IST-004527 ARTIST2
Network of Excellence
on Embedded Systems Design

Cluster Progress Report for Year 4

Cluster:
Real-Time Components

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Policy Objective (abstract)

The development of a general framework for component-based engineering of complex heterogeneous embedded systems is a grand challenge, which the cluster addresses by

- developing a conceptual and technical basis for component-based design of heterogenous systems,
- integrating tool support for modeling systems and predicting their properties,
- developing a proposal for a UML-based standardised modelling language for RT Embedded Systems.

Table of Contents

1. Overview

The Real-Time Components (RTC) cluster was formed in Oct. 2005 by merging the former two clusters on Hard Real-Time (HRT) and on Components. It consists of three activities:

- **Platform: Components Platform for Component Modelling and Verification** (this was the platform-related activity of the former Components cluster, it continues as such). Responsible is Susanne Graf, VERIMAG.
- **Cluster integration: Development of UML for Real-Time Embedded Systems** (this was the standard-related activity of the former Components cluster, it continues as such). Responsible is Sébastien Gérard, CEA.
- **Cluster integration: Component-Based Design of Heterogeneous Systems.** This activity replaces the previous activities *Forums with specific industrial sectors* and *Seeding new research directions*. Responsible is Bengt Jonsson, Uppsala University.

Each of the above 3 activities is reported in a separate Activity Deliverable. This cluster deliverable gives an overall condensed view of activities in the cluster as a whole.

1.1 High-Level Objectives

The objectives of the different activities in the cluster were as follows.

- **Platform: Components Platform for Component Modelling and Verification**: to initiate and strengthen the discussion and collaboration between existing national and European initiatives with the aim of building platforms for model-based development. A second objective was to launch some new initiatives involving Artist and external partners. The first of these federative initiatives were *the French platform project OpenEmBeDD and the IP SPEED, a newly created federative project is the European Combest project.*
- **Cluster integration: Development of UML for Real-Time Embedded Systems**: Initial objective was to contribute to set up the OMG standard for the UML profile for Modeling and Analysis of Real-Time and Embedded Systems (MARTE). *This profile has been globally accepted in June 2007 and is under finalisation process for final adoption in December 2008 through works of the Finalization Task Force. The current objective is to finalize and disseminate the standard, as well as to obtain support for it in various projects and communities, particularly in the automotive and avionics domains.*
- **Cluster integration: Component-Based Design of Heterogeneous Systems**: The activities in the cluster are conducted along three lines with corresponding objectives as follows:
    - **Design of Heterogeneous Systems:** To develop a unifying semantic and conceptual framework for composition of heterogeneous system components. *The BIP and Tag Systems frameworks have been established and used in applications; the concept of expressivity has been defined and analyzed; frameworks for distributed deployment have been developed.*
    - **Interfaces and Compatibility:** To develop techniques for smooth composition of component-based systems. *Theories for interfaces have matured; techniques for verifying contracts and system behaviour have been developed; techniques for synthesis of glue and controllers have been advanced further.*

- **Industrial Liaison***:* To finalize the reporting from the 2005 workshop *Beyond AUTOSAR,* and to conduct an industrial meeting on Integrated Modular Avionics (IMA)*. This meeting was held November 12-13 in Rome at the PARADES offices. Speakers included key persons from Airbus, Dassault-Aviation, Israeli Aerospace Industries, Honeywell and Windriver, plus John Rushby and ARTIST2 participants.*

More detail can be found in the corresponding activity deliverables. In this cluster deliverable, we present an overall view of research activities in the cluster that relate to its general research topics.

1.2 Industrial Sectors

The cluster activities are relevant for industrial sectors in which a major challenge is the need for mastering system integration of complex heterogeneous embedded systems. Several activities focus particularly on the transporation sectors, including the automotive and aeronautics sectors, and some activities have started this year in the sector of energy efficient buildings.

Our society at large depends on the transportation sector to meet the increased demands on mobility required for achieving sustained economic growth. Relative to year 2000, ERTRAC, the European Road Transport Research Advisory Council[1], expects a 32 % increase in individual demand for travel by 2020, and a 38 % increase in goods transport by 2010. ACARE, the Advisory Council for Aeronautics Research in Europe[2], expects a three fold traffic density by 2020 for civil aircrafts. ERRAC, the European Rail Research Advisory Council[3] projects for 2020, that overall transport demand will have grown by 40 % for passengers to 7500 billion passenger-kms and 70 % for freight to 6000 billion ton-kms.

This increase in mobility must not decrease the level of safety achieved today. Expressed in terms of fatal accidents per 100 million person-kms, there was 2003 a 0.7 risk level when driving in cars whilst both flying and using trains is 20 times less risky. Within the automotive domain, we have seen in the last three decades a 50 % reduction of fatal accidents and an 80 % reduction of risk for fatal accident per person-km. The European commission has launched the eSafety Initiative and the Intelligent Car Initiative to assure a further 50 % reduction of road accidents by 2010 and a 70 % reduction by 2020.

The construction and buildings sector consumes enormous amounts of energy, clean water, and materials. Buildings use about one-third of the world's energy — a proportion that will continue to increase as the population grows and becomes more urban and more affluent. In the United States today, the building sector accounts for 40% of the primary energy use, compared to 32% for the industrial sector and 28% for the transportation sector. The use of electric power and heat in the buildings sector also accounts for about 40% of U.S. greenhouse gas emissions. If current trends continue, buildings worldwide will become the top energy consumers by 2025, and are likely to use as much energy as industry and transportation combined by 2050 (US Department Of Energy 2007).

More effective stewardship of resources contributes to the security, environmental sustainability, and economic well-being of the nations. Buildings present one of the best opportunities to economically reduce energy consumption and limit greenhouse gas emissions. Improving how buildings are designed, built, operated, renovated, and recycled could

[1] http://www.ertrac.org

[2] http://www.acare4europe.com

[3] http://www.errac.com

significantly alter how buildings use energy and other basic resources. This challenge will require the development of new, cost-effective building technologies, practices, and standards, the revision and revalidation of building requirements, and the holistic design of energy and resource use within the building, building site, campus, and community.

A key enabling technology to achieve these objectives are embedded systems, that is hardware-software systems realizing key functions for vehicles and vehicle coordination in all three transportation domains, as elaborated below for the automotive domain. Examples of current technological shifts in the domains are briefly indicated below.

- **Aeronautics:** This sector is faced with the challenge of Integrated Modular Avionics (IMA), which drastically changes the OEM/supplier relations. Integration will occur at the level of functions, not any more at the level of packaged hardware modules and devices. Therefore, OEMs are faced with the need of mastering system integration at all levels of the design process (from requirements to hardware). This move will drastically impact how certification will be performed in the future.
- **Automobile:** The move is similar to that in aeronautics, the changes being in fact much more rapid and drastic – within a few years, the OEM/supplier chain will be entirely reconfigured. Added value, for OEMs, will move to completely different components of the car, namely those mostly contributing to building the “concept” and “personality” of each different car. Sharing platforms with competitors is now the trend, as shown by the **Autosar**[4] initiative. . The quest for value added will create stress in the supply chain as Tier 1 suppliers will position themselves as essential providers of electronic content while OEMs will take the lead in extracting value from integration and product conception from mechanical components all the way to software components.
- The **railway sector** shares an increasing reliance on embedded software as well as growth rates with the automotive and avionics sectors. To enhance train based transportation in Europe, the European Commission under TSI Interoperability Directive 96/48/EC and 2001/16/EC is requiring its member states to adhere to the European standard on Rail Traffic Management/ European Train Control Systems (ERTMS/ETCS) guaranteeing interoperability of safety related electronic train components together with a migration road map defining different levels of functionality. At the highest ETCS level, the overall task of collision avoidance between trains while maintaining (as secondary objective) a smooth flow of trains is realized through a complex interplay between the interlocking system and on-board components, using so-called RadioBlockCenter (RBC) Units as interface
- The **building sector** is not as sophisticated in the use of technology as the transportation system. This situation offers both a great potential for improvement and a great challenge to elevate the technology competence of the players involved (the supply/design chain is more articulated than in the transportation sector). By introducing embedded control and wireless technology for sensors communication without much effort, savings of the order of 30 to 40 per cent have been shown to be achievable. Buildings being distributed systems share several of the technical challenges faced by the transportation sector: many heterogeneous components have to interact to deliver a solution to the efficiency problem. The more sophisticated a building (like cars a few years ago), the more complex is the task of managing its operation.

The transportation sectors are currently driving innovation in the area of system level integration of complex heterogeneous embedded systems, for the following reasons:

[4] http://www.autosar.org

- Research related to real-time components in the area of *automation* is still mostly academic, with the industrial move being hampered by the lack of agreed formal bases for the IEC 61131-3[5] and IEC 61499[6] standards for distributed control systems.
- Regarding the area of large information systems (such as military systems, air traffic control systems, telecommunication network systems…), the main focus is on component-based software development in general, with a lesser emphasis on real-time aspects.

In buildings, the coordination of several services such as fire detection, security and comfort (air conditioning), resource distribution (e.g., water, natural gas and electricity), requires component-based thinking. Integration issues induced by the heterogeneity of the services offered go even beyond the issues to be faced in the transportation sector.

Also robots are complex autonomous embedded systems. For a long time, these systems have only been considered from an AI perspective. Proposing adequate component-based system architectures is an important issue in this domain, especially when robots ensure safety or mission critical tasks. Such systems must in general embody an adaptivity to evolutions of the environment which is much stronger than for example in transportation systems, and still respect hard timing constraints.

Both model- and the component-based development approaches allow integration problems to be handled at the earlier phases of system design. Component properties that have global system impact, notably properties of timing and resource consumption, can be specified in interfaces in such a way that global resource usage can be predicted a priori, avoiding hard problems in system integration. The research goals of the cluster address these challenges.

- Wider adoption of model-based approaches will be supported by standards for modelling of Real-Time Embedded Systems (MARTE), as well as by the availability of tool chains for design (e.g. www.papyrus.org), transformation and analysis that are based on such standards. These issues are addressed in both activities on *Platform for Component Modelling and Verification* and *Development of UML for Real-Time Embedded Systems.*
- Composition of models developed for different parts and viewpoints needs techniques for dealing with heterogeneity in design flows. This includes mixing different styles of scheduling policies (e.g., Event-Triggered and Time-Triggered), as well as mixing different Models of Computation.
- The penetration of mobile and wireless embedded systems into traditional domains such as automation, process control, and building automation require an integration of existing knowledge in the field of real-time systems, dependable systems, modelling and component design with the knowledge of mobile embedded systems.

Further technical discussions are needed in order to understand how these problems can be handled in the context of industrial system development.

