Unifying Control and Verification of Cyber-Physical Systems (UnCoVerCPS)

WP6 Dissemination and Exploitation

D6.3 First Report on Dissemination and Exploitation

WP6	D 6.3 First Report on Dissemination and Exploitation
Authors	Axel Busboom, Matthias Althoff, Geoff Pegman, Matthias Wöhrle, Jens Oehlerking, Maria Prandini, Daniel Hess, Javier Sanchez Cubillo, Xavier Fornari, Alexander Walsch
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1. Introduction

This document is the first report on dissemination and exploitation of the Horizon 2020 project UnCoVerCPS (grant agreement number 643921). It covers the dissemination and exploitation strategy and activities during the first twelve months of the project (January – December 2015). Updated versions will be published in June 2017 and in in December 2018, i.e. upon conclusion of the project.

Dissemination mainly aims at publishing and spreading the scientific and technical achievements of the project in order to demonstrate the value of the project and to stimulate future research. Dissemination is achieved by means of publications in journals and on conferences, via workshops, lectures, seminars, etc. Target audiences of dissemination activities include academia, industry, government bodies and the general public. A key dissemination platform for UnCoVerCPS in 2015 was the Cyber-Physical Systems Week (CPSWeek) in Seattle in August. Numerous members of the consortium attended the conference, presented papers, and organized a workshop on Applied Verification for Continuous and Hybrid Systems (ARCH'15). The workshop included the presentations of tools, including tool evaluations, industrial experience reports, and proposals for new, industrially relevant benchmark problems. The presented benchmark problems will be adopted by the UnCoVerCPS project, going forward, to further improve its toolchain and to validate its tools and results against. The proceedings of the workshop have been published and are available at http://easychair.org/publications/volume/ARCH15 (Goran Frehse and Matthias Althoff [Eds.] ARCH14-15. 1st and 2nd International Workshop on Applied Verification for Continuous and Hybrid Systems, EasyChair, 2016, 34).

An important aspect of the dissemination activities in UnCoVerCPS is around open source software tools. Software tools for system synthesis and verification developed within the UnCoVerCPS project are made available under open source licenses so that third parties can apply these tools to their particular problems and/or contribute to further developments of the tools and methods. The consortium also hopes to receive feedback from users for further improvement of the tools and for future research directions. Key tools in UnCoVerCPS are SCADE Suite, commercially available from Esterel, CORA, developed at TUM, and SpaceEX from UJF. As part of the UnCoverCPS project, new versions of both tools have been released in 2015. Further, an effort has started for integration of tools into a consolidated tool for hybrid systems verification.

Exploitation includes all measures for creating commercial value from the project results such as to strengthen competitiveness and create and secure jobs in the domain of cyber-physical systems in Europe. Exploitation can include the development or improvement of products or services, the creation of new businesses or business units, protection and exploitation of intellectual property, or the improvement of processes in organizations in order to increase efficiency or quality. Based on the horizontal UnCoVerCPS approach, three of the four industrial partners in the UnCoVerCPS consortium (Bosch, GE, R.U. Robots) mainly pursue an exploitation route around the application of project results and tools to vertical applications in their respective industries (automotive, wind energy, avionics, human-robot interaction in food assembly), with the aim to enable more cost- and time-efficient design, development, and verification of safety-critical cyber-physical systems. In all four industries, different regulatory and legislative regimes are applicable with regards to systems safety. UnCoVerCPS also aims at addressing and/or influencing these regulatory regimes and ensuring that

systems developed with the UnCoVerCPS approach will ultimately be certifiable in the respective industries. The fourth industrial partner, Esterel, will mainly focus on deployment of horizontal tools for cyber-physical systems design and verification that are applicable across multiple industries and applications.

2. Dissemination and Exploitation Management

Dissemination and exploitation activities in UnCoVerCPS are bundled in work package WP6, led by Politecnico di Milano. The UnCoVerCPS consortium strongly believes that dissemination and exploitation is the joint responsibility of all consortium members. We have therefore widely distributed the tasks and responsibilities in such a way that most of the partners have a relevant responsibility for at least one task, deliverable, or milestone related to dissemination and exploitation. Obviously, multiple project partners contribute to each task, deliverable and milestone.

The responsibilities of the project partners are detailed in the table below:

Responsibility	Description	Owner	Month	Status
Task 6.1	Project website setup and maintenance	TU Munich	Continuous	
Task 6.2	Data and knowledge management	Tecnalia	Continuous	
Task 6.3	Workshop and summer schools	Politecnico di Milano	Continuous	
Task 6.4	Educational activities	TU Munich	Continuous	
Task 6.5	Exploitation	RU Robots	Continuous	
Deliverable 6.1	Website setup	TU Munich	3	Completed
Deliverable 6.2	First version of data management plan	TU Munich	6	Completed
Milestone 31	First version of internal exploitation plan	RU Robots	6	Completed
Deliverable 6.3	First dissemination and exploitation report	GE Global Research	12	Completed
Milestone 32	Presentation of results at a European event	GE Global Research	24	
Deliverable 6.4	Second dissemination and exploitation report	GE Global Research	30	
Deliverable 6.5	Final version of data management plan	TU Munich	48	
Deliverable 6.6	Final dissemination and exploitation report	GE Global Research	48	

3. Dissemination Report

3.1 Dissemination Plan

The objectives of the UnCoVerCPS dissemination activities are:

- to reach out to a large set of target groups via a broad spectrum of dissemination channels;
- to become an integral and visible part of the international cyber-physical systems research community;
- to provide academic services such as organizing workshops and special sessions at conferences;
- to implement structures that allow open-access to scientific results, software tools, and benchmarking examples;

A summary of the dissemination activities influenced or driven by UnCoVerCPS and their number are listed in the table below. More details can be found in the respective sections.

Activity	Number	References
Workshops	10	Section 3.4
Conference papers	25	Section 3.5
Journal articles	10	Section 3.6
Teaching activities	14	Section 3.8
Master theses supervised	6	Section 3.8
Bachelor theses supervised	3	Section 3.8

Key elements of dissemination include a project website which is continuously kept up to date, scientific publications, open source releases of software tools, and educational activities. The website is also used for information and document exchange within the consortium.

An important aspect of the UnCoVerCPS project is that it spans across multiple technical disciplines as illustrated in Figure 1 below.

It involves aspects from the area of cyber-physical systems and embedded systems, in particular cyber-physical systems with strict requirements in terms of safety. It also involves the broad discipline of systems theory, including system dynamics and stochastic systems, and the design and analysis of system controls. This discipline is sometimes also referred to as “cybernetics”. And finally it touches upon multiple application domains related to the four use cases considered in the project, namely power systems, automotive, power generation and robotics. In particular for the robotics and automotive use cases, an important aspect is the modelling of human capabilities and human behaviour as well as the interaction between humans and machine in safety-critical contexts.

This multi-disciplinary nature of the project is considered in the dissemination strategy of this project. We aim at reaching all relevant communities with our dissemination activities, including cyber-physical systems, controls, automotive and power systems.

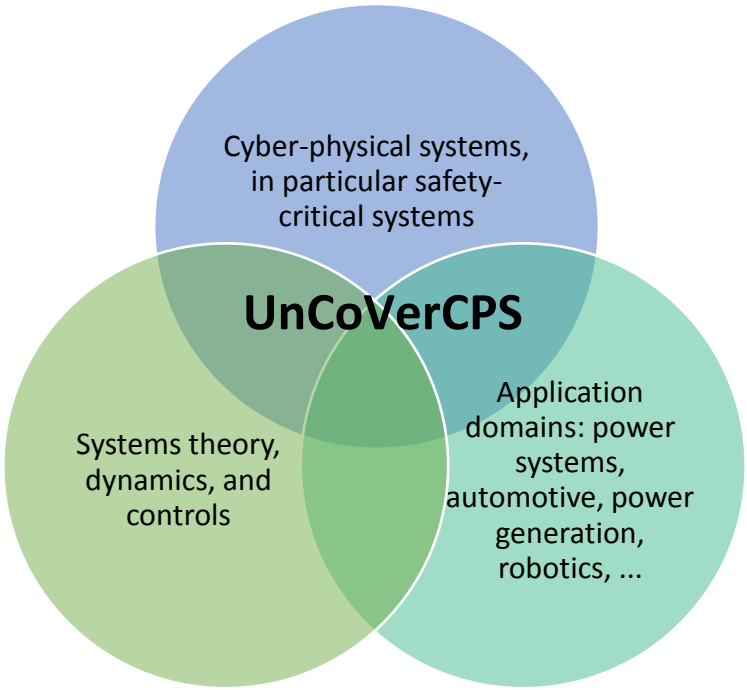

Figure 1: Multidisciplinary nature of the UnCoVerCPS project.

