



IST-004527 ARTIST2
Network of Excellence
on Embedded Systems Design

Cluster Progress Report for Year 3

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 heterogeneous 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.

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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. Following the decisions at the review in November 2006, the set of activities of the clusters was changed: the two activities *Forums with specific industrial sectors* and *Seeding new research directions* were replaced by the activity *Component-Based Design of Heterogeneous Systems*. A main reason for the reorganization was to simplify reporting, and to make reporting better reflect the actual efforts carried out by the cluster.

Accordingly, the new organization for the RTC cluster is:

- **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, from 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, from 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, from Uppsala.

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

- **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. *A unifying metamodel for the Rich Component Model paradigm has been developed*
 - **Interfaces and Compatibility:** To develop techniques for smooth composition of component-based systems. *Several programming language constructs and analysis approaches for timing and resource contracts have been developed. Techniques for synthesizing adaptors for component developed have ben developed.*
 - **Industrial Liaison:** To finalize the reporting from the 2005 workshop *Beyond AUTOSAR*, and to conduct an industrial meeting on Integrated Modular Avionics (IMA). *The documentation and reporting is being finalized The meeting on IMA will be held November 12-13 in Rome.*
- **Platform: Components Platform for Component Modelling and Verification:** to obtain initial versions of tool integrations for the component modelling and verification platform. *A number of new connections between modelling formalisms and validation*

tools have been developed and two very important projects for the platform have been launched, the French platform project OpenEmBeDD and the IP SPEEDS.

- **Cluster integration: Development of UML for Real-Time Embedded Systems:** to prepare an initial submission to the OMG standard for the UML profile for Modeling and Analysis of Real-Time and Embedded Systems (MARTE). *This submission has been now presented and voted for acceptance by the OMG. It is now available in its Beta1 version (according to the standardization rule of the OMG). A Finalization Task Force has been launched by the OMG in order to provide the version 1 of MARTE. The deadline of this FTF is July 2008.*

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 the 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 transportation sectors, including the automotive and aeronautics sectors. 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 Council¹, 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 Europe², expects a three fold traffic density by 2020 for civil aircrafts. ERRAC, the European Rail Research Advisory Council³ 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.

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.

¹ <http://www.ertrac.org>

² <http://www.acare4europe.com>

³ <http://www.errac.com>

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

- 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 61131-3⁵ and IEC 61499⁶ 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.

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.

⁴ <http://www.autosar.org>

⁵ http://en.wikipedia.org/IEC_61131-3

⁶ http://en.wikipedia.org/IEC_61499

- The penetration of mobile and wireless embedded systems into traditional domains such as automation and process control 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:

- 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.
- 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. 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

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 model⁷ and toolset⁸. These approaches does not take into account any behavioral 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 MetaH⁹, Ptolemy¹⁰, and Metropolis¹¹. 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 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 newly started 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, 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..

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 alignment 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 bandwidth 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.

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.

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 the standard itself.

Excellence is revealed by the links the RTC community has with the US and Canadian leading teams also working in the ProMarte consortium, whereas with the tool vendors such as IBM and Telelogic, also part of the ProMarte consortium.

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 heterogeneous 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.

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 meeting *Beyond Autosar*. A similar action line is planned for 2007 regarding the avionics and aeronautics industrial sector, with IMA (Integrated Modular Avionics) as main target. See <http://www.artist-embedded.org/artist/-ARTIST2-meeting-on-Integrated-.html>

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.

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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 consortium¹²). 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 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 (CHES), 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. 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 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 established European Institute for Complex and Safety Critical Embedded Systems Engineering. EICOSE has been selected as the ARTEMIS Innovation Cluster on Transportation. VERIMAG and FT R&D contribute within French MINALOGIC cluster to

¹² <http://fractal.objectweb.org>

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

VERIMAG and EPFL jointly produced a position paper [HS06], 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.

PARADES [SV07] wrote a state-of-the-art and beyond paper in system-level design that overviews present approaches to the design of complex SOC's as well as distributed systems and embedded software. The paper underlines the open areas and the academic and industrial trends to fill the gaps.