1.3 Main Research Trends

To meet the research goals of the cluster, the following research trends within the scope of the RTC cluster have emerged as being of particular importance:

[5] http://en.wikipedia.org/IEC_61131-3

[6] http://en.wikipedia.org/IEC_61499

- Fostering the usage of model-based approaches for designing and analysing real-time and embedded systems relying on standards. The UML profile for Modelling and Analysing Real-Time systems (MARTE), which has been now accepted by OMG, will be a keypoint for developing such model-driven approaches. This standard provides an opportunity for academics to promote their results in terms of formal analysis of real-time systems in a way that may be accepted by industrial users. Indeed, it supplies both the abstraction needed by users to describe their systems, and the facilities to bridge a UML models annotated with MARTE extensions and real-time analysis tools relying on formal techniques.
- Integrating tool support for different development activities, including tools to model systems, and to analyse and predict system properties. To achieve this aim, several projects had been launched already before Artist, for example Safeair, Wooddes, Omega and Modelware. Artist has taken up on these earlier results in the context of a series of projects in which the main objective is theory and toolsupport for integrated model-based system design and making different analysis and development tools interoperable. The main projects are, the national projects OpenEmBeDD, “Usine Logiciel”, and AVACS, the IPs ASSERT and SPEEDS, the STREPS ATTEST and the newly started Combest, and the SPICES ITEA project.
- Specifying and determining extra-functional properties of components and component-based systems, in particular timing, performance, reliability, QoS, memory, and power. Particular problems include capturing the dependency on the characteristics of the underlying platform in a modular way, and specifying different extra-functional properties simultaneously in a both modular and consistent manner.
- Handling heterogeneous system descriptions combining in a mathematically sound way the above functional and extra-functional properties as well as system-design aspects produced by different teams at different stages of systems development. This is essential in allowing for a seamless transmission of the different design aspects (safety analysis, functional design, architecture dimensioning for performance, etc) between different teams.
- Integrating several applications into one (distributed) execution environment. This activity requires a suitable integrated architecture of heterogeneous systems.
- Developing design methodologies and tools that allow architectural space exploration that include distributed platforms such as wired networks of ECUs and wireless infrastructure as well as centralized physical architectures such as Systems-on-Chip (SOCs).
- Developing methods for the design of advanced SoCs. SoCs are bound to be even more critical components in tomorrow’s embedded systems with the advent of multicore processors. The trend for SoCs is to consider them as logically distributed systems as the number of processing units that can be placed on a single chip increases (see the latest quadcore offerings by Intel and AMD, with roadmaps that call for chips that include 8, 16, 32,… cores) and the delays due to interconnects grow to become the dominant factor in performance.
- Developing design methods and supporting tools for energy efficient buildings. Energy efficiency requires a better use of control techniques to adapt energy consumption to users’ requests and environment conditions. These control techniques must take into consideration complex interactions among subsystems that are intrinsically heterogeneous since they deal with many different physical variables in different locations. The control implementation architecture can be centralized or decentralized.

In the case of decentralized implementation, the design of the network that interconnects the controllers, sensors and actuators becomes crucial.

2. State of the Integration in Europe

2.1 Brief State of the Art

The development of a general framework for component-based development of heterogeneous embedded systems is a grand challenge which spans several research topics. A central goal is to support model-based development by progress on formalisms for modeling components, systems and architectures, progress on mappings between and combination of modeling formalisms, techniques for guaranteeing composability of models and components, and techniques for generation of target specific code that behaves faithfully w.r.t. the validated models. A common goal of these topics is to pave the way for better design tools for model- and component-based development.

Component based software design environments already exist that target not only embedded resource constrained systems. An examples is the FRACTAL component model[7] and toolset[8] These approaches does not take into account any behavorial specifications, but they have demonstrated to be successful for designing efficient systems, even in the embedded domain, they encompass both software architecture modelling and executable code generation [PMSD07].

There are currently design tools for the domain of embedded systems, in which systems are designed by putting together pieces that could be termed components. Examples are MetaH[9], Ptolemy[10], and Metropolis[11]. The functions of these tools are in some sense analogous to, e.g., MATLAB/Simulink but some (such as Metropolis) are not limited at the functional description and simulation of designs but include also the link to implementation in physical platform as an integral part of their design. The advantage is that they support a variety of design notations, thereby supporting heterogeneous system design in a syntactic sense. However, “components” can be assembled only in the supporting tool, meaning that different systems and components must all be developed in the same environment (tool) to stay compatible, with the exception of the last version of Metropolis, Metropolis II where foreign tools and heterogeneous descriptions can be accepted and handled. Another class of tools includes environments adopting the “synchronous approach”, such as SCADE or Esterel Studio, which also include tightly integrated and powerful verification tools at the expense of sacrificing the ability to analyze heterogeneous models. For wider adoption of model driven development, it would be desirable with equally powerful tools with verification support in tools for modelling languages adopting the “asynchronous approach” or even a mixture of modeling approaches. Current tools for asynchronous modeling in UML-based formalisms (Artisan, Rhapsody, RoseRT, TAU) have a weaker verification support than e.g., SCADE or Esterel Studio, and there is also a lack of standardized formalisms for modeling real-time embedded systems.

UML emerged in recent years as a modelling standard for software, including also software for embedded systems for which specific UML profiles have been developed. Since several years, the Object Management Group (OMG) had adopted the UML Profile for Schedulability, Performance, and Time (SPT) to model real-time concerns. However, the SPT profile has

[7] http://fractal.objectweb.org

[8] http://think.objectweb.org

[9] http://www.htc.honeywell.com/metah

[10] http://www.ptolemy.eecs.berkeley.edu

[11] http://www.gigascale.org/metropolis

several shortcomings, and there has been a need for modifications to comply with the evolution of other OMG standards, and to have a profile with a broader scope. This has resulted in a Request For Proposals (RFP) for a new UML Profile named MARTE (Modeling and Analysis of Real-Time and Embedded systems, which recently has been already approved. It addresses issues such as compliance with the UML Profile for Quality of Service and Fault Tolerance (QoS & FT), specification of not only real-time constraints but also other embedded QoS characteristics such as memory and power consumption, modelling and analysis of component-based architectures, and the capability to model systems in different modelling paradigms (asynchronous, synchronous, and timed).

The situation concerning tools to analyse systems modelled in UML is not satisfactory. There exist a number of tools for the analysis and verification of functional and timing properties of system models, such as as the Kronos and IF tools (developed at VERIMAG), Uppaal (developed at Aalborg and Uppsala), Hytech (developed at Cornell and Berkeley), the Metropolis tool (developed at PARADES and Berkeley) and several others. The effort made in some recent projects, such as OMEGA, has lead to some encouraging results concerning validation of UML designs [GBC05,GOO06]. The SPEEDS IP-project gathers as core members academic partners with an important back ground in validation and modelling (INRIA, OFFIS, PARADES, and VERIMAG), industrial partners developing software modelling and development environments (Esterel Technologies, Telelogic, TNI, GEENSYS, and Extessy) as well as important users from the embedded systems domain (such as Airbus, EADS, Saab, Bosch, Carmeq, KnorrBremse, and Magna Steyr). The aim of this project is to improve the current situation with respect to analysis methods in a distributed design environment and for systems which may be distributed. An important aspect here is keeping design (and code generation) synchronised with verification. That means that the models used for verification must be obtained automatically from the design models, which obliges the use of some form of compositional verification. For compositional verification exploiting the component structure, we rely on the structural verification of deadlock freedom proposed for BIP [BBSN08].

As stated above, a crucial issue for component-based embedded systems is *heterogeneity* of component models. This heterogeneity concerns different execution models (synchronous, asynchronous, vs. timed), communication models (synchronous vs. asynchronous), as well as different scheduling paradigms. To allow designing heterogeneous embedded systems from diverse types of components, we must develop a coherent ***theory for building complex heterogeneous systems*** which addresses, e.g., the issues of composability and compositionality, and allow predicting and optimizing functional and non-functional properties of the designed systems. Such a comprehensive theory is missing today, thereby making it difficult to understand how to build systems that combine, e.g., synchronously and asynchronously executing components and reason about non-functional properties. First steps have been performed by the group (comprising RTC partners) consisting of A. Benveniste and B. Caillaud (INRIA), L. Carloni (Columbia University, New York), P. Caspi (VERIMAG), A. Sangiovanni-Vincentelli (PARADES and U.C. Berkeley), and S. Tripakis (VERIMAG and Berkeley Candence Labs.) with the work on *Tag Systems,* where systems executions are seen as partially ordered sets of events labelled with *tags* to capture the different aspects of design, both functional and extra-functional (series of papers at Emsoft conferences every year since 2002).

Another crucial issue is to guarantee composability of components by techniques for **component interfaces,** in particular for **non-functional properties.** This involves modelling, specification, prediction, tool support of such properties. It is widely recognized that such technology should be based on a *rich component model* (this concept used in [BBB+00]), which allows to model, specify, and predict timing, QoS, and resources properties of components and of systems composed from components. The *OFFIS* team has developed the Rich Component Model concept for embedded systems design into a framework that allows specifying and verifying functional and non-functional requirements, as well as their horizontal,

vertical, and inter-viewpoint composition at different abstraction levels [DVMJ05]. This will allow to boost the level of re-use in electronic control unit design, while the proposed framework covers the complete development cycle, that is from high-level specification models to design models, allowing informed decisions to be made for the implementation phase. Metropolis uses the notion of quantities and quantity managers to represent and handle non functional properties of systems. The quantity managers allow the concurrent analysis of multiple non functional properties [BWH+].

The main current architectures that support the integration of multiple heterogeneous subsystems onto a System-on-Chip (SoC) are the following: The Æthereal architecture that provides a shared memory abstraction synchronized via TDMA between different SoC components. Æthereal provides encapsulation of components but does not support the aligment of application timing to message schedules. The Sonics SiliconBackplaneNetwork is a commercial on-chip network that supports logical connections between components and that is based on the Open Core Protocol (OCP) standard. The interface operates on signal level and provides bandwith guaranties and bounded latency. The Cell Broadband Engine Architecture has been developed by Sony, Toshiba and IBM for the Cell multi-core architecture. The network structure consists on end-to-end communication links between 9 components on a shared communication bus. Due to the shared bus, this architecture does not scale to systems with a higher number of components. Scalability has been a central issue in the development of the SHAPES architecture by ATMEL and INFN. The SHAPES architecture consists of multi-processor tiles of small processors that can be connected by 3D toroidal distributed packed-switched networks. On each of the multi-tile chips the routing software is responsible for managing the parallelism and thus the achievable scalability of the communication network.Worth mentioning are the efforts by NXP towards constructing multiprocessor systems that are predictable and composable. To reduce system complexity, testing and integration costs, their systems use budget schedulers and provide guaranteed time budgets to tasks to provide for the temporal isolation of software activities. As a feasibility study, a prototype multiprocessor system consisting of 5 cores and an NoC interconnect has been implemented on an FPGA.

Currently available support for non-functional properties in component interfaces include specialized technologies, exemplified by the *Rubus* component model [IN02], that have been developed for particular embedded systems domains. These provide some limited support for handling QoS and resource usage, but only in rather limited situations. To improve this situation, it would be desirable to be able to use the rich flora of existing techniques for specification and analysis of QoS properties. To specify timing properties, different variants of timed automata can be used, as in, e.g., the *Omega* component model [DJPV05], which has a semantics in terms of the IF language, supported by timed automata. For other types of properties, e.g., relating to queuing and performance, models based on queueing networks, Markov chains, etc. have been used. These approaches offer a precise mechanism for specifying and analysing QoS properties. A potential problem is that analysis may not always scale to systems with large numbers of components. For instance, standard schedulability analysis for simple fixed priority scheduled systems typically scales better to large numbers of components than does analysis of systems whose components are specified in detail by timed automata.

Designing components for reuse calls for a system of program annotations rich enough to ensure that the components will interact in a coherent manner when connected together. The dynamic information about the interactions of the component with its environment combines expectations of the component about its environment with guarantees offered in return by the component to its environment. L. de Alfaro and T. Henzinger introduced for that purpose *Interface Automata*, viewed as enriched type systems (the so-called *Behavioral Type Systems*), which capture the temporal aspects of software component interaction. A component refines another component if it imposes less constraint about the environment and

offers more guarantee in return. We obtain in this way a compositional semantics due to the fact that a component can be replaced with a more refined version in any environment compatible with the original component: The refined version may offer more services but both are equivalent in restriction to the set of services of the original component; this situation is reminiscent to the sub-class polymorphism in object-oriented programming. A first extension of this work to timing properties is the work of *timed interfaces* (de Alfaro, Henzinger, Stoelinga) [dAHS02].

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2.2 Main Aims for Integration and Building Excellence through Artist2

2.2.1 To develop a common foundation for building of component-based heterogeneous systems

Integration results from promoting and developing this research area in the following ways:

- Since heterogeneity by essence involves different aspects of design, then different sub-communities of embedded systems area are interested in this subject, e.g., control, real-time, and hardware.
- Therefore, this subject is a crossing point for several ARTIST2 clusters, in particular RTC, Execution Platforms, and Control for Embedded Systems. In fact, these clusters have been participating to the RTC events where this topic was discussed.

