiments will be a major mechanism for achieving these actions. Experiments which are intended as pilots or demonstrators will be subjected to information-gathering described above. In addition, the following actions should be considered:

- Interviews with designers / engineers after the conclusion of the experiment should include collecting their thoughts on how easy it was to integrate formal methods into their design activities and any problems they experienced. The goal is to collect user impressions on ways to improve the integration of collaborative modelling techniques into systems and processes.

5. Terminology, concepts, processes and training are different in different disciplines.

Publicly available "concepts bases" are needed and should be integrated into training courses and materials as well as CPS publications.

- Experiments are a mechanism for studying cross-domain misunderstandings. Interviews conducted after experiments have concluded can also prompt developers to suggest instances when terminology, assumptions or concepts between different domains or disciplines led to misunderstandings during their project. This information (if applicable) can be used to supplement existing concepts bases.

- The training provision of CPSE Labs is a mechanism for dissemination. Training materials and courses in the long term should include helpful pointers on common misconceptions and misunderstandings involved in collaborative modelling.

6. *Lack of marketplace and large-scale dissemination channels to reach SMEs.*

CPSE Labs can work to establish a broad-based marketplace for tools and techniques which is attractive to SMEs. Interactions with experimenters can be helpful for eliciting their ideas on how to reach SMEs.

3 Network-wide Strategies

Complementary to the centre-specific strategies describe in the previous section, this section outlines the measures that CPSE Labs undertakes to integrate these activities. CPSE Labs has, as detailed in the introduction, a wide variety of goals. While most of the Work Packages in CPSE Labs focus on specific aspects of these, Work Package 4 integrates and ensures that the most is made of the sum of them. To that effect WP4 has broken down the overall goals to (among others) more specific, intermediate ones:

1. accomplish effective interactions and synergies among the CPSE Labs centres themselves,
2. promote best practices in CPS engineering and provide professional training,
3. and provide appropriate innovation management for CPSE Labs including establishing marketplaces for selected CPS technology platforms.

These goals have in turn been broken down into concrete integration activities, which are detailed in CPSE Labs Deliverable D4.1. For the sake of clarity the following subsections relate the overall goals of CPSE Labs directly to the integration activities.

3.1 Fostering cross-centre activities and the development of CPS eco-systems

The overall goals of fostering an open, Pan-European network of design centres, defining experiments, spreading CPS engineering practices and promoting cross-regional and cross-sectorial learning has in WP4 been captured as the integration activities of

(a) establishing a learning network among the design centres to exchange best practices in creating innovation eco-systems;

(b) carrying out cross-centre opportunity scouting to identify innovation and other collaboration opportunities;

(c) establishing regional learning networks for exchange of best practices in CPS engineering; and

(d) identifying business opportunities and improvements in practices for CPS innovation management, e.g. by identifying existing best practices for managing networked and open innovation in this field.

None of these activities can be performed if the design centres and the eco-systems they move within are not understood. This understanding is required as much theoretically by expanding on the scientific literature on CPS eco-systems, as practically through a common agreement on what is most important by the representatives of each design centre. The first step towards completing these activities is therefore for each design centre to understand and communicate descriptions of their eco-systems, with one design centre gathering and summarizing this information. The second step is to complement the perspectives of the design centres by interviewing key individuals in the identified CPS-ecosystems, and reporting this back to the design centres.

For (a) and (c) this means a common agreement on what is of interest to exchange and what is required to facilitate this exchange, rather than establishing learning networks; for (b) this means a common agreement on what is of interest to act on, what the obstacles are towards this and how these obstacles are to be overcome. For (d) this means a theoretical understanding of who the key people/roles in this regard are, since this is currently unknown.