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:** Partners of the RTC cluster (INRIA, OFFIS, Timisoara, Uppsala, VERIMAG) participated in the workshop on "Distributed Embedded Systems", organized at the Lorentz Center in Leiden, Nov. 21-24, 2005, by Ed Deprettere and Lothar Thiele (<http://www.lc.leidenuniv.nl/lc/web/2005/177/info.php3?wsid=177>) with large participation from the Execution Platforms cluster (Braunschweig, ETHZ, Linköping) This workshop focussed on comparison and classification of techniques for compositional response-time and performance analysis. In particular, a set of benchmark examples were defined with the aim of evaluating and comparing methods including the real-time calculus, holistic methods, Symta/S, and timed automata.
- **Control:** Several RTC partners (INRIA, PARADES) are prominent members also in the control community (and some of them are members of the HyCON NoE). 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 control.
- **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 visiting 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.
- **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. As an example, partners of the Verification and Analysis cluster (LIAFA) have visited Uppsala for longer periods as part of ongoing longer-term collaboration.

2.4.3 *Interaction with the Standardization community*

The RTC cluster has been, through CEA, Cantabria, and Thales, the driving force in the work of developing a profile of the Unified Modeling Language (UMLTM) for MARTE (Modelling and Analysing of Real-Time and Embedded systems). As part of an OMG activity, the work on MARTE is done in the context of a specific consortium consisting exclusively of OMG members, viz. the ProMarte consortium (www.promarte.org). A presentation of the MARTE work was made in the OMG meeting in Anaheim (September 25-29, 2006). This dissemination activity may eventually lead to further contacts and collaborations between ARTIST2 and specific OMG industrial participants. In the context of the standardization of the MARTE profile, CEA and Thales are working jointly with Peter Feiler and Bruce Lewis, the two key persons of the AADL standard, in order to make both standard align and spent some effort to make both standards converging.

VERIMAG and CEA have been the initiators of the MARTES workshop (www.martes.org) on model-driven development and real-time and embedded systems as a follow-up event on the successful workshop series on Real time embedded systems SIVOES and SVERTS. MARTES has been hold in October 2005 as a satellite event of the MODELS conference. The workshop attracted a number of interesting submissions and participants. The results of the workshop, as well as 2 best papers have been published in an LNCS volume.

Presently, we are actively preparing the second edition, to be held on October 2 or 3, 2006 in Genova, Italy in conjunction with the 9th International Conference on Model Driven Engineering Languages and Systems, MoDELS/UML 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.

2.4.4 *Interaction with the automotive industry*

Specific effort has been dedicated to interacting with the automotive industry. 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 Törnngren (KTH), Rolf Ernst (U. Braunschweig), Sébastien Gérard (CEA)), and affiliates (including: Stefan Kowalewski (RWTH Aachen)) of ARTIST2 had with the Autosar consortium. 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 Autosar approach. 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.

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

¹³ <http://www.artist-embedded.org/FP6/ARTIST2Events/Events/Innsbruck06/>

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 Bangalore (January 2007)

Sébastien Gérard (CEA) and Henrik Lönn (Volvo Tech) are organizing a workshop in the context of the ATESSST project which aims at 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 specially in the context of the Architecture Description Language for Automotive, EAST-ADL.

MdH has a tight cooperation with CC Systems, a subcontracting company developing control systems for different type of vehicular systems. The main issue is the reusability of components where the efficiency of resource utilisation is required.

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.

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), are organizing an ARTIST2 workshop on IMA, to be held November 12-13 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.