Excellence is revealed by the tight links the RTC community has with the leading teams in the US, e.g., belonging to the CHESS project mentioned above, and also by its involvement in a significant number of European research projects (including IPs and STREPs).

2.2.2 To develop and disseminate a more coherent view on handling timing and QoS properties in component-based systems for RTES

In view of the need to develop a widely adopted technology for component-based development of embedded systems, it is vital to strive for convergence between European research teams working on this topic. ARTIST2 aims at providing generic solutions to the key technical problems in this endeavour, and to achieve convergence by means of collaboration between research teams, as well as in-depth contacts with industry in order to understand industrial requirements on this problems and to point out possible technical solutions (as has been the objective of, e.g., the workshop *Beyond Autosar*).

2.2.3 To contribute such a view in UML standardization of RTES aspects

Integration results from in one hand promoting research results of European laboratories in the future UML standard for Real-Time and Embedded systems and in other hand from making the link between the European industry needs in this domain (e.g. Thales and Volvo) and the standard itself. Both ADAMS and ATESST (1 and2) projects are definitively good proof of integration results and common works accomplished by ARTIST partners.

Excellence is revealed by the links the RTC community has with the US and Canadian leading teams also involved at OMG to work on the MARTE standard.

The inclusion of an annex for modelling with AADL in the UML profile for MARTE has initiated an approximation to the AADL standardization group whose version 2 is about to be approved. This connexion is contributing to clarify semantics in both modelling languages and reinforces the transatlantic links hold by these two communities.

2.2.4 To synchronize European efforts on modelling and development tools

Work towards a better integration of validation technology into development suites based on standard or quasi standard modelling languages is the aim of the platform activity of the cluster. For achieving this aim, we take advantage of the modelling frameworks for hetergeneous systems developed in the cluster for allowing a unified representation of models from different frameworks and for sharing validation tools. This aim is shared by a number of national and European collaborative projects initiated by the participants of the cluster. The effort also achieves other important effects: it harmonizes concepts developed by different

groups to avoid fragmentation, it achieves greater impact both scientifically and towards industry in that the combined efforts of several research teams may be combined.

Excellence is revealed by the strong involvement of Artists2 members in many important projects aiming at building such tool platforms, and in particular, by the fact that the important tool builders of the domain – except for Matlab –participate in some way in these projects.

2.2.5 To tighten the links between the academic community and driving industrial sectors such as automobile, avionics, and telecommunications.

Better integration between the academic community and the above mentioned driving industrial sectors has resulted from the meetings *Beyond Autosar and Integrated Modular Avionics*.

There is a great deal of interest in industry to develop a business model whereby companies will act as system integrators and service providers for building managers with the ultimate goal of reducing net energy consumption to zero. The essential technical issues to solve in this novel business model are about systems of systems and integration among heterogeneous components. The academic community can help industry active in this sector to develop further this model thus allowing the community to save substantial amount of energy.

The Artemis Joint Undertaking is gaining momentum as the first set of projects is being awarded. Artemis includes essentially all the important companies that make use of the embedded system technology. Several Artist members are involved in Artemis. Parades is in the Governing Board. The relationships between Artist II and Artemis are strong and effective as many Artist academic partners are involved in Artemis projects.

These ties are also extremely important for improving excellence of the European academic community in the area of real-time embedded systems. Improved excellence will result from getting a better understanding of the technical issues raised by these industrial contexts. Symmetrically, excellence will improve if some feedback, from academia to industry, is found of some value by our industrial partners.

2.3 Other Research Teams

Modelling and design of Component based embedded systems is a field which draws on contributions from many different communities, including the general software engineering community. For embedded systems, focus is also placed on non-functional aspects of systems. Some teams are developing techniques and implementing related software tools to model, specify, and reason about timing and QoS properties (ARTIST2 teams include Aalborg, Cantabria, CEA, EPFL, INRIA, Munich, OFFIS, PARADES, Twente, Timisoara, Uppsala, VERIMAG, and others – it is not possible to include a complete list). Some teams perform this work in the context of a standard modelling language, typically UML, to support a model driven development process. (Cantabria, CEA, MdH, OFFIS; TU/E, IRISA, VERIMAG – again, a complete list is not possible). Other teams (FT R&D) experiment with general purpose component models, either being industrial (such as EJB and COM+) or more advanced (such as the FRACTAL model from the objectweb consortium[12]). ARTIST2 teams are very representative for the work done in Europe and worldwide for model-based development to embedded systems; there are also other prominent teams, e.g., in Braunschweig, Munich, UC Berkeley, and Vanderbilt, with whom we have contacts.

The problem of specifying and reasoning about QoS properties of embedded systems recur in many other contexts in embedded system design, e.g., in scheduling, hardware modelling, systems architecture, etc. It is therefore of interest to avoid duplication of work and distil

[12] http://fractal.objectweb.org

essential principles for the treatment of timing and other QoS properties in component-based systems. Important and original work is ongoing on this topic for example at ETHZ, where interface models for timed systems have been proposed, thus allowing for a component based approach to schedulability analysis.

Real-time components are of great interest among researchers in the United States. Some of the top schools and researchers in the area of embedded systems are vigorously pursuing similar avenues. Because of the many ties that the ARTIST2 partners have with overseas institutions, it is natural that there is convergence of research interests and of technical vistas that makes sharing ideas and collaborating quite productive. In particular, we are in deep technical collaboration with University of California at Berkeley (Ed Lee, Shankar Sastry, Claire Tomlin) and in particular with the Center of Hybrid and Embedded Software Systems (CHESS), where two ARTIST2 partners share part-time positions (Tom Henzinger and Alberto Sangiovanni-Vincentelli) and where others have spent extended research visiting periods. In addition, there had been tight collaboration of INRIA, VERIMAG and PARADES with Vanderbilt University (Janos Sztipanovits and Gabor Karsai) and University of California at Berkeley (Ed Lee, Tom Henzinger, Alberto Sangiovanni-Vincentelli and Shankar Sastry) sponsored by the Columbus STREP of the V Framework. Recently there has been collaboration with the Cadence Berkeley Research Labs and in particular, with Claudio Pinello and Stavros Trikpakis who have contributed to the research carried out by INRIA, PARADES and Verimag on deployment of synchronous models on asynchronous platforms. Finally, Bruce Krogh of Carnegie Mellon University, George Pappas and Rajeev Alur of University of Pennsylvania and John Baras of University of Maryland have authored joint papers with ARTIST2 partners and have been reviewers of several EU projects in the area of embedded and hybrid systems.

2.4 Interaction of the Cluster with Other Communities

2.4.1 Involvement in ARTEMIS and promotion of the area

Several RTC Cluster partners, including CEA, INRIA, OFFIS, PARADES, VERIMAG; and TU Vienna, are actively involved in ARTEMIS, an initiative to form a European technology platform on embedded systems supporting the needs for various industrial and academic embedded application domains, such as the automotive, avionics, but also the real-time requirements of consumer electronics. The interaction with ARTEMIS is expected to influence the work within ARTIST2 positively towards establishing a well-defined conceptual fundament that is useful for academia and industry. Several partners (CEA, INRIA, OFFIS) are involved in EICOSE, the recently establised European Institute for COmplex and Safety Critical Embedded Systems Engineering pushed by two French clusters System@tic Paris Région and Aerospace in association with the German cluster SafeTrans. EICOSE has been selected as the ARTEMIS Innovation Cluster on Transportation. VERIMAG and FT R&D contribute within French MINALOGIC cluster to promote the creation of a center of excellence in ARTEMIS encompassing "Nomadic environments" and "Private space" application contexts of the ARTEMIS SRA chart. Contacts have been taken with Nokia and ElectroBit from the Finlandais Symetra Consortium.

The Joint Undertaking Artemis has been created in February 2008, and is about to close the evaluation of proposals submitted to the first call of the Artemis Joint Undertaking. As described above, EICOSE has played an instrumental role in coordinating the research prioirities of both industrial and academic stakeholders in the transportation domain, contributing significantly to the Artemis Multi Annual Strategic Plan in the formation of three out of eight subprograms also forming the basis for the 1st call. Both OFFIS and CEA are members of the EICOSE steering board.

VERIMAG and EPFL jointly produced a position paper [HS07], which summarizes some current trends in embedded systems design and point out some of their characteristics, such as the chasm between analytical and computational models, and the gap between safety-critical and best-effort engineering practices. The work calls for a coherent scientific foundation for embedded systems design, and discusses a few key demands on such a foundation: the need for encompassing several manifestations of heterogeneity, and the need for constructivity in design. This paper argues that the development of a satisfactory Embedded Systems Design Science provides a timely challenge and opportunity for reinvigorating computer science. Based on this work, EPFL has been working with PARADES on capturing the foundations of predictability and robustness in embedded systems. We have formalized predictability as a form of determinism, and robustness as a form of mathematical continuity.

PARADES [SV08] published a paper that debates whether a unified design methodology across several application domains and abstraction layers is indeed possible. The paper concludes that this methodology exists (PBD) and needs to be widely deployed.

References

[HS07] Thomas A. Henzinger and Joseph Sifakis, The Discipline of Embedded Systems Design. *IEEE Computer* 40(10): 32-40 (2007)

[SV08] A. Sangiovanni-Vincentelli, *Is a Unified Methodology for System-Level Design Possible?,* IEEE Design and Test of Computers, Special Issue on Design in the Late and Post-Silicon Eras, Vol. 25, N. 4, pp. 346-358, July-August 2008.

2.4.2 Interaction with other ARTIST2 Clusters

Since heterogeneity, as well as component-based modelling and analysis naturally involves different aspects of design, then different sub-communities of embedded systems area are interested in this subject, e.g., control, real-time, and hardware. Therefore, RTC topics are a crossing point for several ARTIST2 clusters, in particular RTC, Adaptive Real-Time, Execution Platforms, Control for Embedded Systems, and Verification and Testing. We provide examples of interactions with these clusters.

- **Execution Platforms:** the RTC cluster (Cantabria, EPFL, INRIA, OFFIS, Timisoara, Uppsala, VERIMAG) and the Exeuction Platforms cluster, jointly organized the workshop on “Models of Computation and Communication (MoCC)”, organized at ETH Zurich on Nov. 16-17, 2006, by Albert Benveniste, Paul Capsi, and Lothar Thiele (http://www.artist-embedded.org/artist/MoCC-06.html). The objective of the workshop was to survey the different activites in progress concerned with MoCC , gather recognised specialists of the different disciplines in order to attempt to get a panorama of the models used by each discipline, their commonalities and differences, and the several attempts that have already been proposed in order to merge these concepts within some unified view. The problem of compositional analysis of timing and resource properties has been the topic of collaboration during ARTIST2. In 2008, it resulted in a joint publication between ETHZ and Uppsala at EMSORT 2008. **T**here are several new collaborations between the execution platform and the Real-time components cluster. Verimag and ETHZ have collaborated on a translation from the analytic DOL performance evaluation tool to the executable BIP. The newly started Combest project has partners from both clusters (Verimag, EPFL, INRIA, OFFIS, Parades for RTC, and ETHZ and TU Braunschweig for the execution platforms). OFFIS and TU Braunschweig have coorganised a workshop on the certification of safety critical software controlled systems.
- **Control:** Several RTC partners (INRIA, PARADES) are prominent members also in the control community (and some of them are members of the HyCON NoE). Several

interactions between the components and control cluster exist. Partners of the control cluster were important contributors to the opening day of the workshop **Beyond Autosar**, which was dedicated to the interaction of distributed embedded software and contro**l.** In year 3, 2 workshops have been organised by participants of different platforms; two of them (at DATE and at CAV) involved partners from the control and component cluster. There are also collaborative projects involving partners from both clusters. In particular, Martin Torngren (KTH) is a core partner in the Control for Embedded systems cluster and collaborates on the "safety critical" platform of the component cluster, in particular through participation in the ATESST project. Short visits have been organised between KTH and CEA in 2008, in order to present work on model based engineering as well as software platforms, and to explore possibilities for joint work.