3.2 Project Website

The central platform of the UnCoVerCPS dissemination activities is the project website at http://cps-vo.org/group/UnCoVerCPS. It contains up-to-date information on the consortium members, publications, events, etc. as well as a platform for internal information and document sharing among the consortium members. Figure 2 below shows a screenshot of the homepage of the website. The website is continuously updated throughout the lifetime of the project.

3.3 Project Flyer

The UnCoVerCPS project has published a flyer as a double-sided A4 sheet with key program facts (Figure 3 below). The flyer can be downloaded via the project website (Dissemination). A total of 1,250 of high-quality printouts of the flyer have been produced and are being distributed by all of the consortium partners on conferences, workshops, etc. The flyer contains information on the technical mission of the project, the partners, the use cases and contact information. Its main goal is to raise interest in and awareness of the project, and direct interested parties to the project website for more details.

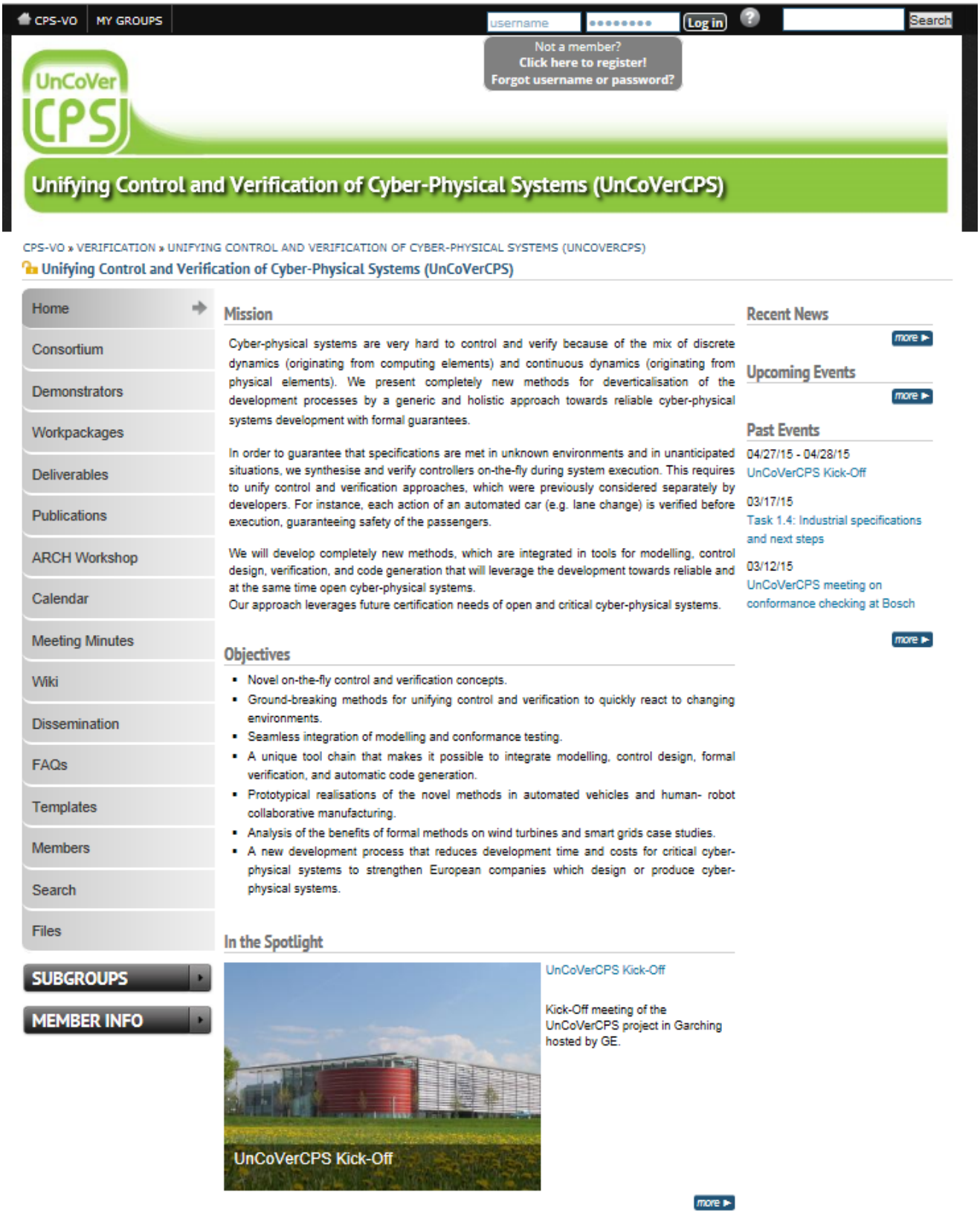

Figure 2: Screenshot of the homepage of the UnCoVerCPS website (http://cps-vo.org/group/UnCoVerCPS), captured on May 4, 2015.

MISSION STATEMENT

UnCoVerCPS provides methods for a faster and more efficient development process of safety- or operation-critical cyber-physical systems in (partially) unknown environments.

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 de-verticalisation 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. Our approach leverages future certification needs of open and critical cyber-physical systems.

CONSORTIUM

Technische Universität München (TUM) - *Coordinator*
Germany

Université Joseph Fourier Grenoble 1 (UJF)
France

Universität Kassel (UKS)
Germany

Politecnico di Milano (PoliMi)
Italy

GE Global Research Europe
Germany

Robert Bosch GmbH
Germany

Esterel Technologies
France

Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Germany

Tecnalia
Spain

R.U.Robots Limited
United Kingdom

UnCoVer CPS

Unifying Control and Verification of Cyber-Physical Systems
UnCoVerCPS

More information about the project is available online.
Please visit **http://cps-vo.org/group/UnCoVerCPS**

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HORIZON 2020

OBJECTIVES

- 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.

 Version 1.5

DEMONSTRATORS

Automated Vehicles

Wind Turbines

Human-Robot Collaboration

Smart Grids

Figure 3: UnCoVerCPS flyer.

3.4 Workshops

Matthias Althoff (TUM) and Goran Frehse (UJF) have organized a workshop on Applied Verification for Continuous and Hybrid Systems ("ARCH") as part of CPSWeek 2015 in Seattle, WA, from April 13-16, 2015 (http://cps-vo.org/group/ARCH). A total of 12 contributions were presented on benchmarks, tools, and experience reports. Many consortium members attended CPS week and this particular workshop. Bosch sponsored the best tool result award at ARCH. The awarded contribution by Chuchu Fan, Parasara Sridhar Duggirala, Sayan Mitra, and Mahesh Viswanathan presented significant "Progress on Powertrain Verification Challenge with C2E2". Due to its great success and a very positive reception in the community, ARCH will take place at the next CPS week 2016, again with a sponsored prize for the most promising tool result.

CPSWeek (Cyber-Physical Systems Week) is the leading annual international conference for cyber-physical systems, under technical sponsorship of IEEE, ACM (Association for Computing Machinery) and others. Under one umbrella, it brings together multiple conference, workshops and tutorials on different aspects of cyber-physical systems research, including embedded systems, hybrid systems, real-time systems, and sensor networks.

