Appendices

A – Glossary of the SPES Modeling Framework

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A

Abstraction layer
An abstraction layer defines a specific level of abstraction and granularity at which the System under Development (SUD(↑)) is examined. The level of granularity of the respective abstraction layer is in turn determined by a structural characteristic that stems from the layer above. Initially, we consider the system as a whole.

D

Decomposition
Decomposition denotes the partitioning of an analysis element or design element (e.g., of a goal, a function(↑), or a logical/technical component(↑)) into parts.

Diagram
A diagram is a graphical representation of a model or of a part of a model as part of a specific modeling language.

F

Function
A function is a projection of the behavior of the entire system (when seen as a black box) resulting in a relation between inputs and outputs with regard to a specific usage purpose.

Functional viewpoint
The functional viewpoint(↑) is a structured description of the functions(↑) that are to be realized along with their interfaces, interactions, and dependencies. The functional viewpoint imposes a structure onto the functional requirements of the SUD(↑). This viewpoint provides different model types that can be used for organizing hierarchies of system functions and the behavior of the system functions at the interfaces as well as their state space.

L

Logical component
A logical component is the result of a logical decomposition of a system into the internal logical structure of the SUD. It encapsulates a specific behavior that contributes to the realization of one or more functions(↑) of the SUD(↑). A logical component has a well-defined interface. A logical component may be decomposed into further logical components.

Logical viewpoint
The logical viewpoint is a structured description of how to organize the realization of the functions(↑) by means of logical components(↑) that are connected with one another. This viewpoint provides different model types that can be used for documenting the logical component architecture of a system, the behavior of the logical components at the interfaces, and their state space.

M

Mapping (between views(↑)/between abstraction layers(↑))
A mapping between views is a relationship between two models representing the views. A mapping can exist between models of different viewpoints(↑) or between models of the same view, but on adjacent abstraction layers(↑).

Model
A model is an abstract representation of an existing reality or a reality to be created. Every model is created for a specific purpose of use.

R

Refinement
Refinement refers to the process of detailing an analysis or design element while preserving its semantics.

Requirement
A requirement is:
1. A need perceived by a stakeholder
2. A capability or property that a system shall have
3. A documented representation of a need, capability, or property

[IREB 2011]

Requirements viewpoint
The requirements viewpoint is a structured description of how to document/specify the requirements of a system. This viewpoint provides different model types that can be used for documenting the system context(↑), system goals, system scenarios, and solution-oriented requirements.

S

(Operational) System context
The context of the SUD(↑) is the part of its environment that has an operational relationship to it during the execution of the system.

System under development (SUD)
The system under development is the subject that is being developed. Within the scope of the SPES engineering approach, the SUD refers to a software system.

T

Technical component
A technical component is a means for describing the technical structure of the SUD. It characterizes a technical resource that is available in the system and implements one or more logical components(↑) fully or in part.

Technical viewpoint
The technical viewpoint is a structured description of how to organize the realization of logical components(↑) by means of technical components(↑). The technical components may be related to each other. This viewpoint comprises different model types that can be used for documenting the hardware, tasks, and schedulers as well as the communication.

V

Validation
Validation refers to the activity of checking whether the requirements capture the stakeholder's needs and fulfill defined quality criteria. The goal is to assess whether a system that satisfies its defined requirements would fulfill its intended purpose. Hence, validation aims at answering the question: "Am I building the correct system?" [Boehm 1984]

Verification
Verification refers to the activity of checking whether a development artifact (e.g., the finalized SUD) satisfies the specified requirements. Hence, verification aims at answering the question: "Am I building the system correctly?" [Boehm 1984]

View
A view is a representation of a whole SUD from the perspective of a related set of concerns (based on [IEEE1471]).

Viewpoint
A viewpoint is a specification of the conventions for constructing and using a view(↑). Viewpoints comprise patterns or templates from which to develop individual views(↑) by establishing the purpose and audience for a view(↑) and the techniques for its creation and analysis (based on [IEEE1471]).

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B – Author Index

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Z

C – Project Structure

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Co-operation

The innovation alliance focused on a strong interaction between science and practice in order to make good progress in the engineering challenges, to verify the approaches, and to transfer the results to engineering methods that are viable in practice. This target was supported by the following:

- Significant application projects from five application areas showing high dynamics and with high economic relevance
- Installation of a central project that interacted with the application projects and provided the necessary methods and tools
- Installation validation work packages in which the results were evaluated using scientific taxonomy

The structure between the different locations in Germany allowed for the inclusion of key resources into the innovation alliance. The close co-operation between the industrial partners and the universities/Fraunhofer institutes has ensured that the results could be evaluated with respect to practical and market-feasible solutions.

Project structure

As stated above, SPES 2020 was structured as a central project and five application projects. The application projects correspond to the SPES 2020 domains automation, automotive, avionics, energy, and healthcare.

The central project itself was divided into work packages one to six. Packages two to five deal with the following topics:

- Model-based requirements engineering
- Model-based architecture design
- Proof of safety, certification, and quality assurance of nonfunctional requirements
- Modeling of parallel real-time processes and verification of the real-time behavior

The foundation was laid in work package one, which developed a methodology for a comprehensive and integrated model-based development. In work package six, the focus was on the empirical evaluation of the methods.