- **Adaptive Real Time:** TU Vienna is interacting with the group of Eduardo Tovar (ISEP-IPP). Björn Andersson and Rene Cunha from ISEP-IPP participated in the Workshop on Basic Concepts in Mobile Embedded Systems held at TU Vienna, November 2006. Wilfried Elmenreich from TU Vienna was visting ISEP-IPP from May to June, 2007. University of Cantabria has had a fruitful interaction with the group of Luis Almeida (Universidade de Aveiro/IEETA) in the integration of the distributed capabilities provide by the IST-FRESCOR project to the FTT-SE flexible network resource. This continues the effort by Ricardo Marau from Aveiro/IEETA after his visit to Cantabria in 2006. Wilfried Elmenreich submitted his habilitation thesis on "Time-Triggered Transducer Networks" and got awarded the habilitation in 2008.
- **Verification and Analysis:** The very essence of the component platform activities is to integrate component based development with validation. Several cluster partners are also active in the domain of verification and have already good connections to this community. Also several projects, such as the French OpenEMbeDD, the German AVACS, the IP Speeds, the forthcoming COMBEST connect (1) teams working on modelling and model transformation techniques and semantic frameworks and (2) teams working on verification algorithms (3) teams from the execution platform cluster. In 2007, two workshops have been organised jointly with verification and analysis platform partners (see interaction with control cluster). This year, one workshop at least puts a strong aspect on modelling and verification, the workshop on UML and Formal methods. But most workshops focussing on modelling aspects, also include topics on validation.
- **Multi-cluster interactions:** the ARTIST summer schools organised in China and in France involved topics and speakers from several clusters. The topics covered by the summer school in France include Modeling and Validation, Compilers and Timing Analysis, Adaptive Real Time Systems, Control for Embedded Systems, Execution Platforms and MPSoC.

2.4.3 Interaction with the Standardization community

The RTcC cluster has been, through CEA, Cantabria, INRIA and Thales, the driving force in the work of developing a profile of the Unified Modeling Language (UML™) for MARTE (Modelling and Analysing of Real-Time and Embedded systems). CEA is leading the OMG task force in charge of finalizing the standard and dealing with its evolutions.

To get feedback on the profile, several tutorials and presentations have been performed and a specif action project, ADAMS – CSA/FP7, has been submitted to the EC – FP7. This focussed action project has been accepted and started in June 2008. In addition, use and integration of MARTE is in the kernel on numerous industrial collaborative projects, in avionics, automotive, telecommunication and railways (e.g; INTERESTED – IP/FP7, Lambda – Systematic Paris

region cluster, ATESST 2 – STREP/FP7, EDONA – System@tic Paris Région, TIMMO – ITEA, IMOFIS – System@tic Paris Région… Particular concerted actions are done to disseminate this standard to automotive domain by integrating its conceptual elements (meta-model) to AUTOSAR standard (objective, namely, of TIMMO – ITEA project). To support this, CEA has solicited, and been accepted in summer 2008, to become an official AUTOSAR member.

Tutorials on MARTE have been provided in several conferences or summer schools by CEA, U. Cantabria and INRIA during 2007 and 2008 (ARTIST2 Winter School 2007 – MOTIVES, "UML for the design of Real-Time Embedded Systems" - www.artist-embedded.org/artist/Overview,577.html; "UML Tutorial: MARTE", Forum on specification & Design Languages, FDL'07, Barcelona, Spain, September 20, 2007 - www.ecsi-association.org/ecsi/fdl/fdl07/def.htm; "MARTE: A New Standard for Modeling and Analysis of Real-Time and Embedded Systems", 19th Euromicro Conference on Real-Time Systems ECRTS 07) Pisa, Italy, July 3, 2007 - http://feanor.sssup.it/ecrts07/tutorial.shtml). In 2008, Verimag and CEA have coorganised with other partners the 1st International Workshop on Model Based Architecting and Construction of Embedded Systems which evolved from the MARTES workshop.

Continuing and activity started in 2006, PARADES in collaboration with the University of California at Berkeley and Columbia University is participating in the definition of APIs for the Open Access (OA) initiative sponsored by SI2 to connect the standard OA physical information database with system-level design tools.

VERIMAG is involved in the AADL standardisation committee and CEA has established good contacts to Peter Feiler, one of the main drivers of the AADL standard. The platform for component-based modelling and verification includes several tools for handling AADL specifications, in particular, translations from AADL to Lustre and to BIP have been realised with the aim to (1) analysing AADL specifications and (2) providing a formal semantics for AADL. In previous years, Peter Feiler was involved in the MARTES workshop organised by CEA and Verimag. This year, two workshops related to AADL have been organised by Artist: the "*EAST-ADL, AADL, MARTE, Autosar harmonization workshop*" and the workshop on UML&AADL (see section 2.4.9)

2.4.4 Interaction with the automotive industry

Specific effort has been dedicated to interacting with the automotive industry. Recall that the automotive industry is one of the two driving sectors for drastic changes to embedded systems design methods, and is certainly *the* sector where changes have been deepest and quickest. This effort was made possible thanks to prior personal strong ties that some key participants (including: Werner Damm (OFFIS), Alberto Ferrari and Alberto Sangiovanni-Vincentelli (PARADES), Martin Törngren (KTH), Rolf Ernst (U. Braunschweig), Sébastien Gérard (CEA)), and affiliates (including: Stefan Kowalewski (RWTH Aachen)) of ARTIST2 had with the Autosar consortium. Albert Benveniste (INRIA) and Werner Damm (OFFIS) jointly organized the *ARTIST2 Workshop* ***Beyond Autosar***[13], held in Innsbruck on March 23-24 2006. The workshop discussed in particular issues related to timing in the Autosar model (the so-called *timing model* of Autosar). More generally, the workshop helped making the academic community aware of the research issues raised by this approach from automotive industry. An elaboration of the results has been presented at EMSOFT 2006 and at a GM Workshop in Bengalore (January 2007).

OFFIS has become a development member of Autosar. This move was proposed to OFFIS by BMW, following in depth technical discussion on the link between the SPEEDS HRC meta-model and the Autosar meta-model regarding timing and safety aspects.

[13] http://www.artist-embedded.org/FP6/ARTIST2Events/Events/Innsbruck06/

The integrated project SPEEDS has developed a layered meta-model of heterogeneous rich components (HRC) and standardized approaches for the integration of commercial industry standard modeling tools to assemble system-level design models with rich interface specifications by combining models expressed in any authoring tool compliant to the integration standard. A SPEEDS Automotive Day was organized to discuss with the automotive industry how the AUTOSAR methodology can be supported by SPEEDS technologies striving to reconcile the advantage of early system-level analysis with the overall AUTOSAR objective of decoupling function design from its implementation. These results have been presented in several highly visible events, including the DATE 2008 Automotive Day, and a keynote presentation at the Annual Mathworks Automotive Conference 2008 in Stuttgart. More in depth technical discussion on the relation between Speeds HRC model and Autosar were conducted at meetings with BMW, Bosch, and Daimler; see also section on standardization.

Sébastien Gérard (CEA) and Henrik Lönn (Volvo Tech) are organizing a workshop in the context of the ATESST project which aims are inviting key persons working on the context of automotive domain in order to share experience on the usage of standards like MARTE, AADL and Autosar especially in the context of the Architecture Description Language for Automotive, EAST-ADL. They also have setup a new project, ADAMS, (in collaboration with Laurent Rioux from Thales and Julio Mdeina from Cantabria) dedicated to promote the usage of MARTE in the contect of the automotive domain. Let's notice also that this project has to deal also with the aeronautics domain.

MDH has strategic long-term co-operations with seven companies: ABB Corporate Research, ABB Robotics, Arcticus Systems, Bombardier Transportation, CC-Systems, Ericsson, and Volvo Construction Equipment. In recent years, the cooperation has been extended to international subsidiaries and partners of these companies. In addition to this strategic cooperation we have cooperation also with several other Swedish and international companies[14]. The strategy has resulted in substantial industrial support, including a 9.6 MSEK donation from ABB, close to 30 graduate students funded by industry, an industrial lab (currently been set up in cooperation with Ericsson and ABB), a top-talent program for recruitment of international master level students, Ajdunct industrial professors from ABB and Volvo, as well as a large number of national and international joint research projects. The cooperation includes the following concrete results:

- further development of the Rubus component model inspired by the Save component model and its implementation in, e.g., Volvo Construction Equipment,
- development of component repository used at CC systems, including components and additional artefacts such as requirements, models and implementations, tests,
- model extraction tools used experimentally at ABB Robotics for modelling real-time properties of legacy systems,
- introduction of model-based approaches for modelling and developing applications in Ericsson,
- work on software decomposition of legacy systems and transformation of development to product-line development at ABB Substation Automation,
- development of a real-time database in cooperation with Mimer,

[14] Additional national cooperation includes PhD-students funded by Ardendo, Level21, Prevas, and Scania, as well as joint projects with around 10 SMEs; internationally we cooperate both with giants, such as Nokia, Philips, and Tata, as well as with SMEs, such as Symtavision, Absint, and Rapita Systems.

- in cooperation with core partners building a master program in industrial software engineering focussing on design, architectural analysis, component-based development and dependability of embedded systems.

PARADES has tight links with the ST automotive division and with the Joint Development Group ST-Freescale and has helped in defining roadmaps for design methodologies, tools and architectures for fault tolerant products. It has a number of interactions with Tier 1 companies including Bosch and Nippon Denso on this very topic. Alberto Sangiovanni Vincentelli is a member of the GM Science and Technology Advisory Board and has fostered joint work with General Motors on distributed embedded system design. In addition, PARADES has contributed to the design of an advanced intelligent component in a tire that consists of a set of sensors, a computing engine, an energy scavenger and wireless communication with Pirelli.

2.4.5 Interaction with the aeronautics industry

Specific effort has been launched to interacting with the aeronautics industry. This effort was made possible thanks to prior personal strong ties that some key participants (including: Werner Damm (OFFIS), Albert Benveniste (INRIA), and Paul Caspi (Verimag)) had with this industry in EU. RTC cluster felt that it was important that the research community around ARTIST2 was made aware of the scientific and technical issues raised by the move to Integrated Modular Avionics (IMA) approach. Recall that the aeronautics industry is one of the two driving sectors for drastic changes to embedded systems design methods, and is certainly *the* sector where changes are most demanding.

Albert Benveniste (INRIA) and Paul Caspi (Verimag), in tight cooperation with John Rushby (SRI, Stanford), have organised an ARTIST2 workshop on IMA, held on November 12-13 2007 in Rome at PARADES location. Speakers include key persons from Airbus, Dassault-Aviation, Israeli Aerospace Industries, Honeywell and Windriver, plus John Rushby and ARTIST2 participants.

Verimag has recently started a direct collaboration with the European Space Agency ESA which has the objective to adapt results of the OMEGA and the ASSERT project to the needs of the engineers at ESA. A first step consists in an adaptation of the IF tool for UML to UML 2 and to the current version of Rhapsody.

2.4.6 Cross-sectorial Interaction with Industry

Since April 2008, the INRIA team has started a cooperation with a electronics faculty and a local SME (DeltaDore). This company is a national leader in the domain of home and industrial building equipment. A framework for cooperation has been set up in order to transfer know-how on timed component based architectures. This domain of industry is a promising field for the dissemination of embedded, soft real time component architectures. The challenges of this field lie in the frequent evolutions of deployed architectures. These evolutions call for self configurable and self adaptable components.