Several consortium members attended the SafeTRANS Industrial Day in Renningen, Germany, on May 20, 2015. The topic of the workshop was "Modelling of Context and Environment for Verification and Testing of Highly Autonomous Systems". SafeTRANS ("Safety in Transportation Systems") is a German competence cluster combining research and development expertise in the area of complex embedded systems in transportation systems. It drives research in human centred design, in system and software development methods for embedded systems, as well as in safety analysis – for avionics and rail – and its integration in certification processes.

Several consortium members attended the ARTEMIS Co-Summit in Berlin, Germany, on March 11-12, 2015 (https://artemis-ia.eu/co-summit-2015/index.html) and represented the UnCoVerCPS project with an exhibition booth. ARTEMIS is a European industry association in embedded and cyber-physical systems. The over 180 members include industry, SMEs, universities and research institutes. ARTEMIS is responsible for the Strategic Research Agenda (SRA) on embedded and cyber-physical systems.

Matthias Althoff participated in a podium discussion on the International Scientific Conference on Mobility and Transport (mobil.TUM 2015) in Munich, Germany, from June 30 – July 1, 2015. The title of the podium was "Cyber physical transport systems – ITS on the move towards the Internet-of-Things".

Matthias Althoff also gave two presentations at the BMW workshop "We live innovations – dialogue Munich" which was held in Munich, Germany, from July 13-15, 2015:

- Provably correct collision avoidance systems
- Formalisation of traffic rules for defending against liability claims in automated driving

Olaf Stursberg gave an invited talk entitled "On optimization-based control of switched uncertain systems" at the MOBOCON Symposium Optimization and Control of Uncertain Systems in Dortmund, Germany, from September 15-16, 2015.

UnCoVerCPS consortium members also gave a presentation at the ARTEMIS Technology Conference 2015 in Turin, Italy, on October 6-7, 2015 (https://artemis-ia.eu/calendar/402-artemis%20technology%20conference%202015.html).

Matthias Althoff further held two invited talks on workshops at the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2015) which was held in Hamburg, Germany, from September 28 to October 2, 2015:

- "Determining the nonexistence of evasive trajectories for collision avoidance systems," part of the 7th Workshop on Planning, Perception and Navigation for Intelligent Vehicles.
- "Safety Control of Robots," part of the workshop Robotic Co-workers: Methods, Challenges and Industrial Test Cases.

Maria Prandini was a co-organizer and lecturer at the invited session "New developments in stochastic systems, control and their applications" at the 54th IEEE Conference on Decision and Control (CDC) in Osaka, Japan, from December 15-18, 2015.

3.5 Conference Papers

Several conference papers have already been published in the context of the UnCoVerCPS project. A pivotal conference for the consortium was the CPSWeek 2015 in Seattle, where the UnCoVerCPS consortium also organized a dedicated workshop. The papers published and submitted by UnCoVerCPS to date are listed in Appendix A.

3.6 Journal Articles

Two journal articles resulting from the UnCoVerCPS project have been accepted for publication: In addition, a number of journal articles have been submitted or prepared for submission. The journal articles published and submitted by UnCoVerCPS to date are listed in Appendix B.

3.7 Upcoming Conferences and Journals Considered for Paper Submissions

Below we provide a – not necessarily exhaustive – list of upcoming conferences and journals that we will consider for paper submission:

- 19th International Conference on Hybrid Systems: Computation and Control (HSCC 2016), April 12-14, 2016, Vienna, Austria. Submission deadline: October 2015.

- 14th International Workshop on Discrete Event Systems, May 30 – June 1, 2016, Xi'an, China. Submission deadline: January 8, 2016.

- 2016 European Control Conference (ECC 2016), June 29 – July 1, 2016, Aalborg, Denmark. Submission deadline: October 20, 2015.

- 2016 American Control Conference (ACC 2016), July 6-8, Boston, MA, USA. Submission deadline: September 27, 2015.

- 55th IEEE Conference on Decision and Control (CDC 2016), December 12-14, 2016, Las Vegas, USA. Submission deadline: March 15, 2016.

- IEEE Transactions on Vehicular Technology (fall 2015), Daniel Hess, Xavier Fornari, Bastian Schürmann, Matthias Althoff.

- IEEE Transactions on Automatic Control (late 2015 / early 2016), Matthias Althoff.

- IFAC Journal "Nonlinear Analysis: Hybrid Systems" (fall / winter 2015), Olaf Stursberg.

- Formal Methods in System Design (Springer), Goran Frehse.

3.8 Teaching Activities

Consortium members have created new teaching material and taught a number of related courses in 2015:

- Goran Frehse: French Summer School MACS, organized by GT MOSAR and SDH, Bourge, France, June 16-17, 2015 (http://jdjnmacs2015.sciencesconf.org/resource/page/id/3).

- Goran Frehse: SyDe Summer School on Modelling and Verification of Cyber-Physical Systems, Bremen, Germany, September 9-11, 2015 (http://www.informatik.uni-bremen.de/syde/index.php?summerschool-21).

- Goran Frehse: AVACS Summer School, Oldenburg, Germany, September 30 – October 2, 2015 (http://www.avacs.org/autumn2015/).

- Matthias Althoff: TUM Summer Seminar on Cyber-Physical Systems, June 8, 2015 (http://www6.in.tum.de/Main/TeachingSs2015SeminarCyberPhysicalSystems).

- Matthias Althoff: Improvements made to regular TUM lecture on Cyber-Physical Systems (http://www6.in.tum.de/Main/TeachingSS2015CyberPhysicalSystems).

- Matthias Althoff: Seminar Cyber-Physical Systems, 17 participants (http://www6.in.tum.de/Main/TeachingWs2015SeminarCyberPhysicalSystems).

- Matthias Althoff: Lecture "Cyber-physical systems," to be held in Singapore in fall 2015.

- Olaf Stursberg: Course on "Discrete Event Systems and Control Theory", University of Kassel, summer semester 2015.

- Matthias Althoff: “Provably Safe Maneuvers of Automated Vehicles”, talk on Artemis Technology Conference, Turin, Italy, October 2015.

- Jens Oehlerking: Guest Lecture at TUM, “Specification models for cyber-physical systems in industrial practice,” Garching, Germany, July 14, 2015.

- Jens Oehlerking: Invited presentation at the final colloquium of the transregional research collaborative AVACS: “Specification models, testing and verification in industrial practice“, Oldenburg, Germany, October 02, 2015.

- Maria Prandini: PhD course on hybrid systems at Politecnico di Milano, June 15-19, 2015 (http://home.deib.polimi.it/prandini/hybrid-systems.htm).

- Maria Prandini: PhD course on hybrid systems at Lund University, October 5-8, 2015 (http://www.control.lth.se/Education/DoctorateProgram/hybrid-systems.html).

- Maria Prandini (lecturer): Mini-Symposium on “Stochastic Control: Computational Approaches to Large-Scale Problems,” in SIAM Conference on Control and its Applications, Paris, July 8-10, 2015.

- Maria Prandini (co-organizer and lecturer): Mini-Symposium on “Stochastic Systems and Applications,” in SIAM Conference on Control and its Applications, Paris, July 8-10, 2015.

One Ph.D. student at Bosch, Hendrik Röhm, is supervised by Matthias Althoff from TUM on topics related to UnCoVerCPS.

Several **Master’s theses** have been supervised in the context of the UnCoVerCPS project to date:

1. Petio Dimitrov: Distributed allocation of a shared energy storage system. Automation and Control Engineering, Politecnico di Milano, 2015. [WP2, WP5]
2. Caterina Brocchini: A chance-constrained approach to the quantized control of a heat ventilation and air conditioning system with prioritized constraints, Politecnico die Milano, 2015. [WP2, WP5]
3. Wuqiang Sun: Algorithms for the identification of the parameters of nonlinear vehicle-dynamic models, DLR, 2015. [Tasks 1.1, 1.3, 5.3]
4. Joao de Campos Salvado: Contingency planning for automated vehicles in urban traffic, DLR, 2015. [Task 5.3]
5. Friderike Meier: Adaptive control of linear systems with time-varying constraints. Control and System Theory, Universität Kassel, 2015.
6. Maximilian Müller: Cooperation of autonomous cars by auction-based control. Control and System Theory, Universität Kassel, 2015.
7. Zonglin Liu: Optimization of multi-agent Markov decision processes using game theory. Control and System Theory, Universität Kassel, 2015.