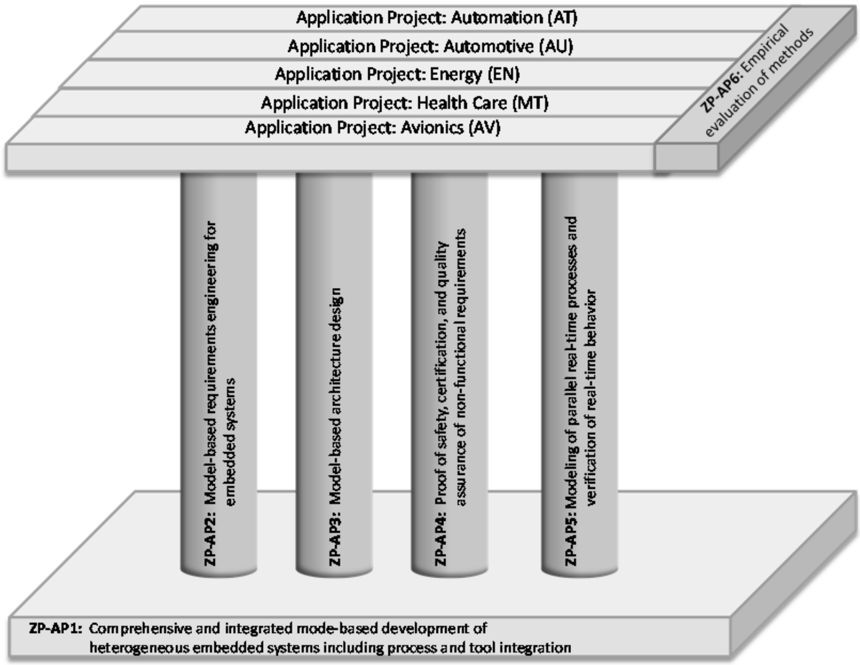

Fig. C *SPES 2020 project structure*

The interplay between the work packages of the central project and the application projects was assured by a strong orientation on case studies from the application domains.

D – Members of the Innovation Alliance

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Airbus Deutschland GmbH

Airbus Deutschland GmbH is one of the world's largest manufacturers for civil aircraft seating more than 100 passengers and Europe's largest industrial undertaking. With some $11 billion in annual revenues, it has won approximately 50% of all orders for jet-powered transport airplanes in recent years. Airbus Deutschland GmbH, the civil aircraft business affiliate of Airbus S.A.S. – Toulouse, is one of the major aerospace companies in Europe. The company is engaged in the development and manufacture of advanced high-performance commercial transport aircraft and is recognized for its technological expertise in nearly all fields of aeronautical engineering. The workforce of Airbus Deutschland currently amounts to approx. 18,500 employees. Research and technology development capabilities of Airbus Deutschland GmbH cover all aspects of aircraft design and optimization, airframe and systems development, and engine integration. For systems integration, IMA (Integrated Modular Avionics), Airbus D has experience in integration of cabin systems through the A380 and will apply and improve this technology in future.

For the SPES 2020 project, Airbus provided a showcase development scenario (architectural framework) from the aircraft systems area as a deployment example for the SPES 2020 development platform. Modeling languages for system requirements were analyzed and checked for integrity characteristics. The requirements for a development platform were formulated from an avionics point of view and the resulting process analyzed. The avionics example scenario was implemented on the development platform and evaluated with respect to processes and tools available at Airbus. Results were validated and potential for improvement delivered by the platform analyzed for future industrial deployment.

Berlin Heart GmbH

Berlin Heart GmbH is the only company worldwide developing, manufacturing, and selling internal and external heart support systems for patients of all ages and all body heights.

These systems support patients with major cardiac insufficiency. As life-sustaining systems, these are medical products in the highest risk level (level III). All components for control and monitoring based on embedded control systems are implemented as safety-critical components. Therefore, especially high standards with regard to requirements management, development, implementation, testing, production, and certification apply.

The Berlin Heart products INCOR® und EXCOR® are market leaders in their respective segments in Germany and in Europe. Employing over 180 people, and doubling revenue to €22 million within three years in 2007, the company has an outstanding performance.

Cassidian (EADS-Deutschland GmbH Defence Electronics)

Cassidian (http://www.cassidian.com) is a global leader in aerospace, defense, and related services. In 2007, EADS generated revenues of €39.1 billion and employed a workforce of approximately 116,000. The group includes the aircraft manufacturer Airbus, the world's largest helicopter supplier Eurocopter, and EADS Astrium, the European leader in space programs from Ariane to Galileo. Its Defence & Security Division is a provider of comprehensive systems solutions and makes EADS the major partner in the Eurofighter consortium, as well as a stakeholder in the missile systems provider MBDA. EADS also develops the A400M through its Military Transport Aircraft Division.

The Cassidian group encompasses inter alia the business unit Defence Electronics (EADS-DE). The high technological competence and experience is founded on a long tradition of famous pioneering companies, mainly in Germany and France. As the sensors, avionics, and electronic warfare house of EADS, Defence Electronics unites advanced sensor and electronic technologies for all types of platforms—manned and unmanned aircraft, helicopters, satellites, vehicles, ships—and provides them with components and subsystems based on the latest radar, electronic, and software technologies. Recent activities covered special equipment on board the A380, demanding electronic systems with different safety levels. Current developments include several computer and communication systems on board new aircraft subject to highest civil certification levels following RTCA/DO 178B level A to C and the corresponding DO 254.

Furthermore, Defence Electronics develops and manufactures mission avionics and self-protection systems, which are mostly established in international co-operations and multinational projects.

Cassidian brings the competency of developing complex, performance- and safety-critical embedded systems to the project. This competency results from the product portfolio that covers embedded systems aircraft, shipping, and ground systems. In SPES 2020, Cassidian concentrated on safety, certification, and quality, as well as real-time and multicore architectures, bringing in its expertise from actual and completed projects. Leading the avionics application project, Cassidian cooperated closely with its partners Airbus, EADS-IW, and Liebherr Aerospace, supporting the academic partners in the avionics subproject.