In future and many state-of-art projects a convergence of different application domains can be observed for different industrial applications (for example, a multipmedia system and safety-critical functions are integrated in a car). In January 2009, the EU STREP project GENESYS (http://www.genesys-platform.eu/) has started with coordination by TU Vienna. The objective of the GENESYS project is to develop a cross-domain reference architecture for embedded systems that can be instantiated for different application domains to meet the requirements and constraints documented in the ARTEMIS strategic research agenda. These requirements are composability, networking, security, robustness, diagnosis, integrated resource management and evolvability. The project will result in a conceptualization of the cross-domain architecture, a specification of cross-domain core services and optional services for the selected application domains, and four exploratory prototypes that will demonstrate and help to

evaluate the feasibility of selected central architectural concepts in the different application domains. The analysis of the requirements and the definition of an architectural style with fundamental principles for cross-domain embedded systems have been completed. The next steps will be the definition of the architectural services, the completion of the methodology framework, the implementation of the prototypes and the assessment of the architecture.

The Inria Triskell team is now part of the S3 (Software Services and Systems) European network of excellence. This network started in March 2008 and will end in 2012. The Inria Triskell team is involved in two joint research activities: adaptation and monitoring principles, techniques and methodologies for service based systems, and End to end quality provision and service level agreement conformance. The Triskell team intends to adapt results gained from Artist cooperation on timed components and use these results in the S3 collaborations in the joint research activities mentioned above. The crossbreed between components for embedded systems (Artist2) and service based architectures (S3) will be supported by experiments in the building automation industrial field. Software architectures in this field require real time, reliability, predictability as well as openness and dynamic reconfiguration.

Within the German Competence Cluster SafeTRANS, two SafeTRANS Industrial focussing on V&V methods and on architecture assessments have been organized, with participants from automotive, aerospace, and rail industries. OFFIS is a founding member of SafeTRANS, with Werner Damm being the SafeTRANS Chairman. SafeTRANS has – through its role as a founding cluster of EICOSE - been as well instrumental in deriving research priorities and subprograme formation for the Artemis Joint Undertaking, see below.

OFFIS is also represented through Werner Damm at the Steering Board level of the German Innovation Alliance on Embedded Systems SPES 2020, which is about to be launched in November 2008. This alliance puts together Academic Institutions and Industrial Stakeholders in Embedded Systems development, providing a foundational basis for applications in multiple industrial sectors, including automation, automotive, aerospace, energy, and medical.

Within the Artemis Innovation Cluster on Transportation, EICOSE, the European Expert Group on Transportation has in several meetings identified research priorities for embedded systems from the perspective of the transportation sector, leading to a proposal of the three candidates for subprogrammes (on cost-efficient methods for the development of safety relevant embedded systems, SP1; on Computing Environemnts for Embedded Systems, SP5, and on Human Centred Design for Embedded Systems, SP8) for the Joint Undertaking Artemis. All three proposals for subprogrammes were after modification integrated in the Artemins Multi-Annual Strategic Work-Plan. All subprogrammes are cross-sectorial in nature, addressing in particular all transportation sectors. From Artist2, Werner Damm from OFFIS as well as Didier Juvien from CEA are members of the Eicose Steering Board, with Werner Damm serving as EICOSE chairman until May 2008.

2.4.7 Interaction with OverseasTeams.

We strive to interact with relevant overseas teams in work on central ARTIST2 topics. We keep close ties with the CHESS project headquartered in University of California at Berkeley[15]. CHESS collects major US teams from key universities[16]. Also, close ties exist with teams working on the area of *Discrete Event Systems* originating from control, as well as the teams working on *Hybrid Systems*[17] and *Communication and Control*[18].

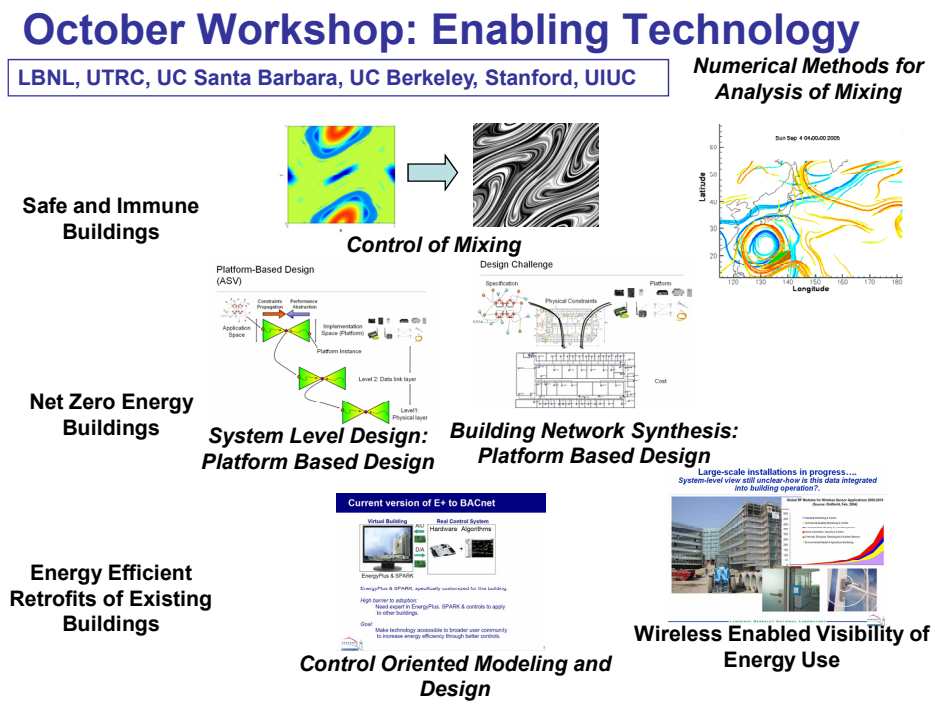
[15] http://chess.eecs.berkeley.edu/ : Center for Hybrid and Embedded Software Systems

[16] http://chess.eecs.berkeley.edu/people/project_personnel/

[17] http://hscc06.csl.sri.com/ is the conference of this domain

A good cooperation contact was established between INRIAs team and that of Iman Poernomo (King's College, UK) on the topic of timed components and the management of stochastic properties of these components. This cooperation has strenghtened in 2007, with a one week stay of an Inria PhD student in Poernomo's laboratory at King's College, UK The cooperation with is now targeting the common definition of an FP7 project proposal on the generation of monitors for distributed component architectures. The monitors supervise the behaviour of the components to detect stochastic anomalies.

Alberto Sangiovanni Vincentelli (PARADES) has an appointment as Professor at the University of California at Berkeley and is instrumental in maintaining close ties with UCB as well as CHESS and the Center for Information Technology Research in the Interest of Society (CITRIS). The recently established Center for Synthetic Biology at UCB offers an interesting application for Artist 2 to explore. The design methods explored at the Center are very similar to some of the design paradigms used in embedded system design such as Platform-Based Design. In addition, a recent initiative of the national Laboratory Lawrence Berkeley Lab of the Department of Energy has launched a partnership among Labs, Industry and Academia (HiPerBRIC[19]) that targets the development of technology for zero energy buildings where Alberto Sangiovanni Vincentelli has a role in the embedded control part of the initiative. In October 2007, Alberto Sangiovanni Vincentelli participated in a workshop where a variety of enabling technologies were discussed as essential elements of the future research. Platform-Based Design, Control Oriented Modeling and Design, and Wireless enables visibility of energy usage belong squarely in the domain of expertise of the Artist II consortium.



[18] See the control conference CDC'2005 http://www.esi2.us.es/~cdcecc05/ where a –plenary has been devoted to this topic.

[19] High Performance Building Research and Implementation Center is an initiative directed by the Lawrence Berkeley National Lab of the Department of Energy of the US which fosters a research partnership among National Labs, Industry and Academia.

TU Vienna has a strong interaction with the Institute of Software Integrated Systems (ISIS) at the University of Vanderbilt (VU). Wilfried Elmenreich from TU Vienna visited ISIS from July to August 2005. Peter Volgyesi shortly visited TU Vienna in October, 2006. Harald Paulitsch from TU Vienna visited ISIS from May to June 2007 participating in the MURI Project titled Frameworks and Tools for High-Confidence Design of Adaptive, Distributed Embedded Control Systems. In 2008 the work on the development of an end-to-end model-based design tool chain prototype for TTP and RTAI Linux within the project had been continued, with the goal to answer the question how one can design and customize model-based design flows targeted towards these types of architectures.

Werner Damm was invited to the strategy workshop on Cyber Physical Systems April 2008 at St. Louis and presented the Speeds model of hierarchical rich components.

2.4.8 Organization of summer schools

The RTC cluster has been strong drivers in the organization of summer schools

- The Summer School on Model Driven Development for Real-time and Embedded Systems (www.mdd4dres.info) in Sept. 2006 in Brest. This was the third edition of this summer school which focuses on model-driven related issues in the context of real-time and embedded systems development. A new edition of this summer school will be held in Spring 2009 in Autrans.
- An ARTIST Summer School on embedded systems design has been organised in in Shanghai, July 12-18 2008, in collaboration with the SEI/ECNU and the LIAMA. This is the third Artist summer school organised jointly with China. The aim is to promote collaboration between European and Chinese research community on embedded systems and related areas. In 2009, a third edition of this summer school is planned.
- An Artist summerschool has also been organised in Autrans, France in September 2008 (http://www.artist-embedded.org/artist/ARTIST2-Summer-School-2008.html). It is the fourth such summer school organised by Artist in Europe, and it is meant to be exceptional in terms of both breadth of coverage and invited speakers. The topics covered in this year's school include Modeling and Validation, Compilers and Timing Analysis, Adaptive Real Time Systems, Control for Embedded Systems, Execution Platforms and MPSoC. A balance is seeked between foundational aspects and applications. Speakers include recognized leading researchers and engineers.

2.4.9 Organization of conferences, workshops, summer schools

The RTC cluster has been co-organizing the following conferences and workshops (for more details: see the deliverable on *Spreading Excellence.*

- Sébastien Gérard (CEA) is also co-organizer of a series of workshops on the UML and AADL. The last edition was hold in conjunction with the 13th IEEE International Conference on Engineering of Complex Computer Systems (ICECCS 2008) in *April 2nd, 2008, in Belfast, Northern Ireland (*http://www.artist-embedded.org/artist/Registration,1370.html*)*.
- Sébastien Gérard (CEA) is also co-organizer of a workshop on UML and formal methods: http://www.artist-embedded.org/artist/New-article,1486.html. This workshop will be held in conjunction with the 10th International Conference on Formal Engineering Methods, ICFEM 2008 (October 27th, 2008, Kitakyushu-City, Japan).
- CEA and INRIA are main organizers of the series of Workshop, MODEVVA (www.modeva.org). The objective of this workshop is to offer a forum for researchers and practitioners who are developing new approaches to V&V in the context of MDE.

