IST-214373 ArtistDesign
Network of Excellence
on Design for Embedded Systems

Cluster Progress Report for Year 4

Cluster:

Modeling and Validation

Cluster Leaders:

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Policy Objective (abstract)
The sheer complexity of future embedded devices seriously challenges current development practice; new, integrated and scalable methods are urgently needed. The use of *model-driven* and *component-based* approaches are seen as a way of obtaining dependable embedded implementations with high performance and with reduced time and cost. Embedded systems involve monitoring and control of complex physical objects or phenomena using a number of dedicated hardware and software components often within a networked Solution.
Therefore, an objective of the cluster is to advance the use of *models, analysis techniques* and *supporting tools* spanning the areas of control theory, computer science, hardware, networks and even mechatronics, all well-established research areas which however have been developed independently.

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1. Overview of the Cluster (2008-2011)

1.1 High-Level Objectives

The sheer complexity of future embedded devices seriously challenges current development practice; new, integrated and scalable methods are urgently needed. The use of *model-driven* and *component-based* approaches are seen as a way of obtaining dependable embedded implementations with high performance and with reduced time and cost. Embedded systems involve monitoring and control of complex physical objects or phenomena using a number of dedicated hardware and software components often within a networked solution. Therefore, the use of models, analysis techniques and supporting tools span the areas of control theory, computer science, hardware, networks and even mechatronics all well established research areas which however –have been developed independently. This has the unfortunate consequence that it often becomes impossible to state, not to mention validate, overall properties of an embedded system.

Overall objectives of the cluster are:

1. Establish a coherent family of modeling formalisms spanning the areas of computer science, control, hardware and networks covering all aspects of embedded systems.
2. Development and combination of efficient means for analysis of models including simulation, testing, static analysis, model-checking, run-time verification, monitoring, diagnosability, controller synthesis.
3. Emphasis on support for compositional design and validation methodologies in terms of allowing new complex systems to be assembled from already constructed and validated components.
4. Realization of coherent tool chains obtained by adjusting and combining the models and tools from the different research areas. This will provide the basis for a cost-efficiency development process allowing for early design-space exploration and verification as well as reduce the sizeable amount of final testing-time and –cost.
5. Interaction with the thematic activities in the Transversal Integration workpackage on validating the formalisms and tools through real industrial development projects and case studies.

-- Changes wrt Y3 deliverable --

No changes with respect to Year 3.

1.2 Industrial Sectors

The modeling and validation techniques and supporting tools developed and disseminated within the cluster have relevance and potential impact on literally *all* industrial sectors developing or using embedded systems solutions. Within the Strategic Research Agenda of the ARTEMIS research platform[1] *Design Methods and Tools* is one of the three research priorities put forward. Here model- and component-based approaches are proposed as necessary for coping with the growing complexity of systems while meeting "time-to-market" requirements. Methods and tools for testing and verification are to play a central role in the ARTEMIS research strategy, as can be seen from the following citations:

- "… methods and tools for simulation, automatic validation and proving, and virtual Verification and Validation (V&V). Methods and tools for developing product lines of embedded systems."
- "… reduce the cost of the system design by 50%. Matured product family technologies will enable a much higher degree of strategic reuse of all artifacts, while component technology will permit predictable assembly of Embedded Systems."
- "… achieve 50% reduction in development cycles. Design excellence will aim to reach a goal of "right first time, every time" by 2016, including Validation, Verification and certification (to the same and higher standards as today)."
- "… manage a complexity increase of 100% with 20% effort reduction. The capability to manage uncertainty in the design process and to maintain independent hardware and software upgradeability all along the life cycle will be crucial."
- "… reduce by 50% the effort and time required for re-validation and recertification after change, so that they are linearly related to the changes in functionality."

The industrial needs for improved tools and methods for system design and validation have also been witnessed by a number of industrial and industry inspired case-studies and projects using model-based testing and verification carried out by the individual partners. Detailed information of these (and others) is to be found in the ARTIST2 Open Repository for Test and Verification Case Studies (https://bugsy.grid.aau.dk/artist2). Based on the above case-studies, it seems that the actual financial benefits of using a model-driven approach are likely to be even greater than those of the ARTEMIS goals, due to the capabilities of capturing functional as well as non-functional problems early on in the development process.

-- Changes wrt Y3 deliverable --

No changes with respect to Year 3.

[1] http://www.artemis-office.org/

1.3 Main Research Trends

With respect to modeling and validation of embedded systems, the overall trends include the need for dealing with increasingly complex systems with an increasing number of (functional and non-functional) features.