2.4.6 Cross-sectorial Interaction with industry

In future and many state-of-art projects a convergence of different application domains can be observed for different industrial applications (for example, a multimedia system and safety-critical functions are integrated in a car). In order to establish a common design methodology and a common architectural style for these industries, TU Vienna has prepared an EU STREP project GENESYS including partners from the automotive (Volvo, TTTech), aerospace (Thales), consumer electronics (ESI, NXP) and telecommunication industries (Nokia)

2.4.7 Interaction with Overseas Teams.

We strive to interact with relevant overseas teams in work on central ARTIST2 topics. We keep close ties with the CHESS project of NSF¹⁴. CHESS collects major US teams from key

¹⁴ <http://chess.eecs.berkeley.edu/> : Center for Hybrid and Embedded Software Systems

universities¹⁵. 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*¹⁶ and *Communication and Control*¹⁷. On the topic of software components, the INRIA Triskell team (Jean-Marc Jézéquel) has established strong research ties with Robert France's team (Colorado State University, USA), with mutual visits of several weeks. Robert France spent 6 months at INRIA during 2007. As a result of this cooperation, a joint proposal has been written and submitted to the US government for funding. This proposal aims at defining a long term cooperation activity for component-based crisis management applications. The main research topics regard real time configuration of communication and control networks, for computer aided decision making. Parts of such systems are embedded in emergency personnel vehicles or in personal communication devices. The proposal specifically addresses issues such as integration between real time communication and control networks from different emergency agencies (police, firefighters, medical operators and army). The proposed work will study appropriate means of abstraction that enable reconfiguration of the networks by non technical operators on the field, while preserving correct behaviour of the systems. The proposal was an answer to a US Navy call for projects on crisis management.

Mälardalen (I. Crnkovic) has strongly established collaborations with the Software Engineering Institute (SEI) at CMU (Kurt Wallnau) and with Monash University in Australia (Heinz Schmidt, affiliated ARTIST2 partner).

Within the work on standardization in OMG, CEA has established very good contact with Carleton University Canada (Dorina Petriu and Murray Woodside) which has been MARTE contributors, but also with SEI (Peter Feiler) to make both MARTE and AADL standards consistent/compatible.

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 strengthened in 2007, with a one week stay of an Inria PhD student in Poernomo's laboratory at King's College, UK. The next step of this cooperation is the stay of a student from King's College at the Irla laboratory, planned for end of 2007. This PhD work will extend the specification languages for time properties of the INRIA team with King's College work on stochastic descriptions of modes. The aim is to merge King's college and INRIA tool chains.

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 CHES 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.

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.

¹⁵ http://chess.eecs.berkeley.edu/people/project_personnel/

¹⁶ <http://hsc06.csl.sri.com/> is the conference of this domain

¹⁷ See the control conference CDC'2005 <http://www.esi2.us.es/~cdcecc05/> where a plenary has been devoted to this topic.

Ivica Crnkovic (MdH) has established cooperation with CESAR (Recife Center for Advanced Studies and Systems) research centre in the area of component-based development and reuse. The component-based development process, component certification and component development maturity model have been developed as common activities. A PhD student stayed at MdH during a period of three years, and Ivica Crnkovic has been a keynote at the 6th Brazilian Workshop on Component-based development (<http://wdbc2006.cesar.org.br/english/>) and will participate as a presnetator in the sunner School on Reuse.

2.4.8 Organization of summer schools

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

- The ARTIST2 MOTIVES Winter School on Component & Modelling, Testing & Verification, and Statical Analysis of Embedded Systems, was held in Trento, Italy, on Feb. 19-23, jointly organized by the RTC, Verification, and Compilers clusters, with over 50 students.

<http://www.artist-embedded.org/artist/Overview.577.html>

- 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.
- REAL-TIME IN SWEDEN 2007 (RTiS'07) is a conference that brings together industry and academia in an effort to share ideas and information about new and emerging topics in the area of embedded and real-time systems. This year the ninth conference in a series of successful biennial conferences since 1991, was organized by the Swedish National Real-Time Association (SNART). The conference was organised as a two day event (August 21-22) hosted by Mälardalen university, and had 95 participants from industry and academia. A part from general contributions on embedded and real-time systems, the conference this year was especially searching contributions in the area of Multi-core systems and Software and tool. Invited speakers at the conference were Prof. Edward Lee (UC Berkeley), Prof. Hermann Kopetz (TU Vienna), and Prof. Erik Hagersten (Uppsala Universitet and Acumem). In association to RTiS'07, the national Swedish strategic research initiative ARTES (A network for Real-time research and Education in Sweden) organised its annual summer school. The school was organised as a three days events in the week August 20 to 24, and attracted 50 participants (mostly Ph.D. students).