In addition, researchers from Cassidian were members of the project architecture team.

EADS-Deutschland GmbH Innovation Works (EADS-IW)

EADS Innovation Works (IW) is the corporate research facility of EADS with operations in France, Germany, Spain, UK, Singapore, and Russia. Its overall workforce comprises more than 700 researchers. EADS-IW covers all the skills and technology fields that are of critical importance to EADS. It is an operational and strategic entity for EADS business units for value-creating products and services through innovative technologies. It feeds the innovation pipeline from the emergence of new technologies to their maturity and transfer into products. EADS-IW, in its endeavor to maximize the innovation potential of EADS, actively operates a worldwide network with world-class universities, schools, and research institutes. In its legal structure, EADS-IW is part of the national entities of EADS.

The German part of EADS Innovation Works in Ottobrunn (near Munich) and Hamburg employs a permanent staff of 220 people, 70% of which are senior scientists. Legally, it is an organizational unit within EADS-Deutschland GmbH, the German subsidiary of EADS N.V.

In SPES 2020, EADS-IW focused on transforming the scientific research results into practical innovations. Working closely together with its partners (e.g., Cassidian and Airbus), EADS-IW defined case studies in SPES 2020 and identified problem areas that partners in the central project worked on . EADS-IW was also engaged in the central project, preparing concrete deliverables, together with its partners, covering topics such as modeling framework, requirements modeling and validation, design verification and formal analysis, as well as technology platform.

EADS-IW had the role of coordinating the industry partners in ZP-AP 3, offering a strong background in systems and software engineering, engineering frameworks, and from other sponsored projects such as VIVACE (Aeronautic) and SPEEDS (Information Technology).

Embedded4You e.V.

Embedded4You offers integrated solutions for embedded systems in industry automation that set the standards for the future by leveraging the individual competencies of its members. The member companies Afra, aicas, Coming, Elma Trenew, Euro Systems, FH München, Fortiss, FTI Group, ISyst, Kölsch & Altmann, Microsys, N.A.T., IMACS, Protos Software GmbH, RST Industrie Automation, sepp.med, Tieto embedded Systems, and XiSys bundle their individual technologies, products, services, and competencies into a comprehensive total package for automation challenges. Through dedicated project leadership, customers get their complete solution from one source.

Embedded4You system solutions, starting with design, via product and go to market, through to life cycle management, enhance the competitiveness of customers with their openness and flexibility. The following members were active in the SPES project:

Elma Electronic GmbH is a global manufacturer of electronic packaging products for the embedded systems market — from components, storage boards, back-planes, and chassis platforms to fully integrated subsystems. The company has a broad base of proven standard products that can be tailored to individual applications, from initial concept to volume production. Elma's reliable solutions, flexibility, and design expertise make Elma a reliable partner for leading electronics companies in the world.

The *FTI Group* success story began with FTI (Flight Test Instrumentation) — the development of test systems. The company is now one of the largest engineering services providers and system developers in the aerospace region Berlin-Brandenburg, specializing in system solutions for aviation. Development, design, and consulting in the high-tech industry and energy sector complete the portfolio.

IMACS GmbH develops and produces instrumentation, control, and automation systems for various industries. Whether single components or complete embedded systems, the solutions are always individual and flexible. In addition, IMACS offers radCASE, a model-based software development system that allows for the comprehensive development of technical software, including code generation.

MicroSys Electronics GmbH, located in Sauerlach close to Munich, designs and develops embedded system solutions, for example, VMEbus, CompactPCI, and other common bus infrastructures. From the very beginning in 1975, customized solutions offering longevity have been a strong part of MicroSys business as well. Successfully deployed products span from computer-on-modules up to fully integrated systems. The miriac™ Modules utilize 32-bit processors such as Freescale Power Architecture, QorIQ-CPUs, Intel MultiCore CPUs, DaVinci ™ Video Processors, FPGAs, and DSP-Designs. With their low power consumption and the compact dimensions of a credit card, the miriac™ CPU modules fit into any application in automotive, industrial automation, medical, railways and transportation, construction, and defense market segments.

Operating systems such as VxWorks, Microware OS-9, Micrium µC/OS, QNX, and Linux or WinCE are supported. Furthermore, MicroSys acts as a sales and support partner in Europe for RadiSys Microware ® OS-9 Real Time Operating System.

Operating system integration and adaptations of communication infrastructures such as CAN, EtherCAT, ProfiNET for industrial, defense, avionics, and medical solutions are an integral part of the business as well.

N.A.T. (Gesellschaft für Netzwerk und Automatisierungs-technologie mbH) is the expert in manufacturing high-performance connectivity products for data and telecommunication solutions. The product portfolio is dedicated to the embedded market, covering requirements from local area networks (LAN) up to wide area networks (WAN). The products include standard interface modules for local and wide area networks based on common hardware standards such as AMC, MicroTCA, VME, compact PCI, PMC, PCI, and others. N.A.T. embedded platforms are complemented by own, sophisticated protocol stack solutions such as ISDN, SS7, ATM, or TCP/IP adapted to common real-time operating systems to build an optimal solution.

RST Automation GmbH builds embedded systems and applications with a focus in industry automation for reliable real-time requirements. The products and solutions are open for easy integration of existing and new technologies. Based on the model-oriented approach of the middleware “Gamma,” which can be seen as a type of “software plug,” it is possible to describe and integrate virtually any hardware and software configuration. The middleware is used to integrate hardware and software into one common platform. Within Embedded4You, the middleware is the main strategy for integrating custom-specific efforts into one homogenous platform.