The need for a scientific foundation for embedded systems dealing simultaneously with software, hardware resources and physical environments have received substantial attention during the last year with significant contributions from the partners of the ARTIST Design Modeling and Validation Cluster. Emphasis is on quantitative modeling as well as component-based design methodology with the ambition of establishing a coherent family of design flows spanning computer science, control and hardware.

The quantitative and component-based modeling formalism are accompanied with advances in analysis techniques allowing for early exploration and assessment of alternative design solutions as well as validation of final implementations. Efforts in combining techniques ranging from simulation, testing, model-checking, run-time verification, artificial intelligence, compositionality, synthesis, refinement as well as abstract interpretation are currently pursued.

Also, a number of newly started STREPs and ARTEMIS projects are actively pursuing the accessibility of state-of-the art research results on quantitative modeling and validation from industrial tool-chains.

-- Changes wrt Y3 deliverable --

No changes with respect to Year 3.

2. State of the Integration in Europe

The objective of the Modeling and Validation cluster is to combine the efforts and skills of the individual leading researchers and research groups in Europe into a world-class virtual team, for advancing the state-of-the-art. The partners span the leading research teams in European level and are well connected with leading research teams outside Europe.

2.1 Brief State of the Art

An important class of industrially applied model-based methodologies in the Embedded Systems domain contains those based on a synchronous execution model (e.g. Lustre, Esterel, and Signal and many others). Other model-based approaches are built around a class of popular tools exemplified by Matlab-Simulink. Originating from the design automation community, SystemC also chooses synchronous hardware semantics, but allows for the introduction of asynchronous execution and interaction mechanisms from software (C++). More recent modeling frameworks, such as UML and AADL, attempt to be more generic in their choice of semantics and thus bring extensions in two directions: independence from a particular programming language; and emphasis on system architecture as a means to organize computation, communication, and constraints.

Design often involves the use of multiple models that represent different views of a system at different levels of granularity. Some transformations between models can be automated; at other times, the designer must guide the model construction. While the compilation and code generation for functional requirements is often routine, for non-functional requirements, such as timing, the separation of human-guided design decisions from automatic model transformations is not yet well understood

By far the most common validation technique applied by the embedded systems industry today is based on rather ad-hoc and mainly manual (hence quite error-prone) testing. Given that some 30-50% of the overall development time and cost are related to testing activities it is clear that the impact of improved validation technologies is substantial.

Whereas validation techniques for assessing functional correctness have reached a certain level of maturity and industrial acceptance, there is a need for mature validation techniques addressing quantitative being accessible from within industrial tool-chains.

-- Changes wrt Y3 deliverable --

No changes with respect to Year 3.

2.2 Main Aims for Integration and Building Excellence through ArtistDesign

The integration of the research groups within the cluster is well established and with significant impact on the larger research community on modeling and validation through strong impact on a number of important international conferences within the area. Also, partners of the cluster – often in collaboration with other clusters – have made significant effort in spreading of excellence beyond the ARTIST2 NoE through PhD schools and industrial seminars. Collaborative European and National projects also play a major role. More systematic knowledge transfer to industry through long-term collaboration on industrial development projects has been performed by individual partners. The national centers ESI (Embedded Systems Institute, Eindhoven, The Netherlands), CISS (Center for Embedded Software Systems, Aalborg, Denmark), and the regional center CRI (Centre de Recherche Intégrative, Grenoble France) have specific resources reserved for such activities.

Also at the national level of the various partners in the Testing and Verification cluster involvement in ARTEMIS are planned with the ambition of having an impact on the long-term take-up of testing and verification technology in industrial practice.

-- Changes wrt Y3 deliverable --

No changes with respect to Year 3.

2.3 Other Research Teams

During the fourth year, the number of affiliated partners contributing actively to the cluster has been remained stable as can be seen from the detailed activity reports on Modeling (D5-(4.1)-Y4) and Validation (D6-(4.2)-Y4) in comparison with the original DoW.

Prominent research groups on validation not being partner of the cluster include a number of teams from United Kingdom, in particular School of Computer Science, Birminghan (probabilistic model checking), Oxford University Computing Laboratory (real-time verification), Microsoft Research Laboratory at Cambridge and Royal Holloway, University of London. Other prominent research groups in modelling and model-based techniques for embedded systems are for example TU Munich and TU Braunschweig. In all of the above cases, individual partners of the cluster are collaborating with the particular research group.