Several **Bachelor's theses** have been supervised by members of the consortium:

1. Ute Schiehlen: Formally correct vehicle prediction on road networks. Robotics and Embedded Systems, TUM, 2015.
2. Natalie Reppekus: Representation of reachable sets in human-robot interaction with a view to online safety control. Robotics and Embedded Systems, TUM, 2015.
3. Hannes Rewald: Auction-based mechanisms for intelligent control of autonomous cars. Control and System Theory, Universität Kassel, 2015.

3.9 Liaisons with other EU Projects

Consortium members have formed an informal liaison with INTO-CPS, a Horizon 2020 project (grant agreement number 644047) working on an integrated tool chain for model-based design of cyber-physical systems. Both projects are obviously highly synergistic, as UnCoVerCPS requires as a prerequisite the ability to do model based design of its systems, all the way from requirements to hardware and software implementations. On the other hand, UnCoVerCPS provides the tools and methods for controller synthesis and verification which, in return, will be required by INTO-CPS, in particular in the case of stochastic and/or hybrid systems.

UnCoVerCPS has also established an informal liaison with Smart-E, a Marie Curie ITN under FP7 (http://smart-e-mariecurie.eu/). Smart-E works on training for early stage researchers and experience researchers in the area of advanced robotics to ensure a sustainable manufacturing sector in Europe. The consortium involves a team of experts in a broad range of areas, including embodied intelligence, soft robotics, compliant robotics, smart materials, safety and human-machine interaction, autonomous systems, dexterous end effectors and statistics. TUM and R.U. Robots are members in Smart-E and will help ensure that UnCoVerCPS results will be applied in Smart-E for certified human-robot interaction. Smart-E researchers, on the other hand, will provide a modular robot for experiments within UnCoVerCPS for testing of on-the-fly control design and verification.

A third liaison has been established with the FP7 Support Action for Vehicle and Road Automation, VRA. VRS shares interests with UnCoVerCPS in the application area of vehicle automation and allows participants to share expertise and cooperate at a European and international level. It aims at maintaining an active European network of experts and stakeholders in the area of vehicle and road automation, contributing to EU-US-JPN international collaboration, identifying deployment needs for the different domains in vehicle and road automation, and at promoting European research through an innovative set of dissemination tools. UnCoVerCPS is represented in VRA and the associated discussion group iMobility Forum (iMF) via DLR. This allows us to directly contribute ideas and results developed in UnCoVerCPS, such as online verification for automated driving, to the discussion groups. An official affiliation of DLR with the VRA network is currently being finalized.

DLR has further participated in the standardisation meeting within the EU FP7 call 10 on June 30, 2015, which was dedicated to vehicle-to-vehicle (V2V) standardisation. Results of these discussions, as well as other projects such as AutoNet2030 and iGame, are considered with the UnCoVerCPS Task 5.3 (Automated Driving). The standardisation meeting also included standards for the use cases and testing methodologies which are relevant to UnCoVerCPS Task 6.5 (Exploitation). In addition, DLR has

presented the UnCoVerCPS project at the iMF Automation Working Group (AWG) meeting on July 1, 2015 at ERTICO Brussels and contributed ideas of UnCoVerCPS to an iMF AWG white paper.

3.10 Liaisons with industry organizations and competence clusters

ARTEMIS-IA is a non-profit association for the area of embedded and cyber-physical systems in Europe. It represents its members – industry, SME's, universities and research institutes – in the ECSEL Joint Undertaking. ARTEMIS-IA continuously promotes the research and innovation interests of its members to the European Commission and the public authorities of the participating states. It continues the work of the European Technology Platform ARTEMIS and is therefore responsible for the ARTEMIS Strategic Research Agenda (SRA) on Embedded and Cyber-Physical Systems which reflects the research and innovation needs in industry. The association aims at a coordinated, pan-European strategy. GE Global Research and Bosch are members.

GE Global Research is in the process of joining Safetrans while Bosch is a long-term member already. Further details regarding Safetrans are already described in section 3.4.

In addition, RUR has held a first meeting with the Health & Safety Laboratory (the research and solution development arm of the UK Health and Safety Executive) to discuss the project approach in relation to safety legislation trends as applied to human-robot interaction. It is intended to follow up this contact once the specific project approach is confirmed.

3.11 International academic exchange activities

The UnCoVerCPS project has also contributed to the attraction of several professors in cyber-physical systems for international exchange stays: Prof. Anca Muscholl from the Laboratoire Bordelais de Recherche en Informatique at Université Bordeaux received a three-year Hans Fischer Senior Fellowship from TUM. Prof. Marco Caccamo from the Department of Computer Science at University of Illinois at Urbana-Champaign received a three-month stipend at TUM as a TÜV Süd Foundation Visiting Professor.

An international collaboration was also initiated between TUM and the Robotics Institute at Carnegie Mellon University (CMU). As part of this collaboration, a TUM student, Robert Lösch, will write his Master thesis in collaboration with John M. Dolan, Principal System Scientist at CMU.

4. Exploitation Report

4.1 Exploitation Plan

UnCoVerCPS will enable faster time to market in the design of controls for safety-critical cyber-physical systems, and hence yield a significant competitive advantage over traditional approaches consisting of manual control algorithm design and verification by means of time-intensive and error-prone manual testing. As part of the project, four use cases are studied in detail (wind turbine controls, automated vehicles, smart grids, and human-robot collaboration); however, it should be obvious that the technology has a much wider range of potential applications in automotive, manufacturing, aerospace, construction, energy and many other industries. Figure 4 below shows the anticipated timeline for bringing the innovations developed in UnCoVerCPS to market. It visualized both the four vertical applications as well as the horizontal research on methodologies and application-agnostic tool chain development.

While the exploitation path of the industrial partners will either be geared towards one or more of the specific use cases (GE, Bosch, RUR) or on the development of world-class tools (Esterel); the academic partners pursue an open source strategy for academic exploitation and dissemination by means of granting open access to all tools developed under the UnCoVerCPS umbrella.

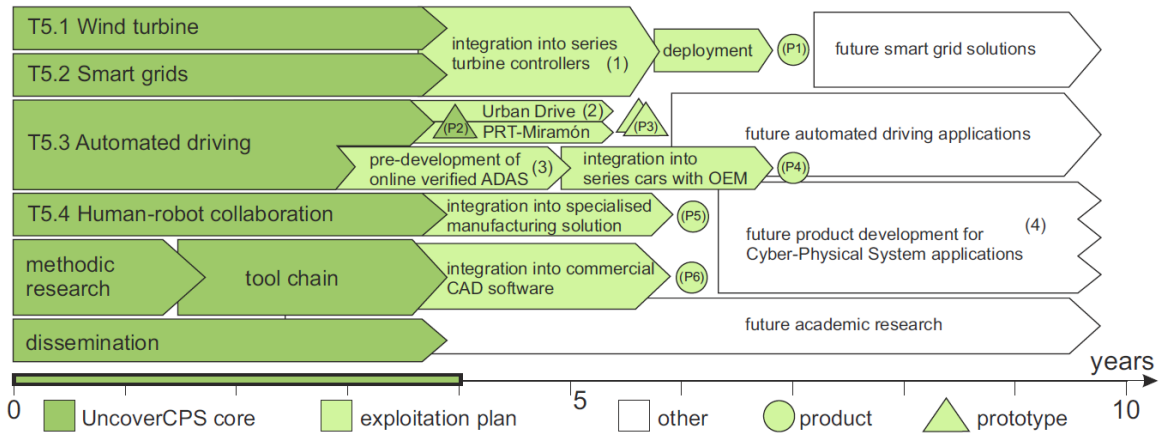

Figure 4: UnCoVerCPS exploitation timeline.