XiSys Software GmbH manufactures the tool XiBase9, a well-structured and portable graphic platform that has been specifically developed for the embedded and real-time environment. Highlights of the software are its efficient resource usage, multilanguage support (Unicode, language switch at runtime), and the extensive protocol and debug mechanisms. The software is operating system-independent (Windows 2000, XP, Vista, Linux, OS-9, x86, PowerPC, SH, ARM, XSCALE, 68k) and can be connected to the Gamma middleware without programming.

Taking its role as a supplier of specialized solutions, Embedded4You's goals in SPES were professionalization of the interdomain production process by focusing on basic, interapplication approaches to leverage the potential of embedded systems and to master their complexity. The work focused on the development of an open platform that integrates and standardizes various key competencies in hardware and software products.

Hella KGaA Hueck & Co.

The automotive supplier Hella KGaA Hueck & Co., Lippstadt, develops and manufactures lighting technology and electronic components and systems for the automotive industry. In addition, joint venture companies produce complete car modules such as air conditioning systems and on-board electrical systems. Hella owns one of the worldwide largest sales organizations for car parts and accessories, with own sales businesses and partner organizations in more than 100 countries. The Hella group has revenues of €3.7 billion.

Hella is among the top 50 international automotive suppliers and among the top 100 largest companies in Germany. Worldwide, more than 25,000 people work in 70 production sites, production subsidiaries, and joint ventures in 18 countries. More than 3000 engineers and technicians work in research and development.

Hella's customers include all leading vehicle and system manufacturers, as well as car parts businesses. In the electronics business area, but also in the growing electronic share of lighting technology products, Hella has built up a broad competency spectrum and deep experience in the development of complex mechatronic systems for the automotive industry. From the latest methods in model-based software development—in SPiCE-compliant development processes using AUTOSAR standard components—numerous crosscutting development approaches for embedded systems in the automotive industry have been defined together with customers and cooperation partners. Hella's main support for the project was in defining, detailing, implementing, evaluating, and optimizing concepts in the automotive work package, and via the definition of area-specific requirements, the company also supported the work of the central project.

IT Power Consultants

IT Power Consultants, based in Berlin, was founded in 2000 and recently changed its name to ITPower Solutions GmbH. Longtime experience of the founders in the area of embedded systems established the company's focus on development processes for embedded software.

Motivated by experiences from customer projects, the company constantly invests in the improvement of the development and testing processes, especially in the area of quality assurance of embedded systems.

In SPES 2020, IT Power Consultants contributed in the areas of requirements engineering and verification of real-time behavior in the medical systems work package, most notably covering the following topics:

- Transition from architectural model to functional model of an embedded system
- Proof of equivalence of software artifacts by back-to-back testing
- Identification of test cases on the basis of nonfunctional requirements
- Hardware-in-the-loop environments for testing real-time properties of embedded systems

Liebherr-Aerospace Lindenberg GmbH

The company founded in 1949 by Hans Liebherr is today a group of companies with more than 32,000 employees in more than 120 enterprises worldwide. Turnover in 2010 was €7.5 billion. All over the world, the name Liebherr stands for a technically demanding and customer-oriented product and service offering.

Liebherr-Aerospace, a worldwide respected supplier of the aviation industry, develops and produces complete hydraulic, mechanical, and electronic systems for cruise control, air conditioning, and landing gear for large and regional aircraft, helicopters, and military aircraft for the global market. Liebherr-Aerospace customers include Airbus, Bombardier, Embraer, Sukhoi, Eurocopter, and others.

In past and current research projects, Liebherr-Aerospace Lindenberg GmbH has contributed to all product areas that laid the foundation for new equipment systems. In addition to the national Luftfahrtforschungs-Programm (LuFo I to IV), on a European level, the 5th, 6th, and 7th framework programs should be mentioned. The generic results from these projects have been transferred to national value creation potentials.

Liebherr-Aerospace brought competencies in the areas of flight control systems and landing gear from pilot interface to hydraulic or electronic actuators into the SPES project. Special focus was on quality of requirements of complex systems — these are key for competitiveness. Therefore, Liebherr-Aerospace contributed to the realization of the SPES 2020 follow-through modeling methodology, especially for the avionics domain, and to the investigation for validation of requirements in early development phases. As a major engagement, Liebherr-Aerospace has proposed an original and efficient approach to optimizing the deployment of functions on computer networks. Liebherr-Aerospace has investigated the improvement of the automation of the verification activities in accordance with the restrictive avionics development standards. In addition, the company produced proposals for the efficient use of multicore platforms for real-time and safety-critical applications.

Robert Bosch GmbH

Bosch is one of the largest industrial enterprises in Germany, creating revenues of €46.3 billion (2007). In the business areas automotive engineering (61% revenue), industrial engineering (13% revenue), and consumer goods and building services engineering (26% revenues), Bosch employs approximately 271,000 employees.

The corporate law structure of Robert Bosch GmbH ensures the corporate independence of the Bosch Group and enables the company's long-term planning. The nonprofit Robert Bosch Foundation GmbH holds 92% of the capital shares.

Bosch sees professional education as part of its social responsibility. Year after year, more than 6000 young people (of those, approximately 4400 in Germany) receive an offer for a high-quality training program. The Bosch Group invests approximately 7.7% of its revenue in research and development, with 29,000 employees. In 2007, 3280 patents were filed worldwide.