The partners of the cluster are collaborating extensively with leading research teams outside Europe both on the level of concrete research problems and topics and in terms of organising the concerned research communities. The cluster has strong links to the work on software verification and testing taking place at Microsoft Research, Redmond, (Ball), NASA Ames and Kestrel Technologies (Holzman, Visser and Havelund), Kansas (Hatcliff), Berkeley (Ed Lee) and Vanderbilt (Stipanovits). Strong links exist to Cadence (Sangiovanni Vincentelli, director of Cadence and core-partner of ARTIST Design via his affiliation with Trento), Rice University, Texas (Vardi). Also ARTIST Design has collaborated with leading research groups and researchers from Israel including Weizmann Institute (Harel), Haifa (Grumberg) and Hebrew University (Kupfermann).

-- Changes wrt Y3 deliverable --

No changes with respect to Year 3.

2.4 Interaction of the Cluster with Other Communities

During the four years members of the cluster has been interacting with a number of neighbouring communities including HW/SW co-design, control theory and hybrid systems, discrete event systems, fault-tolerance, operations research, planning and scheduling as well as performance evaluation and statistics. In all of these areas the model-based and model-checking techniques of the cluster are providing usefull and competitive new techniques, just as several of the areas are challenging the expressiveness of our formalisms and performance of our analysis methods.

Similarly, leading research groups within AI are finding applications of existing search heuristics from planning to the improved model-checking (e.g. Freiburg University, Germany within the AVACS project, and Trento University, Italy).

Members of the cluster has published and given invited talks at main conferences and in journals of these neighbouring communities.

At the *organization* level, members of the cluster have been active in the European ARTEMIS initiative, and are involved in several of the funded projects from the first and second ARTEMIS call including the CESAR and MBAT projects where the most mature of the formalisms and analytical techniques will find their way into industrial practice.

-- Changes wrt Y3 deliverable --

Compared with Y4 interaction has taken place with a number of additional communities including operations research and statistics. Also, several formalisms and methods of the cluster will be made industrially available within the ARTEMIS projects CESAR and MBAT.

3. Overall Assessment and Vision for the Cluster

3.1 Final Overall Assesment

Both research activities with the cluster – the *Modeling Activity* and the *Validation Activity* – have progressed substantially within the four years of the project, and with significant synergy between proposed modeling formalisms and methods and validation techniques they support:

Within the sub-activity *Component Modeling,* the main focus was on defining and composing models with heterogeneous semantics. We considered rich models including non-functional issues, architectures and assumptions on the environment (contracts) and corresponding modeling and/or synthesis environments. Some of the most visible achievements on modeling have been obtained by collaboration in multi-partner projects that mostly have evolved from collaborations within ARTIST. In particular, the European projects ACROSS, ATTEST (1 and 2), CESAR, COMBEST and SPEEDS have been set up due to collaborations in ARTIST and have come up with important results.

Within the sub-activity *Resource Modeling,* we studied the design of resource-constrained systems, where the resource can be quantitative (e.g. energy consumption) or not (e.g. shared memory access). In particular, we considered here problems related to scheduling and resource allocation, to Design Space Exploration and to modeling for performance. The methods and tools developed by the cluster partners have been applied to real-world applications, for example the thermal behavior of an MRI scanner and printers, the Salzburg Helicopter platform, and energy regulation for intelligent buildings.

Within the sub-activity *Quantitative Modeling,* we specifically focussed on design frameworks for quantitative modeling. We have mainly focused on timing and probabilities, but also on multi-valued evaluation. We have in particular also considered the extraction of quantitative properties from non quantitative models, as well as models and theories for non-usual "quantities" such as evolvability, extendability, flexibility and robustness There was an important focus on synthesis.

Within the sub-activity *Compositional Validation* the main focus has been on methods for deriving non-functional properties from properties of their components, with the purpose of developing scalable compositional techniques for performance analysis and verification. Also validation methods based on abstractions and refinements for quantitative models have been developed.

Within sub-activity *Quantitative Validation.* the focus was on design frameworks for quantitative modeling, in particular Markov models, timed automata, priced timed automata, memory models involving stacks and queue and linear hybrid. A main achievement has been the wealth of algorithmic techniques allowing for efficient and scalable validation of formalism whose expressive power was previously out of reach. A particular scalable technique which has emerged is that of statistical model checking which allows several performance properties of very rich models to be established on the basis of simulation *up to a desired level of confidence.*

Within the sub-activity *Cross-Layer Validation* a substantial line of results have been obtained with respect to improved schedulability analysis and WCET analysis supporting multiprocessor and multi-core applications. The methods include WCET analysis and schedulability analysis addressing mixed-criticallity systems including tool implementation using model checking, as well as introduction new task models (e.g. Digraph based) allowing for more scalable and efficient schedulability analysis. Main results within *Cross-Layer Validation* concerns automatic controller synthesis from various rich game models (timed and probabilistic) with possible partial obsevability, and with a number of industrial successful application already having been achieved (e.g. the automatic synthesis of climate control in pig-stable, and synthesis of optimal control of hydraulic pumps). This shows that the distance from fundamental theoretical breakthroughs to industrial impact may be very short. Also, a number of results have been obtained with respect to conformance testing of non-functional properties based on quantitative model. Finally, within the theory of timed automata substantial effort has been made towards the analysis of their robustness: i.e. to what extent does the realization of the model on a non-perfect platform preserve properties already established.