4.2 Bosch Exploitation Plans and Activities

Bosch Mobility Solutions is the largest Bosch Group business sector. In 2014, its sales came to 33.3 billion euros, or 68 percent of total group sales. This makes the Bosch Group one of the leading automotive suppliers. The Mobility Solutions business sector combines the group's expertise in three mobility domains - automation, electrification, and connectivity - and offers its customers integrated mobility solutions. Its main areas of activity are injection technology and powertrain peripherals for internal-combustion engines, diverse solutions for powertrain electrification, vehicle safety systems, driver-assistance and automated functions, technology for user-friendly infotainment as well as vehicle-to-vehicle and vehicle-to-infrastructure communication, repair-shop concepts, and technology

and services for the automotive aftermarket. Bosch is synonymous with important automotive innovations, such as electronic engine management, the ESP anti-skid system, and common-rail diesel technology.

Robert Bosch GmbH targets to leverage the UnCoverCPS tool chain to efficiently develop new technologies and services (i) with decreased development costs and (ii) with shorter development times to bring products and services faster to the market. Bosch's main interest for exploitation is the UnCoVerCPS tool chain for efficiently developing new and safe technologies and services.

Bosch Mobility Solutions has a total revenue for embedded control units of approximately €6bn; this translates to sales of about 150 million embedded control units per year. The development cost for these embedded control units can be estimated to about €1bn. We estimate that leveraging the UnCoVerCPS tool chain, we can save two development iterations for a software function; this corresponds to at least 30% of development cost. Assuming 5% of software functions are safety-critical and amenable to the UnCoVerCPS toolchain, we can save at least €15m. We have started to present the UnCoVerCPS toolchain to developers within the relevant Bosch business units.

The application domain of interest for Bosch is automated driving and in particular the aspect of verified safety of vehicle dynamics. Hence, we focus on the results from the application of the UnCoVerCPS toolchain to the automated driving use case in task 5.3. To this end, we discuss with the mobility business unit applications of UnCoVerCPS to internal pre-development projects in the context of automated driving. In the following, we discuss how such an internal pre-development project may progress along the activities in UnCoVerCPS.

The pre-development phase in Figure 4 (3) for an advanced driver assistance systems (ADAS) with safety guarantees will begin in parallel to our project. Assuming successful technology transfer from academic to industry partners, a pre-development phase of two to four years can be expected. Product and series development in cooperation with an original equipment manufacturer (OEM) will integrate the functions into a real vehicle, taking approximately another two years. The optimal outcome is to bring an advanced driver assistance system to the market as shown in Figure 4 (P4), which has greater flexibility and is better able to adapt to varying traffic situations due to on-the-fly verification.

4.3 GE Exploitation Plans and Activities

General Electric is a widely diversified industrial conglomerate with six globally operating industrial businesses: Power & Water, Oil & Gas, Energy Management, Aviation, Healthcare and Transportation. In all of these businesses, embedded controls and cyber-physical systems are playing an ever increasing role. GE has coined the terms "Industrial Internet" and "Brilliant Machines" to describe its belief that the combination of embedded intelligent controls, advanced sensing and cloud connectivity will be a disruptive trend across many industries that unlocks huge opportunities to increase efficiency, safety, performance, and reduce operational cost. The expectation is that industrial assets as diverse as jet engines, wind turbines, or locomotives will have increasing capabilities to:

1. Observe, i.e. sense and process sensor data into information
2. Orient, i.e. put the observed information into context
3. Decide, based on the information and context
4. Act, i.e. close the control loop

At the same time, many of the industrial assets that GE makes, maintains or operates, are highly safety-critical in nature. This is obviously true for avionics such as flight management systems or a FADEC controlling a jet engine, but it also holds for locomotives, wind turbines, medical imaging systems, power plants or subsea oil production systems where a failure or an incorrect decision of a cyber-physical system could cause severe damage to property, the environment or even human life. In most industries that GE operates in, regulatory and certification requirements are in place to ensure the appropriate level of safety.

In areas such as embedded software for avionics, the cost of validation and verification already accounts for 40-50% of overall software engineering cost. This number increases further as the complexity and autonomy of embedded controls advance. GE has put substantial effort into developing integrated tool chains for the validation and verification of embedded software systems all the way along the V-model, i.e. from high-level requirements engineering to system testing. These tool chains, however, are only applicable to pure software systems which can be modelled as discrete systems. They cannot be readily transferred to systems where the embedded controller interacts with a physical system whose dynamics are continuous or hybrid in nature.

As an example, consider a control software regulating the blade pitch and generator torque of a wind turbine, based on input variables such as rotor speed, generator power, etc. Requirements could be specified in terms of input-output-relationships, and the software could be verified against these. However, this would not provide any safety guarantees at a system level. In reality one would require for the combined system –consisting of the wind turbine with its continuous, nonlinear dynamics, and the controller with its hybrid, nonlinear dynamics – to not exceed any physical limits with respect to speed, mechanical loads, etc. Today this is achieved by manually tuning the turbine controls and running a large number of simulations. While the simulation scenarios are designed in such a way that they include “worst case” scenarios such as storms or grid loss events, there is obviously no formal guarantee that the combined, cyber-physical system can under no circumstances violate the physical limits. Therefore, safety margins need to be built into the controller to account for this possibility, potentially lowering turbine performance. GE expects that the UnCoVerCPS tool chain will ultimately allow the simultaneous design and verification of an optimal turbine controller with guaranteed safety and maximum performance. Similar arguments hold for a large number of other applications.

Exploitation within GE will initially focus on two areas:

1. Optimum wind turbine controller design and verification in collaboration with GE Wind Energy in Salzbergen, Germany (as described above). Efforts in 2015 have focused on requirements engineering and the system model. Going forward, the emerging UnCoVerCPS tool chain will be applied to these requirements and system models, and the results will be compared against the performance of today’s controllers as a baseline. Upon success, the results will be integrated into series turbine controllers.

2. Human factors in aviation, in collaboration with GE Aviation Systems in Cheltenham, UK. GE anticipates that some of the results from the use cases “verified automated driving” and “collaborative human-robot manufacturing” will be applicable to human factors engineering in aviation. As aircraft systems become increasingly more automated and autonomous, the role of the pilot has over time changed from an operator to a task manager. While this simplifies the work of the pilots and increases overall safety, new safety risks emerge with re-

gards to situational awareness. GE will evaluate how results from the two use cases mentioned above can be applied to human-centred design and human factors testing in aviation.

In the longer term, many more applications are conceivable within GE, such as smart grid controls or automation and robotics in healthcare.

4.4 R.U. Robots Exploitation Plans and Activities

R.U.Robots Limited (RUR) develops specialised solutions for human-robot collaborative manufacturing and plans to integrate on-the-fly verification methods developed in UnCoVerCPS into food assembly robots collaborating with human workers. The food industry is Europe's largest manufacturing sector. 99.1% of the food industry is made up of SMEs that generally have an extremely poor take up of automation. Food assembly, in particular, is very much a labour intensive task partly due to the uncertain nature of the products being handled, but mainly due to the requirements for ultraflexibility – in certain cases with entire product changes every 15 minutes. One aspect of ultraflexibility that arises is the need to mix people and robots on a single line (robots cannot do all tasks cost effectively) and then the need for operatives to work in close proximity to robots. Current guidelines for safety of robots at work prevents uncaged robots, except in special circumstances.

The UncoverCPS approach and toolset promises to provide a way to address this issue of safety under close, collaborative working between robots and people. In order to address the exploitation potential of these results RUR will undertake five distinct actions, namely:

1. Tracking and discussing standards and legislative issues.
2. An implementation-options study regarding the incorporation of the UnCoverCPS results in product options.
3. A market study of the potential exploitation routes.
4. Promotion of the UnCoVerCPS tool to the wider robotics community.
5. Final exploitation plan.