At Bosch, protection of the environment is in line with corporate policy. Protection of the environment was formulated as a company target as early as 1973, and has the same significant value as product quality and profit. It is Bosch's vision to improve quality of life with innovative and useful solutions. "Reliability, credibility and legality are the main factors of the economic success of the Bosch-Group," said Hermann Scholl, Chairman of the Board.

The central Corporate Research (CR) team works across business areas and therefore provides a competency network that warrants the development of innovative system concepts as well as the introduction of new technologies.

Focusing necessarily on the competencies, CR/AE2 is a group responsible for the development of software-intensive embedded systems. It develops, integrates, and pilots lead applications and successfully transfers technologies, methods, processes, and tools necessary for the development of software-intensive systems within Bosch, thus warranting Bosch's leading position in the market. The CR/AE2 group brought system design know-how in using cutting edge methodologies for modeling and evaluation, which has been developed in numerous projects, into the SPES project. Therefore, the main focus areas were on "seamless model-based development of heterogeneous embedded systems including process- and tool-integration" (ZP AP1), "structured requirements engineering" (ZP AP 2), "safety and certification" (ZP AP 4), and "empirical evaluation" (ZP AP 6). Here, Bosch provided know-how and the results have already been applied to concrete applications.

In addition, researchers from Bosch were members of the project architecture team.

RWE Energy AG

RWE Energy, based in Dortmund, bundles the integrated sales of electrical power, gas, and water, as well as the network business for 12 regions in Germany and Continental Europe.

RWE Energy employs 28,323 people in Germany, Austria, Hungary, Slovakia, Poland, and the Netherlands.

As a leading player, RWE Energy aligns itself with the requirements of 23.1 million customers. In Germany and wide parts of Central Europe, prosumers of RWE Energy get their energy and water solutions from one shop, making RWE Energy a number one address for all questions concerning energy and water supply, with €28.2 billion annual revenues.

Annual sales of 168.3 billion kilowatt hours of electrical energy makes RWE Energy the number two in Germany and number three in Europe. In water supply, RWE Energy is the number one in Germany, selling 107 million cbm per year. Gas sales are 258 billion kilowatt hours annually.

With two focal points, sales and network, RWE Energy brought deep insight from energy supply areas, as well as practical and theoretical knowledge of planning and running energy networks, into the SPES project. In addition, RWE Energy was able to leverage know-how from research projects and internal projects already completed and covering smart grids and virtual networks.

Siemens AG

Siemens is a global powerhouse in electronics and electrical engineering, operating in the fields of industry, energy, and healthcare, as well as providing infrastructure solutions, primarily for cities and metropolitan areas. For over 160 years, Siemens has stood for technological excellence, innovation, quality, reliability, and internationality. The company is the world's largest provider of environmental technologies. Around 40 percent of its total revenue stems from green products and solutions. In fiscal year 2011, revenue from continuing operations totaled €73.5 billion, and net income from continuing operations €7.0 billion. At the end of September 2011, Siemens had around 360,000 employees worldwide on the basis of continuing operations. The company employs some 27,800 researchers and developers worldwide who work on innovations that secure existing business and open up new markets. In fiscal year 2011, Siemens invested €3,925 million in research and development. In the same period, the employees submitted around 8,600 invention reports — around 40 per workday. The role of Siemens AG in the project was manifold:

- Firstly, Siemens adopted the role of a developer and manufacturer of automation equipment including corresponding software. Siemens provides a wide spectrum of automation components, as well as control and management systems for the various industry segments (process industries, discrete industries, service industries), holding a worldwide number 1 position in many segments.
- Secondly, Siemens was active in the role of a system integrator, equipment manufacturer, and turnkey contractor respectively. Siemens is an engineering company offering customer-specific facilities, plants, and automation solutions for selected

industry segments (e.g., automotive, building automation, electric power generation, transmission, distribution, metals and mining, chemical, transportation and logistics).

- The third role of Siemens AG was that of a healthcare solution provider with key competencies and innovation strength in diagnostic and therapeutic technologies, as well as an integrated supplier of data processing solutions for the whole clinical chain.

Together with a broad know-how in product life cycle management (PLM) software, Siemens covers all necessary competencies for industrial product and solution development using embedded systems — from product development to production design and engineering to generation of automation software.

In addition, researchers from Siemens were members of the project architecture team.

SWM Services GmbH

SWM Services GmbH is a 100% subsidiary of Stadtwerke München GmbH (SWM), acting as internal service provider for services in the areas energy data, trade fair services, network and facility services, as well as information and process technology.

Stadtwerke München, Munich's municipal utilities company, is one of the largest energy and infrastructure companies in Germany. Over one million private households, SMEs, and business clients benefit from the services provided by SWM on a daily basis. For decades, SWM has provided energy (electricity, natural gas, district heating) for the Bavarian capital in a safe and environmentally benign way. Among other things, the SWM development push for renewable energy and the push for eco-friendly district heating are an example to other districts. Furthermore, SWM supplies the megacity with fresh drinking water from the Bavarian Voralpenland—one of the best in Europe—and with 18 indoor and outdoor swimming pools, SWM operates one of the most modern bathing environments in Germany. The MVG transport subsidiary is responsible for the subway, bus, and tram systems, and is therefore a significant pillar in Munich's public transport network. SWM employs around 7500 staff and in the 2010 fiscal year, turnover reached around €3.8 billion.

As a public utility company, SWM Services GmbH has broad experience in all supply areas, especially in the energy area. In addition, SWM has in-depth knowledge in model-based system and software development, and brings first project experience in the area of embedded systems for smart metering and virtual power plants into the SPES project.