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*).

- The ARTIST2 workshop on *Model of Computation and Communication for embedded systems* was organized in Nov. 2006 in Zurich, jointly organized by the RTC cluster, and the Execution platforms cluster.
- An ARTIST2 workshop on *Basic Concepts in Mobile Embedded Systems* has been organized in Vienna in December 2006 in the framework of the RTC Cluster.
- Sébastien Gérard (CEA) and Susanne Graf (VERIMAG) are main organizers of the series of Workshop, MARTES (www.martes.org). This series of workshop is the result of a merge between two previous series of workshops, SIVOES and SVERTS organised respectively by CEA and VERIMAG. The concerns of MARTES workshops are related to domain-specific aspects in the modelling, analysis and validation of

distributed, embedded and/or real-time systems. Experiment feedbacks relating to Model Driven Development, Model Driven Engineering and Model Integrated Computing usages are considered. The third edition has been co-located with the Models/UML conference in Genova (Italia), in Oct. 2006.

- 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 in Genova (Italia), and will be continued in 2007.
- INRIA and VERIMAG are the initiators of a series of workshops dedicated to synchronous languages (SLAP - <http://web.uni-bamberg.de/wiai/gdi/SLAP07/>). The workshop topics are synchronous model of computation, synchronous languages and programming formalisms, compiling techniques, formal verification, test and validation of programs, case-studies, education, etc.
- VERIMAG is also a co-initiator and co-organiser of the symposium on Formal Methods for Components and Objects FMCO (<http://fmco.liacs.nl/fmco06.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 will take place a special issue bringing together groups of a set of related EU projects and NoEs; Artist is one of those groups.
- Albert Benveniste (INRIA) and Paul Caspi (Verimag), in tight cooperation with John Rushby (SRI, Stanford), and with local support by Alberto Ferrari at PARADES are organizing an ARTIST2 workshop on Integrated Modular Avionics (IMA), to be held November 12-13 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. See <http://www.artist-embedded.org/artist/-ARTIST2-meeting-on-Integrated-.html>
- Alain Girault (INRIA) and Pascal Raymond (VERIMAG) co-organised the SYNCHRON'06 workshop on synchronous languages (<http://www.artist-embedded.org/artist/Synchron-06.html>). This workshop is devoted to all aspects of synchronous programming: languages, compiling techniques, formal methods, programming environments, execution platforms, semantics issues, code generation... This year was the occasion of recalling the career and the achievements of Paul Caspi for his retirement in 2007.
- Alain Girault and Robert de Simone (INRIA) co-organised the FMGALS'07 workshop on formal methods for Globally Asynchronous Locally Synchronous systems (<http://www.artist-embedded.org/artist/FMGALS-2007.html>).
- Ivica Crnkovic (Mdh) in cooperation with SEI/CMU, TUFTS University and RMIT University has organised Component-Based Software Engineering Symposium <http://goanna.cs.rmit.edu.au/~hws/CBSE10/index.shtml>
- Ivica Crnkovic (Mdh) in cooperation with Tu/Eindhoven has organised a Component-Based Software Engineering Track as a special track of Euromicro SEAA conference (<http://www.idt.mdh.se/ecbse/2007/>)

- Tom Henzinger and Werner Damm have organized a workshop Foundations of Component-based Design to be held at the Embedded System Week in Salzburg (Sep 30, 2007).
- KTH and VERIMAG have organised the workshop “Towards a Systematic Approach to Embedded Design” as a satellite event of DATE 2007 (<http://www.artist-embedded.org/artist/Organisers.html>). The aim was to to increase the awareness for potential industrial users about existing leading-edge academic embedded systems design tools. Results from several Artist platform activities and related external tools and challenges where presented
- CEA, Aalborg University, KTH and VERIMAG have organised the workshop “Tool platforms for Embedded Systems Modelling, Analysis and Validation” (<http://www.artist-embedded.org/artist/Organisers.html>) as a satellite workshop of CAV 2007. The motivation for the workshop was the discussion of the specific problems raised in the context of embedded systems and the presentation of solutions from the perspective of design and development. The main aim was to intensify the cross fertilisation between the formal methods and the embedded systems communities. Results from several Artist platform activities and related external tools and challenges where presented.
- OFFIS has organised the workshop “Modeling and Safety Standards - How to Get it Right” as a satellite event of SafeTronic 2006. The aim of this workshop was to present SafeUML which has been defined in the OPRAIL project.