An immediate opportunity with respect to cross-centre collaboration – cf. goal (b) above – is to build on common areas in which the individual centres are active. As described in Section 2, the CPSE Labs Design Centres provide technologies and expertise in various CPS application domains, including automotive, industrial automation, Smart Cities and urban sustainability, autonomous systems, and maritime systems. The competencies provided by the centres in their focus domains are, however, complementary in the sense that they are relevant in multiple domains. For instance, dependability engineering methods are important for safety-critical systems in most, if not all, of the above mentioned domains; similarly, co-simulation techniques or model-based engineering methods are employed by various centres. Therefore, one of the goals of the CPSE Labs network is to identify the synergies that can be achieved by acting on shared interests. One element in this respect is to define topics for experiments that are supported by two or more Design Centres together.

The process up until this point is described in detail in the first version of D4.1. Subsequent iterations of D4.1 will describe how to go forward with establishing learning networks, and make good on identified opportunities.

3.2 Professional Training

The overall goal of promoting cross-regional and cross-sectorial learning is in WP4 also supported by a parallel activity to the one described in the previous subsection. This activity aims to consolidate the resources available to the design centres.

A first step towards this is to survey the relevant training already available from the CPSE Labs design centres. A natural second step is to contrast this with the relevant training available from external sources that the CPSE Labs design centres know of. Based on this information gaps in the professional training given by CPSE Labs can be identified. Through this analysis a relevant and achievable set of professional training courses can be established.

As with the activities in the previous subsection, subsequent iterations of D4.1 will describe how to go forward with this understanding and how to create a relevant learning network. Our initial idea is to start with, prioritize, the identified training that is given within the experiments supported through the open calls. This training will, as that most likely to be relevant, be the first to be expanded to a wider audience. The best ways to deliver training through CPSE Labs can thus be understood, evaluated and optimized. After this the sustainability of the learning network will be assured by focusing the activity on how to maintain training after CPSE Labs has ended.

4 Impact

In order to track the progress of the project, CPSE Labs has defined a set of key performance indicators (KPIs) to measure our impact, focusing on tangible successes towards innovation acceleration and product creation. The following table lists these measures and includes the individual Design Centre's target values for the three years of the project life-time.

Table: CPSE Labs key performance indicators and contributions by the Design Centres

ID	KPI	Total CPSE Labs Target	FRA	GER-N	GER-S	ESP	SWE	UK
A	# organizations involved in the regional learning networks	> 100	>20	>15	>15	>15	40	>25
B	# SMEs and mid-caps participating as third party experiment partners through cascading funding	20	>3	>4	5	3	>=1	5
C	# companies contributing to experiments or using results	> 40	>8	>6	10	6	>8	>5
D	# user-supplier experiments conducted by the consortia	18-20	6	1-2	5	3-6	3-4	5
E	# unique assets contributed to marketplace	> 20	4	3	3	>=3	5	>3
F	# validated business opportunities developed through experiments	10	1-2	1-2	3	3		1-2
G	# ratio of experiments successfully meeting the proposed innovation targets	> 80%, 0% complete failure	>80%	>80%	80%	>80%	>80%	>80%
H	# technology platforms from large-scale projects in experiments	5-7	1-2	1-2	1	2	2	1-2
I	# high-quality proposals received and evaluated in open call process	50	>8	6	12	20	>=5	17
J	# assets in marketplace	20		3	4	3	5	4
K	# stakeholders in database	500	80	50	50	>40	200	125

L	# evaluation and exploitation of large-scale EU and national projects for transferable CPS technology	30	5	5	5	5	5	5
M	# contributions to standardization	5		1	2	1	>=1	1
N	# creation of new as well as improved products and services	8	2	2	2	2		2
O	# incubation of business ideas as well as creation of start-up and spin-off companies	5		-	1	>=1	>=1	1
P	# scientific or market-oriented publications	Mean 1 per experiment	1/exp.	1/exp.	1/exp.	1/exp.	>=5	1/exp.
Q	# visits on the CPSE Labs website	15000 over a period of 6 months	n/a	n/a	n/a	n/a	n/a	n/a
R	# performed CPSE training sessions	1 per design centre	1	1	2	1	>=3	1
S	Mean # individuals participating in CPSE training sessions	5	10	10	15	10	15	10