Being involved in the energy application area, SWM leveraged this experience and actively supported the definition and validation of the application-specific requirements. Another focus area was the implementation and evaluation of an integrated simulation environment for smart grid development. The work of the central project was supported by the execution of practicability tasks.

TeCNeT GmbH

TeCNeT, organization for TeleCooperate NeTwork Systems & Service mbH, was founded in 1994 as a service provider and developer of innovative products. Its main competencies are in the areas of information and telecommunication technology, as well as in medical systems and control engineering.

TeCNeT offers a full range of services from technical consulting, to support for development and manufacturing, to full-service offerings from the idea to ready-to-use implementation of the solution. Its main strengths are flexibility, speed, and cost-efficiency, which can be measured by the satisfaction of TeCNeT's customers.

Customers include: CeWe Color AG & Co. OHG, the Fraunhofer Institut für Fabrikautomatisierung und Fabrikbetrieb, Gesellschaft für angewandte Informatik (GfaI), Berlin Heart GmbH, as well as other smaller regional businesses.

TeCNeT's contribution to SPES 2020 comprised of leveraging the existing know-how for the development of embedded systems for supervision of patients and the medical devices necessary for maintaining their health.

TÜV SÜD AG

TÜV SÜD group is a future-oriented and successful service business. 13000 employees support more than 5 million customers (individuals, companies, and institutions) worldwide.

The subsidiary TÜV SÜD Automotive GmbH is a modern service company providing a complete portfolio, for example, in the area of safety electronics for automotive and electronic industry sectors. With its competence center Electronic Safety, TÜV SÜD Automotive GmbH is active as an intersectoral support and test center for safety electronics with a main focus on functional safety and software.

In this role, TÜV SÜD Automotive GmbH consults, tests, and certifies manufacturers of safety-related embedded systems. Experience from test and certification of safety-related embedded systems (using model based technologies) was brought in into the SPES project. TÜV SÜD Automotive GmbH has made sure that the technologies developed will be testable and certifiable in accordance with international (safety) standards.

Vector Informatik GmbH

Vector supports manufacturers and suppliers of the automotive industry and of associated businesses with a professional and open platform composed of tools, software components, and support services for the development of embedded systems. The know-how is offered in terms of products, as well as a holistic support-offering including systems and software engineering. Workshops and seminars complete Vector's portfolio.

Vector Informatik GmbH is part of the Vector group that includes other companies in Germany (Vector Consulting Services GmbH, aquintos GmbH), France (Vector France S.A.S), Sweden (VecScan AB), United Kingdom (Vector GB Limited), China (Vector Automotive Technology Co., Ltd.), USA (Vector CANtech, Inc.), Japan (Vector Japan Co., Ltd.), South Korea (Vector Korea IT Inc.), and India (Vector Informatik India Pvt. Ltd.). The Vector group employs more than 1000 people and achieved revenues of €195 million in 2011. All sites of the Vector group have been certified according to ISO 9001:2000.

In SPES 2020, Vector worked in the automotive work package and contributed practical expertise in developing embedded systems.

In the product line “Process Tools,” Vector is developing the PREEvision tool. PREEvision supports the model-based development of electric/electronic systems from the early architecture design to production maturity of embedded systems.

In the automotive industry, embedded systems are mainly being developed in terms of a platform or product line concept. Vector therefore contributed to the work package “Variability management for model-based development” and provided experience from the practical deployment of PREEvision in the automotive industry

Fraunhofer FIRST

The Fraunhofer Institute for Computer Architecture and Software Technology (FIRST) was founded in 1983 as an institute of the Society for Mathematics and Data Processing (GMD), and has been part of the Fraunhofer-Gesellschaft since July 2001. Today, some 140 employees work in the three departments Modeling, Systems Architecture, and Quality Assurance.

Researchers at Fraunhofer FIRST combine long-standing know-how of hardware architectures and software methods with extensive skills in quality assurance in order to advance safety, efficiency, and usability of embedded systems. Main goals are the development of premium, easy-to-use, and intelligent technologies that adapt to the user’s needs and support them optimally. To achieve these goals, Fraunhofer FIRST develops innovative methods and technologies and advises companies during the entire development chain: from modeling to architecture and quality control to the completed product.

The research group is concerned with real-time-capable, reliable, and secure integration of multicore processors into embedded systems. It aims at reducing the complexity of developing efficient embedded multicore systems, while at the same time exploiting performance potentials and maintaining the reliability of the overall system. Multicore systems should remain real-time-capable and energy-efficient even under optimal workloads.

The research group Embedded Systems advises clients on the selection of methods and tools, architectural designs, prototypical implementation of components and subsystems, and on the evaluation, test, and certification of the embedded multicore systems.

In the SPES context, the following key competencies of FIRST researchers were most relevant:

- Model-based test generation and execution
- Verification and static analysis of industrial customer software
- Fault tolerance concepts and reliability quantification
- Architecture of embedded control elements, FPGA, System-On-Chip
- Comprehensive tool know-how for the development of embedded systems.

With these competencies, FIRST led the work package ZP-AP5 “Real-Time and Safety” within the central project and made major contributions in AWP-MT.

Fraunhofer IESE

Fraunhofer Institute for Experimental Software Engineering (IESE) in Kaiserslautern is one of the worldwide leading research institutes in the area of software and systems development. A major portion of the products offered by its collaboration partners is defined by software. These products range from automotive and transportation systems, through automation and plant engineering, information systems, healthcare, and medical systems, to software systems for the public sector. The solutions allow flexible scaling. This makes the institute a competent technology partner for organizations of any size — from small companies to major corporations.