3. Overall Assessment and Vision for the Cluster

3.1 Assessment

As outlined in Section 1, the RTC cluster was formed in Oct. 2005 by merging the former two clusters on Hard Real-Time (HRT) and on Components. Following the decisions at the review in November 2006, the activities of the clusters was changed: the two activities *Forums with specific industrial sectors* and *Seeding new research directions* were replaced by the activity *Component-Based Design of Heterogeneous Systems*. A main reason for the reorganization was to simplify reporting, and to make reporting better reflect the actual efforts carried out by the cluster. When summarizing the third year, our conclusion is that this restructuring was very beneficial in that it better emphasized on continuous longer-term research lines in the cluster, and the view that workshops and seminars are a means to support them. This is not in contradiction to the rationale for structuring the new cluster into "Seminar activities" at the beginning of Y2, which was (quoting from last years report)

we feel that open meetings organized under the umbrella of the two new activities are a better vehicle for European integration in the area of the cluster than would be "regular" cluster meetings

since workshops and industrial fora have continued, and "regular" cluster meetings have been replaced by interaction at project meetings, conference and workshops.

This restructuring has had some little inconvenience, though. Since general management and organizational cluster meetings have been less numerous, less opportunities have been given to the *UML for Real-Time systems* activity to feed the cluster with information related to UML. In order to provide to ARTIST2 partners a detailed view of the MARTE standard, CEA plans to organized 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 standardization which has been launched in July 2007 and will end in July 2008.

Last year, the idea of connecting more closely the Platform activity of the component cluster to the one of the Verification and Testing cluster was not considered to be practical because of their focus being quite different. Nevertheless, we have started this year to coorganise meetings involving participants and presentations of different Artist clusters and associating them with top events of the different domains implied. This year two such workshops took place, involving the component platform, the verification platform and the platform on control for embedded systems. The first one took place together with DATE 2007 and the second together with CAV 2007. All participants considered thes initiatives interesting and we hope to increase this way the interaction bewteen partners from different domains.

3.2 Vision and Long Term Goals

The different RTC activities have different roles regarding vision and long term goals:

- The vision and long term goals of the activities on *Component-based Development of Heterogeneous Systems* is to contribute to developing a conceptual and technical basis for component-based design of heterogenous systems. This work is conducted partly by application and implementation work, which is carried out in larger collaboration projects, partly as conceptual work which is presented and discussed in workshops and conferences. A critical role of ARTIST2 is to foster contact and cross-fertilization between these two lines of work, partly by organizing workshops, and by maintaining a community with links to many different ongoing activities. As long as the problems of

component-based development are perceived as important by industry, containing large unsettled research problems, we believe that the need for this kind of activity will persist.

- 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 build a set of platforms or tool suites supporting such model-based design approaches based on the use of existing (or presently developed) user level modelling notations and formalisms supported in commercial tool suites. 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).
- The need for a good and effective connection between UML-RT related standardisation bodies and the active academic community will 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.

3.3 Plans for Year 4

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

3.3.1 Technical Description

Future plans for the respective activities include:


- **NoE integration: Component Based Design of Heterogeneous Systems.** There have been significant advances in the development of theory and approaches for component-based design. In particular, work on interface theory and conservative approximations has been instrumental to build the foundation upon which new tools and methodologies can be built. In the next 18 months, we plan to develop further the theory with the notion of “abstract semantics” that is an important element of the new STREP COMBEST that includes several Artist 2 Partners. On the tool side, we plan to study the integration of BIP and Metropolis as two frameworks that will allow the composition and the analysis of heterogeneous parts. In this domain, the use of the metamodels developed in SPEEDS and Metropolis will be considered. The sequence of meetings in different industrial sectors will continue by considering the avionics domain, and subsequently in the consumer electronics domain. The work on concrete approaches for handling different types of non-functional properties in component-based systems will be continued, by extending approaches for interface specification to handle reliability properties, and by developing a more uniform and scalable approach to reason about timing and resource properties.