Tracking and discussing standards and legislative issues

In order to utilise the UnCoverCPS approach it is necessary that it is implemented in a way that is consistent with safety legislation and regulations. As an SME, RUR has very limited capability to effectively influence standards and legislation. That is why much of the activity will involve tracking current movements in standards and legislation and then assessing how the UnCoVerCPS approach can be made consistent with these. Currently there is much interest in collaborative working between people and robots and there is a current ISO Tech Committee (184) that is looking at safety standards for robots with capabilities beyond those of a standard industrial robot. There is currently a draft standard (ISO / TS15066) which specifically addresses collaborative working between humans and robots. RUR will investigate in which ways this standards work would permit or cause difficulties for the UnCoVerCPS approach in order to influence the way that we try and implement it within the project.

Second, RUR has opened dialogue with the UK Health & Safety laboratory which looks at future requirements for legislation and certification in order to investigate the trends in safety approaches that may be conducive to the use of UnCoverCPS technologies.

Third, RUR will try to influence others in the community (see "Promotion" below) and convince them of the benefits of the UnCoverCPS approach with a view to getting longer term influence on such things as standards.

An implementation-options study regarding the incorporation of the UnCoverCPS results in product options

The aim of the implementation-options study is to evaluate the ways that the UnCoVerCPS approach could be implemented and the effect that different approaches would have upon the necessary hardware and software systems that would need to be included within robots developed by RUR. It is unlikely that UnCoverCPS will be a simple add-on or wrapper but more likely that it will involve architectural changes to the system. One of the critical areas that will have a large difference is the type and number of sensors utilised and their need to themselves being safety certified. The primary output of this study will be a first order cost assessment of various approaches that can then be used in the market study to determine the cost options for the robot system.

A market study of the potential exploitation routes

Although food assembly is the primary target for RUR's GRAIL robot system, there is potential for it to also be exploited in other markets. One of the potential difficulties of the food assembly market is the extreme price sensitivity for capital purchases and the low rate of acceptance of new technologies. It may therefore be possible to implement the combination of GRAIL robot, with UnCoverCPS technologies in markets other than food assembly. This study will aim to identify those potential markets and to evaluate the price sensitivity and potential sales volumes for those markets. This work will feed the final exploitation plan work by RUR.

Promotion of the UnCoVerCPS tool to the wider robotics community

An important part of the exploitation work is the adoption of the UnCoverCPS approach by potential end users and other robot suppliers. The latter is because if RUR is the only supplier using the approach then it is unlikely to get widespread acceptance as a suitable safety approach within the robotics community.

Therefore RUR will firstly work with end user groups such as the UK Food Engineering and Manufacturing Group to hold seminars and contribute to workshops in order to raise the awareness of the food industry of the benefits of the UnCoVerCPS tool chain in allowing automation with the required flexibility to the industry. As well as raising awareness it would be intended to use these events to elicit feedback from the industry as to the potential uses such a system could perform.

In addition RUR will use its position as a well networked European robotics firm to inform the rest of the European robotics industry about the UnCoVerCPS approach and its potential benefits. This would be done in conjunction with organisations such as euRobotics aisbl, EUnited Robotics and the British Automation and Robotics Association. The aim would be to get a critical mass of interested companies that could firstly provide feedback on potential uses of the approach but also be able to exert any necessary influence over future standards work.

Exploitation Plan

The final work undertaken by RUR would be the production of an exploitation plan with respect to the use of the UnCoVerCPS approach within the robotics industry. This work, as well as informing RUR's own post-project exploitation activities, will feed directly into deliverable 6.5.3.

4.5 Esterel Exploitation Plans and Activities

Esterel Technologies, as a subsidiary of ANSYS, Inc, is in charge of the development of the virtual system paradigm with the goal to aggregate multi-physics simulation and embedded software controllers. Our solutions can be applied to various domains such as Aerospace & Defence (A&D), Automotive, Railway Transportation, Industry and Energy. System complexity is increasing, in particular in the cyber-physical systems class. This is particularly true in Automotive with Advanced Driver Assistance Systems (ADAS), but also in A&D systems requiring a high safety level and for which on-line failure prediction is key. Esterel Technologies expects to get a better understanding of the needs of real application cases from the UnCoVerCPS project. Leveraging these applications and the cooperation with research partners, the SCADE and Simplorer toolsets will be improved.

The automotive use case offers two opportunities. The first one is related to the development of the controller in charge of the trajectory selection. This project will allow determining how to integrate the model with its environment and to understand the interaction between the continuous and discrete part. A demonstrator will be issued at the end of project that will be used to gain interest from potential customers. A similar cooperation with DLR regarding HMI in simulators resulted in a presentation at the SCADE User Group Conference, and a reference for customers visits. The second one, although not directly related to cyber-physical systems, is vehicle-to-vehicle communication, which could be also a good example of the use of SCADE tools for protocols.

The wind turbine example will be used as an example of development of a hybrid model. As the model mixes state machines and continuous equations, it provides a demonstration example for the hybrid extensions of the SCADE and Simplorer tools and the related code generation.

The interoperability between the SCADE and Simplorer tools, SpaceEx and CORA can lead to the availability of a gateway module that could be used by academics partners or industrial customers interested in this topic. The research department of an automotive OEM has expressed interest in this work. Esterel Technologies would also utilize its academic program which could help jumpstart the diffusion of such results.

4.6 DLR Exploitation Plans and Activities

DLR plans to incorporate results and methods from UnCoVerCPS into ongoing research projects and future demonstrations such as Urban Drive which strives to realise fully automated passenger vehicles in urban areas by 2020. By reducing the risk of technical failure, safety verification is a key enabler for automated driving. DLR will integrate on-the-fly verification techniques developed in UnCoVerCPS into its Urban Drive roadmap. We have started this process by replacing the trajectory tracking controller of the automated vehicle by a controller developed in SCADE Suite. We will derive correctness properties for this controller using the CORA toolbox. A combinatorial search algorithm for con-

tingency manoeuvre planning has been developed which makes use of on-the-fly verification principles and builds on the correctness properties derived for the underlying SCADE Suite trajectory tracking controller. In addition to safeguarding the automated vehicle operation in UnCoVerCPS and in future projects, the newly developed control systems serve as demonstrators for the UnCoVerCPS paradigms, the application in the development process and as an example for the UnCoVerCPS toolchain.

4.7 Tecnalia Exploitation Plans and Activities

Exploitable result of UnCoVerCPS project: Tecnalia autonomous & collaborative vehicle demonstrator

In the framework of UnCoVerCPS project, Tecnalia, as Technological Research Center, will use the project results for further private and collaborative research activities. The most valuable result for Tecnalia is the autonomous vehicle demonstrator, which will be able to perform safe collaborative manoeuvres at the end of UnCoVerCPS project.

The exploitation activities to be developed involving the mentioned result are described in the following paragraphs.

Dissemination activities to promote UnCoVerCPS results in the automotive sector

Tecnalia is an active member of several European Automotive platforms, such as the European Green Vehicles Association (www.egvi.eu, EGVIA), where a specific 'Automated Driving Roadmap' has been launched in the frame of the European Road Transport Research Advisory Council (www.ertrac.org, ERTRAC) in July 2015, and it is being deployed.

UnCoVerCPS results will be spread in different events, such as the annual meeting of European Automotive Research Partners Association (www.earpa.eu, EARPA). These events are attended by the main stakeholders involved in the vehicle automation supply chain (OEMs, Tier1 & 2s, integrators and infrastructure agents). Thanks to them it will be possible to gain specific feedback about the use of UnCoVerCPS results and to review the project Exploitation Plan, taking into account the opinion of potential users present in these dissemination events.