Under the leadership of Prof. Dieter Rombach and Prof. Peter Liggesmeyer, Fraunhofer IESE has spent the last fifteen years making major contributions to strengthening the emerging IT hub of Kaiserslautern. In the Fraunhofer Information and Communication Technology Group, it cooperates with other Fraunhofer institutes in developing trend-setting key technologies for the future.

Fraunhofer IESE is one of 60 institutes of the Fraunhofer-Gesellschaft. Together they have a major impact on shaping applied research in Europe and contribute to Germany’s competitiveness in international markets.

The work at Fraunhofer IESE focuses mainly on methods for the development of software-intensive embedded systems as well as the empirical evaluation of such methods.

Fraunhofer IESE has been engaged in the engineering-like development of embedded software and systems for more than a decade, and has proven itself as one of the leading research institutes worldwide. One of its internationally respected unique selling propositions is the empirical evaluation of research results in the area of software and systems engineering. This competency was brought to the project by Fraunhofer IESE taking the scientific lead of the work package ZP-AP6 “Empirical Methods Evaluation” within the central project.

A second focus of the institute was on the model-based development of safe and highly reliable embedded systems. Given this expertise, Fraunhofer IESE led the workpackage ZP-AP4 “Proof of Safety, Certification, and Quality Assurance of Nonfunctional

Requirements." In this role, the institute developed methods, techniques, and tools for proof of safety, certification, and quality assurance in SPES.

In addition, researchers from IESE were members of the project architecture team that made major contributions towards an integrated model-based methodology.

OFFIS e.V.

The "Oldenburger Forschungs- und Entwicklungsinstitut für Informatik-Werkzeuge und – Systeme," OFFIS for short, was founded in 1991 and has a close cooperation agreement with the University of Oldenburg. OFFIS sees itself as an application-oriented research and development institute, and as "Center of Excellence" for selected topics in computer science and its application domains. OFFIS focuses its research and development work on IT systems in the application areas transportation, healthcare, and energy. Revenue is approximately €12 million.

In SPES 2020, the R&D division Transportation was involved. Its research focuses on methods, tools, and technologies for the development of reliable, cooperative, and supporting systems in the application area transportation. The division comprises several working departments, and offers a wide spectrum of competencies in the areas systems and software engineering, electrical engineering, and planning theory. Main research topics include methods, processes, and tools for the establishment of safety in transportation systems, as well as methods for analysis and design of E/E architectures. A special focus is on real-time aspects and component-based design.

OFFIS has participated in numerous national and European research projects, including OPRAIL, Verisoft, SafeAIR, SPEEDS, COMBEST, ArtistDesign, ESACS, ISAAC, and MISSA, and continues to do so today. Because of its competencies in the area of real-time, OFFIS is also a partner in AUTOSAR and, via SafeTRANS, a member of EICOSE, the ARTEMIS Innovation Cluster on transportation.

In SPES, OFFIS led the work package ZP-AP3 "Model-Based Architecture Development" within the central project and participated in the work packages ZP-AP1, ZP-AP4, and ZP-AP5 with a focus on the range of topics around "model-based architecture design." This included the development of an integrated, cross-domain approach that can be adapted to the specific requirements of the respective application domains. In addition, researchers from OFFIS were members of the project architecture team that made major contributions towards an integrated model-based methodology.

As a partner in the ARTEMIS project CESAR, OFFIS arranged for synergies related to the CESAR Reference Technology Platform.

University of Kaiserslautern

Software Engineering Research Group: Dependability

The research conducted by the research group Software Engineering: Dependability at the faculty of Computer Science at the Technical University Kaiserslautern focuses on methods for developing embedded software that meets high quality standards. Current goals concern object-oriented methods, especially with respect to applications in safety-critical, highly available real-time systems. In particular, the research considers the ongoing growth of software and its distributed architecture. Many projects are conducted in collaboration with industrial partners.

In the SPES 2020 context, the research group Software Engineering: Dependability worked on the question of how software engineering and safety engineering can be interweaved more closely, e.g., by automatically deriving safety models from the software design and—vice versa—the integration of measures into the software development process to increase safety.

Software Engineering Research Group: Processes and Measurements

The research group Software Engineering: Processes and Measurement at the faculty of Computer Science at the Technical University Kaiserslautern has its expertise in modeling and quantitative prediction of integrated development processes, as well as in empirical analysis of software development methods and tools.

Today, software development projects are characterized by overshooting time and budget limits significantly. The main reason for this is insufficient knowledge of the potentials and limits of particular development methods and tools in a concrete project environment. On the other hand, process modeling methods that would allow coordination of the activities of the individual members of the development team, as well as a progress control with regard to content, are missing.

The work of the research team in SPES focused on developing methods to model complex development processes and to instrument them for prediction and progress control, as well as on the empirical analysis of individual methods and tools.

Technische Universität München (TUM)

TUM is one of the leading universities in Germany. TUM's top performances in research and education, interdisciplinary studies, and talent promotion stand out. Strong alliances with businesses and scientific institutions across the world play a part in this. TUM was one of the first "Universities of Excellence" of the nationwide Excellence Initiative and impressed this cooperative in 2006 with its concept of "TUM. The Entrepreneurial University."

The Department of Informatics attaches high importance to a close link between scientific research and study. The systems and tools developed there are constantly being tested by students and research staff in a practical deployment. In SPES, the chairs Software & Systems Engineering (Prof. Broy) and Embedded Systems & Robotics (Prof. Knoll) were engaged.