An ARTIST2 workshop on Integrated Modular Avionics will be held November 12-13 in Rome. Speakers include key persons from Airbus, Dassault-Aviation, Israeli Aerospace Industries, Honeywell and Windriver, plus John Rushby and ARTIST2 participants.

- **Platform: Components Platform for Component Modelling and Verification.** Platform: Components Platform for Component Modelling and Verification. In the next 18 month period, we will continue to populate the global picture by adding new connections between tools and between formats. We will continue the work the unification of model representations (in particular at tool level), so as to be able to ease the exchange of models and the reuse of backend tools. An important part of the work will be performed within the IP project SPEEDS and the System@tic/Usine Logicielle projects OpenEmBeDD and ATTEST The COMBEST project that is about to start and which involves the ARTIST key partners on modelling of heterogeneous component systems is likely to strongly impact the platform at a later stage. Nevertheless, the results of that project will be ready only towards the very end of ARTIST2 . An important issue addressed will concern methods and a technology enabling the use of efficient but specific techniques in the context of complex heterogeneous systems.
- **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 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. This task force has the mission to handle the issues that may be received until December 2007 and to provide a finalization report for beginning of July 2008. The version 1.0 of MARTE will be then available. Our work within the next 18 months is then firstly to continue to experiment MARTE and find remaining bugs in the specification in order to generate issues using the OMG's Issue Reporting Procedure. This first period will last until December 22nd, 2007. This date is the official closure time for receiving the issues the FTF will have to deal with. The issues received after this date may not be handled within this FTF cycle, and may be deferred to the next revision of MARTE. Secondly, we will work on solving the received issues and produce FTF report to the OMG for beginning of July 2008.

4. Cluster Participants


4.1 Core Partners

Team Leader Cluster leader for RTC Cluster, and for activity “component-based design of heterogeneous systems”	
	<p>Bengt Jonsson</p> <p>http://user.it.uu.se/~bengt/</p>
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	<p>ASTEC, Competence Center for Software Technology, 1995-2005. http://www.astec.uu.se/</p> <p>WOODDES (IST project) A UML profile for Automotive industry http://wooddes.intranet.gr/</p> <p>Advance http://www.liafa.jussieu.fr/~haberm/ADVANCE/</p> <p>Regular model checking (www.regularmodelchecking.com)</p>


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	Member of the Editor Board of our Springer Journal on Software and Systems Modeling (SoSyM) Co-organizer of the Summer School MDD for DRES (www.mdd4dres.info) Co-organizer of the workshop series MARTES (www.martes.org) Member of the ISORC 2007 PC
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


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	<p>HyTech, a model checker for hybrid systems. mtc.epfl.ch/software-tools/hytech</p> <p>Mocha, a design and verification framework for reactive modules. mtc.epfl.ch/software-tools/mocha</p> <p>Giotto, a programming language for control applications. mtc.epfl.ch/software-tools/giotto</p> <p>Blast, a software verifier. mtc.epfl.ch/software-tools/blast</p>
Awards / Decorations	<p>Fellow, IEEE.</p> <p>Member, Academia Europaea.</p> <p>Member, German Academy of Sciences (Leopoldina).</p>