Fostered research activities in Spain on Road Automation thanks to the new legislation in the frame of Automated Driving

In November 2015 a new instruction 15/V-113 was launched by the Spanish DGT (Dirección General de Tráfico), directly related to the Ministry of Internal Affairs of Spain. The denomination of this new instruction is *'Authorization trials or research studies with automated vehicles driving on roads open to general traffic'*. This very challenging approach accelerates the market take-up of Road Automation and opens a broad environment field for fostering Spanish research activities on Automated Driving, where Tecnalia's collaborative autonomous & collaborative vehicle demonstrator resulting from UnCoVerCPS project will be deployed. New business opportunities for Tecnalia are framed in research project activities such as the following ones:

- New private contracts for implementing UnCoVerCPS project results into different urban vehicle types developed by Spanish industrial companies, spin-offs and SMEs, such as MASER, LARRAIOZ, MONDRAGON AUTOMOCION and others.
- AIRPORTS *'Airport Improvement Research on Processes & Operations of Runway, TMA & Surface'.* Spanish Collaborative project where the vehicle demonstrator will be further developed for airport areas.

Use of Tecnalia autonomous & collaborative vehicle demonstrator after UnCoVerCPS project for further European research

Tecnalia will look for new business opportunities in the research and industrial community, spreading its development activities thanks to the use of the resulting autonomous vehicle of UnCoVerCPS into new collaborative projects in the frame of the ERTRAC 'Automated Driving Roadmap', in running and future projects such as the following ones:

- IOSENSE 'Flexible FE/BE Sensor Pilot Line for the Internet of Everything': Ecsel Innovation Project, starting at the end of 2015.
- MOB-ON-PARKS 'Mobility Plans Based on Integrated Staff Management for Technology Parks': European proposal in the frame of LIFE Program 2014-2020 for environment and climate action.
- New proposal to be launched in January 2016 within the H2020-ART-2016-2017 calls, specifically on *ART-04-2016. Safety and end-user acceptance aspects of road automation in the transition period.*

OEMs and Tier1s from the automotive sector specially focused on Road Automation will gain access to UnCoVerCPS results through these collaborative projects with Tecnalia.

4.8 Open Source Software Releases

Two of the central tools which are developed and improved within UnCoVerCPS are SpaceEx (http://spaceex.imag.fr) and CORA (http://www6.in.tum.de/Main/SoftwareCORA). New versions of both tools have been released throughout 2015.

SpaceEx and CORA apply different technologies to perform reachability analysis. Reachability and safety verification is particularly challenging for continuous and hybrid systems due to the complexity of representing and computing with continuous sets of states.

The development of SpaceEx was spawned by recent progress in finding efficient data structures and algorithms for reachability computation. Reach set approximations are efficiently computed for continuous linear dynamics with hundreds of variables. Its wrapping-free algorithm is particularly efficient when zonotypes or support functions are used as set representations. The underlying model in SpaceEx is a composition of hybrid automata, including extensions such as hierarchy and templates. The tool allows the development of heterogeneous analysis methods, such as using different set representations in different parts of the state space, or at different levels of refinement, or combining symbolic computation with simulation. The SpaceEx analysis tool is available as a virtual machine server that can be run locally in a protected environment, with a web-based frontend. It is also available as a command line tool for experienced users. In addition there is a Java-based model editor for the creation and modification of SpaceEx model files. All three components are released under the

GPLv3 license. SpaceEx is made available by Verimag, which is a research institution affiliated with the University Joseph Fourier in Grenoble. Multiple updates of the SpaceEx components have been released throughout 2015 with contributions from the UnCoVerCPS project.

The Continuous Reachability Analyser (CORA) is a collection of MATLAB classes for the formal verification of cyber-physical systems using reachability analysis. A less efficient algorithm is used based on abstracting the original dynamics to linear differential inclusions. The advantage of this algorithm is that it can also be applied to nonlinear differential equations and even to nonlinear differential-algebraic equations. This is particularly important for industrial applications, a vast majority of which involve nonlinear systems. CORA is designed in such a way that representations can be exchanged without the need to modify the code for reachability analysis. Since the toolbox is based on MATLAB, its installation and use is platform independent. A major new release ("CORA 2015") was published in 2015, with contributions from the UnCoVerCPS project.

As a major next step, UnCoVerCPS aims at the integration of CORA and SpaceEx. A student at TUM, Evgeny Agamirzov, is currently working on porting MATLAB based CORA algorithms to C++ such as to enable integration into SpaceEx. Once the integration into SpaceEx is finished algorithms will run without MATLAB and be published as open source. Evgeny Agamirzov will join DLR for his Master thesis, which will further contribute to spreading knowledge about CORA and SpaceEx across the UnCoVerCPS consortium.

4.9 IP Strategy

The generation and protection of Intellectual Property has not been a central element for the UnCoVerCPS project to date. This is due to the fact that the industrial partners will typically benefit from applying the developed tools and methods to faster design and verification of cyber-physical systems. This will give them a strong competitive advantage. However, the industrial partners will continuously revisit the IP strategies with regards to the respective use cases and file patent applications where appropriate.

5. Summary and Outlook

This report has described the dissemination and exploitation activities of the UnCoVerCPS project for the period of January to December 2015, as well as plans for the next years.

Core elements of dissemination in 2015 have been conference publications, in particular the ARCH'15 workshop as part of Cyber-Physical Systems Week in Seattle, the UnCoVerCPS web site and flyer, teaching activities and open source software releases. The ARCH'15 workshop has not only raised awareness of UnCoVerCPS in the relevant scientific and industrial communities, but also provided the consortium with valuable input in the form of industrially relevant benchmark problems that the UnCoVerCPS toolchain will be evaluated against. ARCH will take place at CPS Week 2016 to review progress of tools and methods against the benchmark problems as well as gather new benchmarks from the community.

A further element of UnCoVerCPS is the dissemination of results in the form of ope- source software, in particular CORA and SpaceEx. While both tools have been significantly improved throughout 2015 and new versions have been release, TUM and UJF have also commenced a joint activity towards integration of both tools. To this end, CORA algorithms are in the process of being ported to C++ for integration into SpaceEx. The consortium expects tool chain integration activities to continue in 2016, which will also include the integration of tools for capturing requirements for hybrid-systems in a semi-formalized form.

Another focus for 2016 will be participation in a major event at a European level in order to further raise awareness of the project in the H2020 community and to strengthen networking and concertation at a European level.

Commercial exploitation activities have commenced in 2015, both horizontally with regards to tools (Esterel, TUM, UJF, Universität Kassel) and vertically with regards to a wide range of safety-critical CPS applications (Bosch, GE, R.U. Robots, Politecnico di Milano, DLR, TECNALIA). Commercial exploitation is expected to gain more momentum, going forward, and will also take into consideration regulatory and legislative aspects from the individual application domains.

Appendix A: Conference papers published and submitted in the context of UnCoVerCPS

Goran Frehse. Reachability of Hybrid Systems in Space-Time. ACM/IEEE Int. Conf. Embedded Systems (EMSOFT'15), Oct. 4-9, 2015, Amsterdam, The Netherlands. [WP3]

Matthias Althoff: "An introduction to CORA 2015," ARCH'15 (satellite workshop of CPSWeek 2015), April 13, 2015, Seattle, USA.

Luca Parolini, Simone Schuler and Adolfo Anta: "Benchmark problem: an air brake model for trains,"ARCH'15 (satellite workshop of CPSWeek 2015), April 13, 2015, Seattle, USA.

Hendrik Roehm, Rainer, Gmehlich, Thomas Heinz, Jens Oehlerking and Matthias Woehrle: "Industrial Examples of Formal Specifications for Test Case Generation," ARCH'15 (satellite workshop of CPSWeek 2015), April 13, 2015, Seattle, USA.

Federico Terraneo, Alberto Leva and Maria Prandini: "A switched control scheme to handle quantisation in the design of high-precision computing system components," Poster at ACM/IEEE 6th International Conference on Cyber-Physical Systems (within CPSWeek 2015), April 13-16, 2015, Seattle, USA.

Javier Sanchez Cubillo and Jesus Marcos Olaya: "Technology transfer process for autonomous mobility as cyberphysical systems – the H2020 UnCoVerCPS project," 13th Symposium on Advanced Space Technologies in Robotics and Automation (ASTRA 2015), May 11-13, 2015, Noordwijk, the Netherlands.