The workshop will discuss V&V of model transformations and code generation; techniques for validating a model or generating test cases from models including simulation, model-checking, and model-based testing; application of MDE to validation, testing, and verification; tools and automation; case studies and experience reports. In 2006, the MoDeVa workshop was been co-located with the MODELS/UML conference in Genova (Italia), and in 2007, in Nashville. In 2008, it has been collocated with ICST'2008, Lillehammer, Norway: CEA and Supélec organized the MoVaH 2008, Workshop on Modeling, Validation and Heterogeneity co-located with ICST 2008, Lillehammer, Norge (wwwdi.supelec.fr/fb/MoVaH08)

- VERIMAG is also a co-initiator and co-organiser of the symposium on Formal Methods for Components and Objects FMCO (http://fmco.liacs.nl/fmco07.html) the aim of which is to bring together researchers and practioners in the areas of software engineering and formal methods to discuss the concepts of reusability and modifiability in component-based and object-oriented software systems The 5th issue has been organised in November 2006 in Amsterdam; In 2007 has taken place a special issue bringing together groups of a set of related EU projects and NoEs; Artist2 is one of those groups. In 2008, the organisation has been taken over by a new group of people.
- Albert Benveniste (INRIA) and Paul Caspi (Verimag), in tight cooperation with John Rushby (SRI, Stanford), and with local support by Alberto Ferrari and Alberto Sangiovanni Vincentelli (who chaired the meeting) at PARADES have organized an ARTIST2 workshop on Integrated Modular Avionics (IMA), held November 12-13 in Rome at PARADES location. Speakers included key persons from Airbus, Dassault-Aviation, Israeli Aerospace Industries, Honeywell and Windriver, plus John Rushby and ARTIST2 participants. See http://www.artist-embedded.org/artist/-ARTIST2-meeting-on-Integrated-.html
- Tom Henzinger, EPFL, and Werner Damm, OFFIS, have organized the Second International Workshop on Foundations of Component-based Design, held at the Embedded System Week in Salzburg on Sep 30, 2007.
- CEA LIST (Christophe Gaston) and Supélec (Frédéric Boulanger) co-organized the MoVaH workshop (http://wwwdi.supelec.fr/fb/MoVaH08/) at the ICST 2008 conference in Lillehammer in April 2008. The topic of this workshop was the modelling and validation of heterogeneous systems.
- MdH organized the workshop COMES'08) on Component Models for Embedded System. This was a workshop with limited number of attendance to foster intensive interactions, supported by the PROGRESS research centre, MRTC, and ARTIST2. Its aim was to present and discuss the current research and practical results in development of embedded system using component-based development approaches, as well as to discuss and point out the challenges and possible solution directions in applying the component-based approach to achieve predictability of component-based embedded software systems. The workshop was lively, with over 30 participants from PROGRESS and the international research community. http://www.mrtc.mdh.se/progress/COMES/
- PARADES and EPFL organized the workshop: From Embedded Systems to Cyber-Physical Systems: a Review of the State-of-the-Art and Research Needs on Monday, April 21, 2008 in St. Louis, MO, USA. The theme of the workshop was presenting an overarching view of methodologiesand theories for the design of embedded and critical systems as it has emerged in the past five years and discussing the future in terms of the extension of the notion of embedded systems to Cyber-Physical Systems (CPS). In the overview of the present status of the discipline, the workshop addressed heterogeneous system composition, design methods based on abstraction and

refinement, interface theories, mapping of abstract entities to implementation platforms and industrial applications. The presentations featured industry representatives who gave their perspective of what are the gaping holes in the state of the art in their business segment and how to bridge academic accomplishments with industrial practice. The discussion about the extension of the theories and methodologies to the new generation of CPS reviewed the necessary steps and a possible roadmap for research. The discussion included public research organizations. European Community representatives, Werner Damm as Autosar and Artemis representative and Philippe Reynaert, DG INFSO Embedded Systems, provided the state-of-the-art and the research initiatives on embedded systems in the EU.

- OFFIS and TU Braunschweig have organised the workshop "SafeCert 2008 – Certification of Safety-Critical Software Controlled Systems" (http://safecert08.offis.de) as a satellite event of ETAPS 2008. The major question addressed in the workshop was how to embed formal methods and tools in a seamless design process which covers several development phases and which includes an efficient construction of a safety case for the product.
- Alain Girault and Eric Rutten (INRIA) organized the Model-driven High-level Programming of Embedded Systems, SLA++P'08 (a satellite event of the European Joint Conference on Theory and Practice of Software, ETAPS 2008), in Budapest, Hungary, March 2008. The keynote speaker was Grégoire Hamon from Mathworks. See http://www.artist-embedded.org/artist/SLA-P-2008,1231.html
- Thierry Jéron (INRIA) co-organized the MOVEP'08 summer school on modeling and verifying parallel processes, in Orléans, France, June 2008. See http://www.univ-orleans.fr/movep2008/
- In the context of the ATESST project, CEA and KTH organised two workshops. The "EAST-ADL, AADL, MARTE, Autosar harmonization workshop" which provided useful information exchange between the project and the respective standardization initiatives. It was agreed to maintain contacts, and to organize follow up meetings. Identified topics of common interest include Timing, Error modeling and Methodology. The second one is on the "Model based development of automotive embedded systems - The EAST-ADL approach" (march 3, 2008 - www.md.kth.se/RTC/atesst-open-workshop_v1.1.pdf).
- CEA co-organises the workshop on UML and AADL is held in conjunction with the 13th IEEE International Conference on Engineering Complex Computer Systems, ICECCS 2008, this workshop gathered researchers and practitioners interested in all aspects of the representation, analysis, and implementation of DRE system behaviour and/or architecture models. http://www.artist-embedded.org/artist/-UML-AADL-2008-.html
- CEA and Verimag coorganised (with external partners) the 1st International Workshop on Model Based Architecting and Construction of Embedded Systems held in conjunction with MODELS 2008 as a follow-up workshop of the SVERTS and MARTE workshops organised in previous years, the objective of this workshop is to bring together researchers and practitioners interested in model-based software engineering for real-time embedded systems. We were seeking contributions relating to this subject at different levels, from modelling languages and semantics to concrete application experiments, from model analysis techniques to model-based implementation and deployment. Given the criticality of the application domain, a particular focus is on model-based approaches yielding efficient and provably correct designs.
  http://www.artist-embedded.org/artist/ACES-MB-08.html
- CEA co-organises (with external partners) the 1st IEEE International workshop UML and Formal Methods as a satellite of ICFEM 2008 in Japan. For more than a decade now, the two communities of UML and formal methods have been working together to

produce a simultaneously practical (via UML) and rigorous (via formal methods) approach to software engineering. The fact that the UML semantics is too informal has led many researchers to formalize it with different existing formal languages. The main objective of this workshop is to encourage new initiatives of building bridges between informal, semi-formal and formal notations.

http://www.artist-embedded.org/artist/UML-FM-08.html

- MdH and Uppsala (via ARTES and SNART) have driven the organization of the Swedish Embedded Systems Meeting in Stockholm, March 5, 2008, where results of Swedish research programs on Embedded systems are presented, and further developments are discussed. http://www.snart.org/conference/2008/ses/

3. Overall Assessment and Vision for the Cluster

3.1 Assessment for Year 4

We only summarize the main points here. Details can be found in the progress reports of the four activities.

- **Cluster integration: Development of UML for Real-Time Embedded Systems.** The MARTE standard has been now accepted by OMG and is available in its Beta1 version according to the normal OMG process for standardization. The vote of the standard took place in Brussels in the week 26 of 2007 and it has been adopted unanimously. We received the congratulations of every OMG Architecture Board member for the job that has been done. In the meantime, the FTF (Finalization Task Force) has been launched. CEA is chairing this FTF and IBM and Thales are co-chairs. The mission of such OMG's task force is to handle the issues that have been raised by users of the specification and to provide a finalization report consisting of resolutions for the issues and a new updated version of the specification. The first FTF for MARTE has been finished in June 2008. The participants of this FTF (including, CEA, Thales and INRIA) have decided to ask for a second FTF in order to be able to deal with remaining unresolved issues. This second FTF will finish in spring 2009.
  In order to provide to ARTIST2 partners a detailed view of the MARTE standard, CEA was planning to organize a specific ARTIST2 meeting on MARTE in order to give to ARTIST2 partners the opportunity to influence the standard and raise issues that can be taken into account during the Finalisation Task Force phase of the MARTE specification. Due to some delay in the standardization of MARTE, this has not been achieved. However, among other, Artist2 NoE, enable CEA, Volvo, Thales and Cantabria to setup a new FP7 project, ADAMS. And this latter project will enable us to achieve this purpose to disseminate more widedly MARTE inside the Artist Design NoE.
- **Platform: Components Platform for Component Modelling and Verification**. In the year, significant work has been done on this platform. We have populated the global platform picture by adding new connections between tools and between formats. The main projects continue to be OpenEmbedd, SPEEDS, and ATESST. The Persiform toolchain of the subplatform for performance critical systems has started to be integrated into the subplatform for the analysis of safety critical embedded systems in the context of the OpenEmBeDD project. This is achieved by (1) adapting the input language of the tool chain to a (small) MARTE sub profile and by adapting the resource library so as to include platforms relevant for hard real-time systems. In the OpenEmBeDD project, a large part of the initially planned platform is now realised (see the report from the platform). In the SPEEDS project, the integration of analysis tools into the SPEEDS bus has significantly progressed.

- **NoE integration: Component Based Design of Heterogeneous Systems.** The last year has seen the consolidation of the lines of work on handling heterogeneity that have been pursued during Aritst2: Significant theoretical results have been gather around the BIP framework; BIP has been integrated with several other frameworks, such as Fractal and IF, and a large body of work on distributed implementation has been performed. Also the work on component models has matured, in particular on the HRC component model. During the review of the Integrated Project SPEEDS, a complete design flow interconnecting commercial of the shelf modelling tools through the HRC meta model to various analysis tools (contract compliance, architecture exploration, real-time analysis, safety analysis, hosted simulation) were presented. The reviewers considered the Rich Components approach underlying the SPEEDS HRC meta-model to have the potential of achieving a break-through for component based design of embedded systems.

3.2 Overall Assesment since the start of the Artist2 NoE

Overall, the RTC cluster of Artist2 has succeeded in three key respects: The work on the MARTE profile of UML has been carried out and successfully been completed within the course of Artist2. A significant number of tool chains have been initiated, established, and triggered a large number of collaborations between involved partners. Finally, the conceptual work on modelling of component-based heterogeneous systems has created links between the partners of Artist2, and generated material for several continued collaboration projects, including IP SPEEDS, COMBEST, GENESYS, ADAMS, OpenEmbeDD, and ATESST.

3.3 Vision Beyond the Artist2 NoE

Embedded real-time components are used in more and more application domains, which go clearly beyond avionics and automotive. Building automation is one of these domains, with a predictable growth in the next ten years. This growth is motivated by many factors. Two factors are of particular importance: energy saving and health care for the elderly. The increasing concerns about energy use and pollution has made energy conservation and use of renewable sources of energy a primary goal of the European Community. In this context, we believe that the overall activity of ARTIST 2 is essential since embedded control and monitoring will be a pillar to achieve possibly overambitious goals to have buildings that consume zero net energy by 2012.

The lines of work of the different RTC activities will be continued in many forms.

- As already mentioned in the previous section, the need for a good and effective connection between UML-RT related standardisation bodies and the active academic community still remain. This is the role currently played by the activity *Development of UML for Real-Time Embedded Systems.* This role should remain fulfilled even after the end of ARTIST2 and the effort to disseminate around the MARTE specification will be more and more effective in the incoming year. Both the ADAMS project and the Artist Design NoE will two of the most important support for achieving this purpose.
- The aim of the component platform activity is to show the feasibility of and possibly to improve the design approaches for component based heterogeneous systems in the cluster by providing tool support for it. To this aim, we have started to build a set of platforms or tool suites supporting such model-based design approaches based on user level modelling notations, notations supported in commercial tool suites, and new modelling paradigms being developed in this cluster. At a longer term, the today isolated tool suites showing partial solutions should be usable consistently also in a combined fashion due to the existence of semantically well-founded component

frameworks flexible enough to represent and meaningfully combine models from different user tools and possibly different abstraction levels or view points and that can be exploited by back-end tools (analysis and code generation). Generally speaking, most of the activities of the platform activities will be continued in the modelling and validation cluster of the Artist Design NoE in some form, even if the platform will not be identified as such in the new NoE. T

- The challenge of putting model-based design of embedded systems on a firm scientific basis has met with further problems that should be addressed. Important problems include to bridge the dichotomy between operational and transformational modeling approaches. Operational means automata-based: these approaches work on a component level, and have been successful in model checking, protocol verification, and code generation. Transformational means stream-based: these approaches work on the system level, and have been successful in performance analysis. While operational approaches have difficulties to scale to systems, transformational approaches suffer a loss of precision. Further important topics include resource modeling, to permit the exploration of trade-offs between multiple dimensions, such as functionality, reliability, performance, and resource consumption. To overcome the problem that current models for modeling quantitative properties of systems systems (Markov processes; timed automata; hybrid automata) tend to be brittle and overly sensitive towards arbitrarily small numeric perturburances, we plan to develop robust models for stochastic, timed, and hybrid systems. On the tool side, we will continue to study the integration of BIP and Metropolis as two frameworks that will allow the composition and the analysis of heterogeneous parts. The sequence of meetings in different industrial sectors will continue by considering the building, avionics, consumer electronics and automotive domains (a meeting is planned for November 12th and 13th, 2008 at PARADES to discuss these application domains and see how Artist Partners can contribute to solidify a design methogology and supporting tools for industry. A major focus of future work will be to establish well defined bridges between innovation potentials for component based design and industry standards, notably Autosar.