<p>Team Leader Co-cluster-leader for RTC cluster (end by Jan. 2007)</p>	
	<p>Albert Benveniste http://www.irisa.fr/distribcom/benveniste/</p>
Technical role(s) within ARTIST2	<p>Former ARTIST2-Hard Real Time cluster leader. Now Real Time Components cluster leader. Co-leader of activities <i>Forums with industrials</i> and <i>Seeding new work directions</i>. Co-organizer of meeting <i>Beyond AUTOSAR</i>.</p>
Research interests	<p>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</p>

	diagnosis, application to vibration mechanics.
Role in leading conferences/journals/etc in the area	Member of the Editorial Board of the <i>Proceedings of the IEEE</i> , Associated Editor at Large of the <i>IEEE Transactions on Automatic Control</i> ; PC member of several conferences including EMSOFT.
Notable past projects	<p>SACRES, Solutions for Safety Critical Embedded Systems, IST project 1996-1999</p> <p>SAFEAIR (IST-1999-10913, 2000-2002). Avionics Systems Development Environment http://www.safeair2.org/safeair/index.htm</p> <p>SPEEDS (ongoing IP)</p> <p><u>MAGDA</u> RNRT project (1998-2001). Models and algorithms for distributed fault management in telecommunications networks.</p> <p><u>MAGDA2</u> RNRT project (2002-2003). Models and algorithms for end-to-end distributed fault management in telecommunications networks.</p> <p><u>SWAN</u> RNRT project (2003-2006). Self-Aware Management in networks and Web services.</p> <p>Eureka projects in vibration mechanics</p> <ul style="list-style-type: none"> • <u>SINOPSYS</u> (1997-1999). In-operation modal analysis and monitoring. • <u>FLiTE</u> (2001-2004). Automated input/output and output-only modal identification and monitoring with application to aeronautics including flutter onset monitoring. • <u>FLiTE2</u> (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
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.

	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


	<p>Integrated Safety Systems Within WP System Dependability provide formal verification guidelines http://www.easis.org</p> <p>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.</p>
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Team Leader	
	<p>Alberto Sangiovanni Vincentelli (PARADES) http://www.parades.rm.cnr.it</p>
Technical role(s) within ARTIST2	<p>Bring in Expertise in embedded system modelling, validation, tools and methodologies and IC design.</p> <p>Deep involvement in cooperation with the industry: tools (co-founder Cadence and Synopsys), telecommunications (Telecom Italia), automotive (member of the GM STAB)</p>
Research interests	<p>Embedded system design methodologies and tools including modelling, validation, synthesis and formal verification, semantic foundations.</p>
Role in leading conferences/journals/etc in the area	<p>Program Committee Member CODES and EMSOFT.</p> <p>Member of the Editorial Boards</p> <p>Member of the ARTEMIS High-level Group and Steering Committee</p>
Notable projects	<p>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.</p> <p>HYCON NoE: Taming Hybrid Systems</p> <p>Center for Hybrid and Embedded Software Systems (CHESS) co-director</p>

	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, Gulliemini-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


	<p>Paul Caspi (VERIMAG)</p> <p>http://www-verimag.imag.fr/~caspi/</p>
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	<p>IST RISE: Reliable Innovative Software for Embedded Systems (2002-2005)</p> <p>IST Next-TTA: High Confidence Architecture for Distributed Control Applications (2001-2004)</p> <p>IST Crisys (terminated in 2001)</p> <p>IST SafeAir (terminated in 2001)</p>

<p>Team Leader</p> <p>Responsible for JPIA-Platform Platform for Component Modelling and Verification</p>	
	<p>Susanne Graf (VERIMAG)</p> <p>http://www-verimag.imag.fr/~graf/</p>
Technical role(s) within ARTIST2	<p>Participant in the Real-time and Component Cluster</p> <p>Responsible for JPIA-Platform Platform for Component Modelling and Verification</p>
Research interests	Formal modeling and analysis of reactive and timed systems.


Role in leading conferences/journals/etc in the area	<p>PC member of CAV 2005, MODELS 2006, FMICS 2006, FMCAD 2006, TACAS 2007</p> <p>PC chair of ATVA 2006</p> <p>Board of European Association of Software Systems and Technologies, EASST</p> <p>Animation of ASERT, the group on Embedded Systems ASERT within the CNRS virtual lab ASR</p>
Notable past projects	<p>IST INTERVAL - Consistent timing extensions for Telecom standards SDL, MSC and TTCN</p> <p>IST OMEGA - Correct Development of Real-time Embedded Systems Formal verification of embedded systems based on UML http://www-omega.imag.fr/</p> <p>IP ASSERT</p> <p>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.</p>