Daniele Ioli, Alessandro Falsone and Maria Prandini: "Optimal energy management of a building cooling system with thermal storage: A convex formulation," 9th International Symposium on Advanced Control of Chemical Processes ADCHEM 2015, June 7-10, 2015, Whistler, British Columbia, Canada.

Luca Deori, Simone Garatti and Maria Prandini: "A model predictive control approach to aircraft motion control," American Control Conference ACC 2015, July 1-3, 2015, Chicago, IL, USA.

Alessandro Falsone and Maria Prandini: "An Iterative Scheme for the Approximate Linear Programming Solution to the Optimal Control of a Markov Decision Process," European Control Conference 2015, July 15-17, 2015, Linz, Austria.

Matteo Ragaglia, Maria Prandini and Luca Bascetta: "Poli-RRT*: optimal RRT-based planning for constrained and feedback linearisable vehicle dynamics," European Control Conference 2015, July 15-17, 2015, Linz, Austria.

Christian Hillmann and Olaf Stursberg: "Decentralized control of distributed discrete event systems with linear dependency structure," 11th IEEE International Conference on Automation Science and Engineering, August 24-28, 2015, Gothenburg, Sweden.

Giorgio Manganini, Alessandro Falsone and Maria Prandini: „A majority voting classifier with probabilistic guarantees," IEEE Multi-Conference on Systems and Control MSC2015, September 21-23, 2015, Sydney, Australia.

Konstantin Schaab and Olaf Stursberg: "Decentralized robust control of power grids using LPV-models of DAE-systems," 1st IFAC Workshop on Linear Parameter Varying Systems, October 7-9, 2015, Grenoble, France.

Konstantin Schaab and Olaf Stursberg: “Robust decentralized LPV control for transient stability of power systems,” accepted at the 9th IFAC Symposium on Control of Power and Energy Systems, December 9-11, 2015, New Delhi, India.

Goran Frehse: “Computing Maximizer Trajectories of Affine Dynamics for Reachability,” IEEE Conference on Decision and Control 2015, December 15-18, 2015, Osaka, Japan.

Giorgio Manganini, Luigi Piroddi and Maria Prandini: “A classification–based approach to the optimal control of affine switched systems,” IEEE Conference on Decision and Control 2015, December 15-18, 2015, Osaka, Japan.

Luca Deori, Simone Garatti and Maria Prandini: “Stochastic control with input and state constraints: a relaxation technique to ensure feasibility,”IEEE Conference on Decision and Control 2015, December 15-18, 2015, Osaka, Japan.

Daniele Ioli, Alessandro Falsone and Maria Prandini: “An iterative scheme to hierarchically structured optimal energy management of a microgrid,” IEEE Conference on Decision and Control 2015, December 15-18, 2015, Osaka, Japan.

Stefano Minopoli, Goran Frehse: “SL2SX Translator: From Simulink to SpaceEx Verification Tool,” to be submitted.

Kostas Margellos, Alessandro Falsone, Simone Garatti, Maria Prandini: “Constrained optimal control of stochastic switched affine systems using randomization” submitted.

Daniele Ioli, Alessandro Falsone and Maria Prandini : “Energy management of a building cooling system with thermal storage: a randomized solution with feedforward disturbance compensation", submitted.

Andrea Belloni, Luigi Piroddi and Maria Prandini “A stochastic optimal control solution to the energy management of a microgrid with storage and renewables", submitted.

Petio Dimitrov, Luigi Piroddi and Maria Prandini: "Distributed allocation of a shared energy storage system in a microgrid", submitted.

Riccardo Maria Vignali and Maria Prandini: “Input design for piecewise affine systems: a method for satisfying a reachability specification while detecting the relevant inputs” , submitted.

Daniele Ioli, Alessandro Falsone, Simone Schuler and Maria Prandini: “A compositional framework for energy management of a smart grid: a scalable stochastic hybrid model for cooling of a district network”, submitted.

Bastian Schürmann and Matthias Althoff: “Convex interpolation control with formal guarantees”, submitted to Hybrid Systems: Computation and Control, 2016.

Hendik Roehm, Jens Oehlerking, Matthias Woehrle and Matthias Althoff: “Reachset conformance testing of hybrid automata”, submitted to Hybrid Systems: Computation and Control, 2016.

Bastian Schürmann and Matthias Althoff: “Closed-form expressions of convex combinations for controller design”, submitted to American Control Conference, 2016.

Appendix B: Journal papers published and submitted in the context of UnCoVerCPS

Accepted for publication:

Alessandro Falsone, Luigi Piroddi and Maria Prandini. A randomized algorithm for nonlinear model structure selection. Automatica 2015. [WP1]

Giorgio Manganini, Matteo Pirotta, Marcello Restelli, Luigi Piroddi and Maria Prandini. Policy search for the optimal control of Markov decision processes: a novel particle-based iterative scheme. IEEE Transactions on Cybernetics. [WP2]

Submitted or prepared for submission:

Alessandro Falsone and Maria Prandini. A randomized approach to the prediction of critical situations for air traffic due to an uncontrolled space debris reentry. Submitted to IEEE Transactions on Control System Technology. [WP2, WP3]

Luca Deori, Simone Garatti and Maria Prandini. "Trading performance for state constraint feasibility in stochastic constrained control: A randomized approach. Submitted. [WP2, WP5]

Francesco Borghesan, Riccardo Vignali, Luigi Piroddi, Martin Strelec, Maria Prandini. Energy management of a building cooling system with thermal storage: an approximate dynamic programming solution. Submitted. [WP1, WP2, WP5]

Yang Yang, Jun Zhang, Kai-quan Cai, Maria Prandini. Multi-aircraft conflict detection and resolution based on probabilistic research sets. Submitted. [WP2, WP3]

Riccardo Vignali and Maria Prandini. Minimum resource commitment for reachability specifications in a discrete time linear setting. Submitted. [WP1]

Luca Deori, Simone Garatti and Maria Prandini. Model predictive control for trajectory tracking in aircraft control. In preparation. [WP2, WP3]

Kostas Margellos, Alessandro Falsone, Simone Garatti and Maria Prandini. Distributed constrained optimization and consensus in uncertain networks via proximal minimization. Submitted. [WP2]

Matthias Althoff. On computing the Minkowski Difference of Zonotopes. Submitted to Journal of Computational Geometry.

Appendix C: Papers by consortium partners thematically related to UnCoVerCPS

Stefano Minopoli and Goran Frehse: “Running SpaceEx on the ARCH14 Benchmarks,” ARCH'15 (satellite workshop of CPSWeek 2015), April 13, 2015, Seattle, USA.

Goran Frehse, Sergiy Bogomolov, Marius Greitschus, Thomas Strump and Andreas Podelski: “Eliminating Spurious Transitions in Reachability with Support Functions,”HSCC’15, April 14-16, 2015, Seattle, USA.

Martin Jilg, Jens Tonne and Olaf Stursberg: “Design of distributed H_2-optimized controllers considering stochastic communication link failures”, American Control Conference ACC 2015, July 1-3, 2015, Chicago, IL, USA.

Jens Tonne, Martin Jilg and Olaf Stursberg: “Constrained model predictive control of high dimensional jump Markov linear systems”, American Control Conference ACC 2015, July 1-3, 2015, Chicago, IL, USA.

Leonhard Asselborn and Olaf Stursberg: “Probabilistic control of uncertain linear systems using stochastic reachability”, 8th IFAC Symposium on Robust Control Design, July 8-11, 2015, Bratislava, Slovak Republic.

Leonhard Asselborn and Olaf Stursberg: “Robust control of uncertain switched linear systems based on stochastic reachability,” 5th IFAC Conference on Analysis and Design of Hybrid Systems, October 14-16, 2015, Atlanta, GA, USA.

Dominic Groß and O. Stursberg: A cooperative distributed MPC algorithm with event-based communication and parallel optimization. IEEE Transactions on Control of Networked Systems, 2015.