The above and other challenges will be addressed in current and to-be-initiated collaboration projects between Artist2 partners and others. Examples include ArtistDesign, and the omgoing projects SPEEDS, COMBEST, and GENESYS.

4. Cluster Participants

4.1 Core Partners

Team Leader **Cluster leader for RTC Cluster, and for activity "component-based design of heterogeneous systems"**	
	Bengt Jonsson http://user.it.uu.se/~bengt/
Technical role(s) within ARTIST2	Participant in discussions, contributions regarding compositionality, modelling, analysis of timing properties, tool building (TIMES)
Research interests	Research interests include: embedded systems, semantics, verification, modelling, specification, testing of distributed and embedded systems
Role in leading conferences/journals/etc in the area	Have been PC member of most conferences in the area.
Notable past projects	ASTEC, Competence Center for Software Technology, 1995-2005. http://www.astec.uu.se/ WOODDES (IST project) A UML profile for Automotive industry http://wooddes.intranet.gr/ Advance http://www.liafa.jussieu.fr/~haberm/ADVANCE/ Regular model checking (www.regularmodelchecking.com)

Team Leader **Participant in the activity on "Development of UML for Real-Time Embedded Systems"**

	Dr. Sébastien Gérard, CEA
Technical role(s) within ARTIST2	Leader of the standardization effort for the UML Profile for Modelling and Analysis of Real-Time and Embedded Systems: MARTE (prospective standard of the OMG)
Research interests	Modeling for RT/E Systems, code generation, RT/E analysis such as WCET and schedulability analysis.
Role in leading conferences/journals/etc in the area	Associate editor of the Journal of Software and System modelling (SoSyM) Co-organizer of the series of Summer Schools MDD for DRES (www.mdd4dres.info) Co-organizer of the workshop series MARTES (www.martes.org) Member of the PC for ISORC 2007, 2008 and MODELS 2008
Notable past projects	WOODDES (IST project) A UML profile for Automotive industry http://wooddes.intranet.gr/ EAST-AEE (ITEA project) An Architecture Description Language for Automotive: EAST-ADL FAMILIES (ITEA project) FAct-based Maturity through Institutionalisation Lessons-learned and Involved Exploration of System-family engineering http://www.esi.es/Families/ ATESST 1 (IST project) project for defining an Autosar compatible Architecture Description Language and based on UML and its MARTE extension www.atesst.org

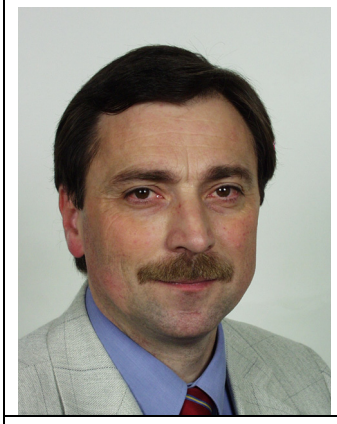
Team Leader **Participant in the activity on "Component-Based Design of Heterogeneous Systems"**	
	Prof. Thomas Henzinger, EPFL http://mtc.epfl.ch/~tah
Research interests	Formal modeling and analysis of reactive, timed, and hybrid systems. Design and implementation of hard real-time systems.
Role in leading conferences/journals/etc in the area	Chair, advisory board, ACM Conference on Embedded Software. Associate editor, ACM Transactions on Embedded Computing Systems.
Notable past projects	HyTech, a model checker for hybrid systems. mtc.epfl.ch/software-tools/hytech Mocha, a design and verification framework for reactive modules. mtc.epfl.ch/software-tools/mocha Giotto, a programming language for control applications. mtc.epfl.ch/software-tools/giotto Blast, a software verifier. mtc.epfl.ch/software-tools/blast
Awards / Decorations	Fellow, IEEE. Member, Academia Europaea. Member, German Academy of Sciences (Leopoldina).

Team Leader **Co-cluster-leader for RTC cluster (end by Jan. 2007)**	
	Albert Benveniste http://www.irisa.fr/distribcom/benveniste/
Technical role(s) within ARTIST2	Former ARTIST2-Hard Real Time cluster leader. Now Real Time Components cluster leader. Co-leader of activities *Forums with industrials* and *Seeding new work directions.* Co-organizer of meeting *Beyond AUTOSAR.*
Research interests	Research interests include: embedded systems, synchronous languages, heterogeneous systems; large distributed systems, telecommunication network and service management, true-concurrency theory; automatic control, system identification and diagnosis, application to vibration mechanics.
Role in leading conferences/journals/etc in the area	Member of the Editorial Board of the *Proceedings of the IEEE,* Associated Editor at Large of the *IEEE Transactions on Automatic Control*; PC member of several conferences including EMSOFT.
Notable past projects	SACRES, Solutions for Safety Critical Embedded Systems, IST project 1996-1999 SAFEAIR (IST-1999-10913, 2000-2002). Avionics Systems Development Environment http://www.safeair2.org/safeair/index.htm SPEEDS (ongoing IP) MAGDA RNRT project (1998-2001). Models and algorithms for distributed fault management in telecommunications networks. MAGDA2 RNRT project (2002-2003). Models and algorithms for end-to-end distributed fault management in telecommunications networks. SWAN RNRT project (2003-2006). Self-Aware Management in

	networks and Web services. Eureka projects in vibration mechanics • SINOPSYS (1997-1999). In-operation modal analysis and monitoring. • FliTE (2001-2004). Automated input/output and output-only modal identification and monitoring with application to aeronautics including flutter onset monitoring. • FliTE2 (2005-2008). Industrial transfer of Flite results, aeroelastic flutter monitoring.
Awards / Decorations	1990 CNRS Silver Medal; 1991 IEEE Fellow

Team Leader **Participant in the activity on "Development of UML for Real-Time Embedded Systems"**	
	Dr. Jean-Marc Jézéquel, full professor of computer science at the university of Rennes 1, France
Technical role(s) within ARTIST2	Leader of the Triskell INRIA team http://www.irisa.fr/triskell/
Research interests	Model driven software engineering based on object oriented technologies for telecommunications and embedded systems.
Role in leading conferences/journals/etc in the area	Associate editor of the Journal of Software and System modelling, of the Journal of Object technology; conference chair of SPLC-Europe 2005, UML2002, chair of steering committee of UML2004, PC member of UML2006, CBSE2006, SPLC2006
Notable past projects	QCCS (IST project) Quality Controlled Component Based Software http://www.qccs.org FAMILIES (ITEA project) FAct-based Maturity through Institutionalisation Lessons-learned and Involved Exploration of System-family engineering http://www.esi.es/Families/

Team Leader **Responsible for the activity "Industrial Liaison"**	
	Prof. Dr. Werner Damm (OFFIS) http://www.offis.de
Technical role(s) within ARTIST2	Bring in Expertise in embedded system modelling and validation. Deep involvement in cooperation with the automotive industry. Co-organizer of the Workshop "Beyond Autosar"
Research interests	Embedded system modelling and validation, formal verification, semantic foundation, safety analysis
Role in leading conferences/journals/etc in the area	Co-Program Chair CAV2007 and Program Committee Member CAV2008 Member of the Editorial Board "Formal Methods in System Design" Chairman of the competence cluster SafeTRANS Chairman of the ARTEMIS Innovation Cluster on Transportation Member of the ITEA2 Roadmap3 Steering Board Member of the Steering Board of the German Innovation Alliance on Embedded Systems
Notable projects	OMEGA - Correct Development of Real-time Embedded Systems Formal verification of embedded systems based on UML http://www-omega.imag.fr/ AVACS - Automatic Verification and Analysis of Complex Systems This project addresses the rigorous mathematical analysis of models of complex safety critical computerized systems. http://www.avacs.org/ SPEEDS - Speculative and Exploratory Design in Systems Engineering Provide a semantics based modelling methods with analysing techniques to support the construction of complex embedded systems by composing heterogeneous subsystems together with a speculative tool-supported design process. SPES 2020 Software Platform for Embedded Systems German Innovation Alliance on Embedded Systems providing sectorial foundations for applications in automation, automotive, aerospace, enery, and medical sectors

	Prof. Dr. Bernhard Josko (OFFIS) http://www.offis.de/
Technical role(s) within ARTIST2	Participating in several activities bringing in the expertise on real-time UML verification
Research interests	Modelling and analysis of embedded systems, formal verification, real-time UML, SysML
Notable projects	OMEGA - Correct Development of Real-time Embedded Systems Formal verification of embedded systems based on UML http://www-omega.imag.fr/ EASIS – Electronic Architecture and System Engineering for Integrated Safety Systems Within WP System Dependability provide formal verification guidelines http://www.easis.org SPEEDS - Speculative and Exploratory Design in Systems Engineering Provide a semantics based modelling methods with analysing techniques to support the construction of complex embedded systems by composing heterogeneous subsystems together with a speculative tool-supported design process.

Team Leader	
	Alberto Sangiovanni Vincentelli (PARADES) http://www.parades.rm.cnr.it
Technical role(s) within ARTIST2	Bring in Expertise in embedded system modelling, validation, tools and methodologies and IC design. Deep involvement in cooperation with the industry: tools (co-founder Cadence and Synopsys), telecommunications

	(Telecom Italia), automotive (member of the GM STAB)
Research interests	Embedded system design methodologies and tools including modelling, validation, synthesis and formal verification, semantic foundations.
Role in leading conferences/journals/etc in the area	Program Committee Member CODES and EMSOFT. Member of the Editorial Boards Member of the ARTEMIS High-level Group and Steering Committee
Notable projects	SPEEDS - Speculative and Exploratory Design in Systems Engineering Provide a semantics based modelling methods with analysing techniques to support the construction of complex embedded systems by composing heterogeneous subsystems together with a speculative tool-supported design process. HYCON NoE: Taming Hybrid Systems Center for Hybrid and Embedded Software Systems (CHESS) co-director Gigascale System Research Center, Core theme leader RIMACS: Industrial Automation
Awards/Decorations	IEEE Fellow, Member National Academy of Engineering, Kaufmann Award for pioneering contributions to EDA, IEEE Graduate Teaching Award, Gulliemin-Cauer Award, Darlington Award, Aristotle Award, University of California Distinguished Teaching Award

	Alberto Ferrari (PARADES) http://www.parades.rm.cnr.it
Technical role(s) within ARTIST2	Bring in Expertise in embedded system modelling, validation, tools and methodologies and IC design. Involvement in cooperation with the industry: architectures and tools

Research interests	Embedded system design methodologies and tools including modelling, validation, synthesis and formal verification, semantic foundations.
Role in leading conferences/journals/etc in the area	PC member in DAC07, DATE07, DATE08
Notable projects	SPEEDS - Speculative and Exploratory Design in Systems Engineering Provide a semantics based modelling methods with analysing techniques to support the construction of complex embedded systems by composing heterogeneous subsystems together with a speculative tool-supported design process. HYCON NoE: Taming Hybrid Systems RIMACS: Industrial Automation
Awards/Decorations	

Team Leader	
	Paul Caspi (VERIMAG) http://www-verimag.imag.fr/~caspi/
Technical role(s) within ARTIST2	Participant in the Real-time and Component Cluster, in particular the activity “Seeding new research directions”
Research interests	Model-based development, synchronous languages, models for heterogeneous systems
Role in leading conferences/journals/etc in the area	PC member of ACSD 2005, RTAS 2006, WESE2006