Software & Systems Engineering chair

The research and teaching efforts of Prof. Broy's chair Software & Systems Engineering are centered around core topics of software and systems development. This includes foundations, methods, processes, models, description techniques, and tools.

The research focuses on development of critical embedded systems, mobility and context-awareness, and development methods for complex industrial-scale software systems. The methods are supported by a number of research tools. Theorem-proving techniques explore the foundational aspects of software engineering. The methods developed in the group have been validated in various industry cooperations in the telecommunications, avionics, automotive, banking, and business information systems domains.

The chair is involved in an extensive number of basic and applied research projects. Additionally, it offers targeted enterprises specific consulting services, and develops tool prototypes and demonstrators. The Software & System Engineering chair took the overall project lead for the entire SPES project. With regard to content, the research focus was on developing an integrated modeling theory in the context of the SPES central project. Several tools for the development of embedded systems have been provided. Therefore, besides the research of the theoretical modeling theories, these practical competencies were also brought into the project. In addition, researchers from TUM were members of the project architecture team that made major contributions towards an integrated model-based methodology.

Embedded Systems and Robotics chair

The primary mission of the Embedded Systems and Robotics chair is research and education of machines for perception, cognition, action, and control. The chair is organized into four research areas:

Human Robot Interaction and Service Robotics, including work on the integration of speech, language, vision, and action; programming service robots; development of new application scenarios for sensor-based service robots; robot systems for education;

Medical Robotics, covering all aspects of manipulator and instrument control for complex surgical procedures, e.g., visualization of all types of patient data, haptic feedback for delicate handling, skill transfer, shared control, multimanipulator cooperation;

Cognitive Robotics, encompassing a comprehensive area of topics ranging from sensor models by the way of individual sensor processing entities (e.g., for high-speed face tracking) to high-level cognitive skills for navigation, adaptation, learning;

Cyber-Physical/Embedded Systems are investigated with special emphasis on fault tolerance and high availability; special topics are the design of very small redundant systems and the associated software development models and tool chains.

In SPES, the contribution was to provide leading edge technology for developing solutions in the automation area. The focus was on the development of domain-specific tools for the generation of nonfunctional properties (QoS, safety, communication in distributed systems, time-behavior). The analysis of domain concepts, development of middleware architectures, and comprehensive code generation were given prominence.

University of Duisburg-Essen – The Ruhr Institute for Software Technology (paluno)

Created in 2003 by the merger of the University of Duisburg and the University of Essen, the University of Duisburg-Essen is the youngest university in North Rhine-Westphalia and one of the ten largest universities in Germany. In many disciplines, the University of Duisburg-Essen ranks amongst the top ten German research universities. Over the past three years, research income has increased by approximately 100 percent.

In 2010, the research institute "paluno – The Ruhr Institute for Software Technology" at the University of Duisburg-Essen was founded. Paluno's six professors and their research teams bring in experience from application domains as diverse as insurance, automotive, healthcare, energy, and logistics. Their competencies cover most phases and layers of software engineering. With partners throughout Europe, paluno researches and applies methods and tools for design, implementation, and operation of future software-intensive systems. Paluno's research and transfer paradigm encourages mutual benefit from basic research, applied research, and bilateral industry cooperation.

In SPES 2020, the research team of Prof. Pohl, together with Bosch, led the work package ZP-AP2 on model-based requirements engineering. Paluno coordinated all activities in the area of requirements engineering within the central project and within the application projects. In addition, paluno co-led the research activities in the application domain "energy." paluno's main contribution is the development of a methodology for model-based requirements engineering of embedded systems.

In addition, researchers from paluno were members of the project architecture team that made major contributions towards an integrated model-based methodology.

University of Paderborn – Software Engineering Group

The Software Engineering Group of the University of Paderborn is headed by Prof. Dr. Wilhelm Schäfer. The main research topics are model-driven, component-based development and analysis of software, including techniques based on UML (Unified Modeling Language). Embedded or mechatronic systems with real-time and safety-critical constraints, as well as business information systems, are considered as target domains. Further research areas include approaches for reengineering and the object-oriented specification of software process models.

The Software Engineering Group participates in several national and international research projects, often in close cooperation with partners from industry. The group is a founding member of the Software Quality Lab (s-lab), undertaking industry-driven research with a strong focus on software quality, and has a long tradition in cooperating with research groups from mechanical and electrical engineering of the Heinz Nixdorf Institute. In particular, the cooperation with the Product Engineering and Control Engineering Groups recently led to the formation of the Fraunhofer Project Group on Mechatronic Systems Design, which is located in Paderborn and belongs to the Fraunhofer-Institute for Production Technology IPT. Prof. Schäfer is a member of the board of directors of the project group and scientific director of its Software Engineering Department.

In SPES, the Software Engineering Group, together with s-lab and Fraunhofer IPT, participated in the automotive application project. In addition, Prof. Schäfer was deputy coordinator of this application project. In cooperation with the automotive supplier Hella KGaA Hueck & Co., the project developed a seamless model-based design methodology that complies with the maturity model Automotive SPICE. The methodology partially automates the transitions between the different design phases and viewpoints (from requirements to AUTOSAR) in a systematic way, with a strong focus on consistency and traceability. A further focus was on the integration of tools that allow the simulation of functional and real-time behavior in early development phases. In order to incorporate the results into the central project, the Software Engineering Group further contributed to the first three work packages of the central project.

E – List of Publications

K. Pohl et al. (eds.), *Model-Based Engineering of Embedded Systems: The SPES 2020 Methodology*,
DOI 10.1007/978-3-642-34614-9, © Springer-Verlag Berlin Heidelberg 2012

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