Scientific Coordinator of the ARTIST2 NoE Responsible for activity on “Deisgn of Heterogeneous Systems”	
	<p>Joseph Sifakis (Director of VERIMAG) http://www-verimag.imag.fr/~sifakis/</p>
Technical role(s) within ARTIST2	<p>Scientific Coordinator</p> <p>Participant in the Real-time and Component Cluster</p> <p>Participant in JPIA-Platform Platform for Component Modelling and Verification</p>


Research interests	Component based design, QoS Control, Modeling and Validation
Role in leading conferences/journals/etc in the area	<p>EmSoft'06 : Executive Committee (http://www.it.uu.se/conf/EMSOFT06/)</p> <p>Date'07 : Chair of the Embedded Software Track, and member of the Executive Committee (http://www.date-conference.com/)</p> <p>Editorial boards: •</p> <p>Formal Methods in System Design (http://www.springerlink.com/content/1572-8102/)</p> <p>Software Tools for Technology Transfer (http://sttt.cs.uni-dortmund.de/)</p>
Notable past projects	<ul style="list-style-type: none"> • 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	CNRS Silver Medal in 2001


	<p>Prof. Dr. Hermann Kopetz</p> <p>Real-Time Systems Group</p> <p>Institute of Computer >Engineering</p> <p>Vienna University of Technology</p> <p>http://www.vmars.tuwien.ac.at</p>
Technical role(s) within	Team Leader TU Vienna

ARTIST2	
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	<p>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</p> <p>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.</p> <p>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 rigorous safety requirements of the aerospace industry. http://www.vmars.tuwien.ac.at/projects/nexttta/</p> <p>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/</p>
Awards / Decorations	Fellow of the IEEE

	<p>Dr. Wilfried Elmenreich Real-Time Systems Group Institute of Computer >Engineering Vienna University of Technology http://www.vmars.tuwien.ac.at</p>
Technical role(s) within	Team Member TU Vienna


ARTIST2	
Research interests	expertise in sensor networks, sensor fusion and smart transducer interfaces
Role in leading conferences/journals/etc in the area of fault-tolerant real-time systems	Organizer of the annual Workshop on Intelligent Solutions in Embedded Systems (WISES)
Notable past projects	<p>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/</p> <p>CoMa Concepts and methods for the configuration and maintenance of the time-triggered fieldbus system TTP/A.</p> <p>TTSB – Time-Triggered Sensor Bus Elaborate the concepts for a modern and cost-effective fieldbus with deterministic real-time behavior.</p>

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 development approaches. 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	<p>Member of the PC of RTAS 07 Area B: Development, Verification, and Debug Tools for Real-Time and Embedded Systems</p> <p>PC Member in FDL'07, Forum on Specification and Design languages</p> <p>PC Member for ECRTS'08</p>
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

	<p>Prof. Ivica Crnkovic Mälardalen University Department of Computer Science and Electronics http://www.idt.mdh.se/~icc</p>
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	<p>Co-chair of technical committee for Euromicro Software Engineering and Advance Applications conference (SEAA) , General Chair of Euromicro SEAA 2006, Program chair 2007</p> <p>Member of Steering committee of ACM SIGSOFT Symposium of Component-based Software Engineering, General chair 2006, Program Chair 2004.</p> <p>General Chair of ACM SIGSOFT European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering 2007</p> <p>Co-Editor – Journal of Systems and Software – special editions in Component-based Software Engineering, 2007, 2005, 2003</p>
Notable past projects	<p>SAVE and SAVE++ – Design of safety critical vehicular systems, funded by Swedish foundation for Strategic Research, http://www.mrtc.mdh.se/SAVE/</p> <p>FLEXCON - Flexible Embedded Control Systems, , funded by Swedish foundation for Strategic Research, http://www.control.lth.se/FLEXCON/</p> <p>CBSE Network - Component-Based Software Engineering Network</p> <p>Q-IPRESS – Fp7 STREP</p> <p>FLEXI – ITEA2 project</p>
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)