Notable past projects	IST RISE: Reliable Innovative Software for Embedded Systems (2002-2005) IST Next-TTA: High Confidence Architecture for Distributed Control Applications (2001-2004) IST Crisys (terminated in 2001) IST SafeAir (terminated in 2001)

Team Leader **Responsible for JPIA-Platform Platform for Component Modelling and Verification**	
	Susanne Graf (VERIMAG) http://www-verimag.imag.fr/~graf/
Technical role(s) within ARTIST2	Participant in the Real-time and Component Cluster Responsible for JPIA-Platform Platform for Component Modelling and Verification
Research interests	Formal modeling and analysis of reactive and timed systems.
Role in leading conferences/journals/etc in the area	Editorial board of STTT, PC member of CAV 2005, MODELS 2006, FMICS 2006, FMCAD 2006, TACAS 2007, PC chair of ATVA 2006 Board of European Association of Software Systems and Technologies, EASST Animation of ASERT, the group on Embedded Systems ASERT within the CNRS virtual lab ASR
Notable past projects	IST INTERVAL - Consistent timing extensions for Telecom standards SDL, MSC and TTCN IST OMEGA - Correct Development of Real-time Embedded Systems Formal verification of embedded systems based on UML http://www-omega.imag.fr/ IP ASSERT SPEEDS - Speculative and Exploratory Design in Systems Engineering Provide a semantics based modelling methods with analysing techniques to support the construction of complex embedded systems by composing heterogeneous subsystems together with a speculative tool-supported design process. http://www.speeds.eu

Scientific Coordinator of the ARTIST2 NoE Responsible for activity on "Deisgn of Heterogeneous Systems"	
	Joseph Sifakis (Director of VERIMAG) http://www-verimag.imag.fr/~sifakis/
Technical role(s) within ARTIST2	Scientific Coordinator Participant in the Real-time and Component Cluster Participant in JPIA-Platform Platform for Component Modelling and Verification
Research interests	Component based design, QoS Control, Modeling and Validation
Role in leading conferences/journals/etc in the area	EmSoft'06 : Executive Committee (http://www.it.uu.se/conf/EMSOFT06/) Date'07 : Chair of the Embedded Software Track, and member of the Executive Committee (http://www.date-conference.com/) Editorial boards: • Formal Methods in System Design (http://www.springerlink.com/content/1572-8102/) Software Tools for Technology Transfer (http://sttt.cs.uni-dortmund.de/)
Notable past projects	• ARTEMIS ETP (http: www.artemis-office.org/) • ARTIST FP5 (http://www.artist-embedded.org/ARTIST_FP5_PublicReport.pdf) • EmSoC regional initiative • IST OMEGA (http://www-omega.imag.fr/) • IST ADVANCE (http://www.liafa.jussieu.fr/~haberm/ADVANCE/main.html) • RTP SECC (http://www.systemes-critiques.org/SECC/) • RNTL Espresso (http://www.inria.org/recherche/equipes/espresso.en.html) • Nano network
Awards / Decorations	ACM Turing award in 2007, CNRS Silver Medal in 2001

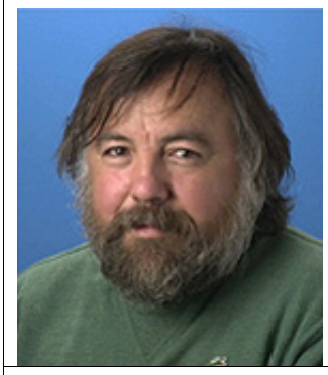
	Prof. Dr. Hermann Kopetz Real-Time Systems Group Institute of Computer >Engineering Vienna University of Technology http://www.vmars.tuwien.ac.at
Technical role(s) within ARTIST2	Team Leader TU Vienna
Research interests	expertise in fault-tolerant systems architecture and inventor of the TTA concept
Role in leading conferences/journals/etc in the area of fault-tolerant real-time systems	Chairman of the IFIP WG 10.4 on Dependable Computing and Fault-Tolerance DSN steering committee member
Notable past projects	DECOS - Dependable Embedded Components and Systems Develop the basic enabling technology to move from a federated distributed architecture to an integrated distributed architecture. http://www.decos.at TTEthernet – Time-Triggered Ethernet Establishing of a time-triggered (TT) Ethernet with predictable temporal performance and strong fault-isolation for safety-critical real-time control systems and multimedia systems. NEXT TTA Enhance the structure, functionality and dependability of the time-triggered architecture (TTA) to meet the cost structure of the automotive industry, while satisfying the rigourous safety requirements of the aerospace industry. http://www.vmars.tuwien.ac.at/projects/nexttta/ DSoS - Dependable Systems of Systems Develop significantly improved means for composing a dependable "system of systems" (SoS) from a set of largely autonomous component computer systems. http://research.cs.ncl.ac.uk/cabernet/www.laas.research.ec.org/dsos/

Awards / Decorations	Fellow of the IEEE

	Dr. Peter Puschner Real-Time Systems Group Institute of Computer Engineering Vienna University of Technology http://ti.tuwien.ac.at
Technical role(s) within ARTIST2	Team Member TU Vienna
Research interests	Hard real-time systems for safety-critical applications, with a focus on the worst-case execution time (WCET) analysis of real-time programs and software/hardware architectures for time-predictable computing.
Role in leading conferences/journals/etc in the area of fault-tolerant real-time systems	Member of the Euromicro Technical Committee on Real-Time Systems, the steering committee of the Euromicro Conference on Real-Time Systems (ECRTS) Member of the advisory board and organizers committee of the IEEE International Symposium on Object- and Component-Oriented Distributed Computing (ISORC) conference series Chair of the Steering Committee of the Euromicro Workshop on Worst-Case Execution-Time Analysis (WCET) series Chair of the Steering Committee of the IFIP Workshop on Future Technologies for Embedded and Ubiquitous Computing Systems (SEUS)
Notable past projects	DECOS - Dependable Embedded Components and Systems Develop the basic enabling technology to move from a federated distributed architecture to an integrated distributed architecture. http://www.decos.at MoDECS - Model-Based Development of Distributed Embedded Control Systems Model-based construction of distributed embedded control systems: shift from a platform-oriented towards a domain-oriented, *platform-independent* development of composable, distributed embedded control systems. http://www.modecs.cc NEXT TTA

	Enhance the structure, functionality and dependability of the time-triggered architecture (TTA) to meet the cost structure of the automotive industry, while satisfying the rigourous safety requirements of the aerospace industry. http://www.vmars.tuwien.ac.at/projects/nexttta/
Awards / Decorations	

Team Leader **Participant in the activity on "Development of UML for Real-Time Embedded Systems"**	
	Dr; Julio Medina , University of Cantabria
Technical role(s) within ARTIST2	Integration of Schedulability Analysis and Component-Based modelling and delopment approachs. Work in the standardization effort for the UML Profile for Modelling and Analysis of Real-Time and Embedded Systems: MARTE, recent standard of the OMG.
Research interests	Real-Time Systems, Object Oriented and Component-based Modelling, Real-Time Distributed Systems, Unified Modelling Language (UML), Flexible scheduling strategies, Real-Time Programming and Operating Systems, Rate Monotonic Analysis (RMA) and Schedulability Analysis
Role in leading conferences/journals/etc in the area	Member of the PC of RTAS 07 Area B: Development, Verification, and Debug Tools for Real-Time and Embedded Systems PC Member in FDL'07, Forum on Specification and Design languages PC Member for ECRTS'08
Notable past projects	FIRST THREAD

Team Leader	
	Jacques Pulou (FTR&D/MAPS/AMS/SUME) http://rd.francetelecom.com/fr/groupe/rd/index.html
Technical role(s) within ARTIST2	Participant in the Real-time and Component Cluster, in particular the activity "JPIA-Platform Platform for Component Modelling and Verification"
Research interests	Formal modelling and verification, performance analysis
Role in leading conferences/journals/etc in the area	

Team Leader	
	Thierry Coupaye (FTR&D/MAPS) http://rd.francetelecom.com/fr/groupe/rd/index.html
Technical role(s) within ARTIST2	Participant in the Real-time and Component Cluster, in particular the activity "JPIA-Platform Platform for Component Modelling and Verification"
Research interests	Formal modelling and verification, performance analysis
Role in leading conferences/journals/etc in the area	
Notable past projects	IST

4.2 Affiliated Academic Partners

	Prof. Ivica Crnkovic Mälardalen University Department of Computer Science and Electromics http://www.idt.mdh.se/~icc
Technical role(s) within ARTIST2	Affiliated partner, active in real-time components. Member of group building RT component model SaveCCM. Initiator of cooperation with Swedish Industry, cooperation with Mohash University, Australia, and SEI(Carnegie Mellon University, US
Research interests	Component-based software engineering, Development processes
Role in leading conferences/journals/etc in the area	Co-chair of technical committee for Euromicro Software Engineering and Advance Applications conference (SEAA) , General Chair of Euromicro SEAA 2006, Program chair 2007 Member of Steering committee of ACM SIGSOFT Symposium of Component-based Software Engineering, General chair 2006, Program Chair 2004. General Chair of ACM SIGSOFT European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering 2007 Co-Editor – Journal of Systems and Software – special editions in Component-based Software Engineering, 2007, 2005, 2003
Notable past projects	SAVE and SAVE++ – Design of safety critical vehicular systems, funded by Swedish foundation for Strategic Research, http://www.mrtc.mdh.se/SAVE/ FLEXCON - Flexible Embedded Control Systems, , funded by Swedish foundation for Strategic Research, http://www.control.lth.se/FLEXCON/ CBSE Network - Component-Based Software Engineering Network Q-IPRESS – Fp7 STREP FLEXI – ITEA2 project
Awards / Decorations	Industrial Software Engineering, donation from ABB for professorship

Team Leader Participant in the activity on "Seeding new research directions"	
	Dr. Marius Minea, Institute e-Austria Timisoara http://www.ieat.ro http://www.cs.upt.ro/~marius
Technical role(s) within ARTIST2	Affiliated partner IeAT has expertise in formal verification (model checking), especially for real-time systems, and compositional reasoning including assume-guarantee techniques. Within the cluster, the partner is working on: - abstraction and compositional reasoning techniques for real-time models. Starting from models such as timed automata, the goal is to generate more abstract timed interfaces that can be used to reduce - modeling and performance analysis of embedded systems consisting of tasks with given timing parameters (period, deadline, jitter). Using analysis techniques borrowed from network calculus and timed automata, the challenge is to computer performance characteristics such as availability and response time in a modular fashion starting from individual components.
Research interests	formal verification (model checking), compositional and assume-guarantee reasoning, real-time and embedded systems, model-based testing, verification of security protocols
Notable past projects	Verification of telecommunications code written in SDL Model-based testing and automated test generation with Rational Test RealTime (with Siemens VDO Automotive)

4.3 Affiliated Industrial Partners

<photo>	David Lesens (EADS) http://www.astrium.eads.net/families/space-access-propulsion-launcher-rocket/launch_systems/ariane-5-fr
Technical role(s) within Artist2	Participation in the platform for component based modelling and verification. Proposal of case studies concerning architecture modelling (integration of AADL and UML) and timing analysis in the ASSERT project. Participated in a common publication [HJR+07]
Notable past projects (optional – max 5)	Safeair, Omega

<photo>	Alain Leguennec (Esterel Technologies) http://www.esterel-technologies.com/products/scade-suite/
Technical role(s) within Artist2	Participation in the platform for component based modelling and verification.

	collaboration on the SPEEDS platform
Notable past projects (optional – max 5)	Safeair, ASSERT

<photo>	Veronique Fabre (Thales) http://www.thalesgroup.com/aerospace/index.html
Technical role(s) within Artist2	Participation in the platform for component based modelling and verification. collaboration on the extension of Persiform platform in the context of OpenEmBeDD
Notable past projects (optional – max 5)	

5. Internal Reviewers for this Deliverable

Alan Burns, U. of York