Note that the cluster has organised relatively few closed ARTIST meetings, but we considered more interesting to meet at the margin of conferences and workshops organised by the cluster partners or collaborators from other ARTIST clusters. The organisation activities of the cluster and the intervention of cluster memebers as invited speakers of conferences and summer schools have been quite consequent, as can be seen from the list provided in the activity reports of the cluster.

-- The above is new text, not present in the Y3 deliverable --

3.2 Assessment for Year 4

Both research activities with the cluster – the *Modeling Activity* and the *Validation Activity* – have progressed substantially within the fourth year, and with significant synergy between proposed modeling formalisms and methods and validation techniques they support:

Within the sub-activity *Component Modeling* and *Compositional Validation* several partners have worked substantially and collaboratively on compositional design and verification methodologies for functional, timing and other non-functional aspects. These methods span assume/guarantee reasoning, interface automata as well as modal transition systems for rich models. In particular, composition frameworks have been proposed, as well as frameworks addressing design for integratability, maintainability, as well as methods for component adaptation (e. g. in the case of protocol mismatches). Also, theoretical foundations and coordination languages for heterogeneous systems have been further developed. Moreover, frameworks for tool integration based on meta-models and model-transformations have been consolidated and applied to case studies.

Within the sub-activity *Resource Modeling (*of the *Modeling Acitivity)* the focus in the fourth year was on design space exploration, multi-core scheduling, modelling paradigms for quantitative resources, in particular for performance, and derivation of distributed implementations from global specifications.

Within the sub-activity *Quantitative Modeling (*of the *Modeling Acitivity)*, in the fourth year, the focus was on design frameworks for quantitative modeling, in particular weighted automata, priced timed automata and quantitative communication models. This activity includes also some activities on synthesis of models guaranteeing quantitative properties, including for non-quantitative models.

Within sub-activity *Quantitative Validation* work from previous years on improved schedulability analysis and WCET analysis supporting multiprocessor and multi-core applications has been made. The methods include WCET analysis and schedulability analysis addressing mixed-criticallity systems as well as introduction new task models (e.g. Digraph based) allowing for more scalable and efficient schedulability analysis. Substantial work has been made with timed automata as based, including frequency analysis and off-line test slection, analysis of parametric quantitative models, analysis of resource consumption using energy- and price-extensions of timed auotmata, as well as highly scalable statistical model checking of performance properties of timed automata models. Finally, notions of metrics (providing notions of approximate correctness) and robustness for timed automata models have been substantiated and refined.

Within the sub-activity *Cross-Layer Validation* substantial work has been made on further improved methods for model-based testing. This work on conformance testing of real-time systems using time- and data abstraction, asynchronous testing and test-case generation for embedded Simulink, includes incremental testing of composite systems, off-line test generation from timed automata models, model-based test generation for data-intensive systems, as well as runtime monitoring. Closely related to that of testing is work on the learning of (probabilistic) automata.

-- The above is new text, not present in the Y3 deliverable --

3.3 Indicators for Integration

The interactions planned between partners included the following ones which alle have been achieved and mostly still continue:

- Tool Connection
  - Connections to SPEEDS;
    The HRC component format has been stabilized and some tools allow its exploitation which takes place in the CESAR project involving several SPEEDS partners and some other projects.
  - UPPAAL & RAPTURE & MODEST;
    Partially obtained with the introduction of a branch of UPPAAL supporting Probabilistic Timed Automata. The goal is extended to link to the probabilistic model checkers MRMC and PRISS
  - Metropolis and HDL (Giotto);
    Partially obtained.
  - ARTS & UPPAAL (from simulation to verification);
    Has been achieved allowing for simulation as well as verification of schedulability properties of MPSoC to be made. Future effort includes simulation and verification of performance properties (energy and memory consumption).
  - UPPAAL and CIF translators has been developed within the MULTIFORM project.
  - TrueTime.
    Future connections to TrueTime from a number of other tools are made possible by interfacing with Simulink.
- 10 Joint publications between partners/year - *Achieved*
- 2 open workshops / year - *Achieved*
- Connections between tools of partners; joint meetings. - *Achieved*

-- Changes wrt Y3 deliverable --

The above text is adapted from the Year 3 Deliverable.

3.4 Future Directions

The long-term vision of the cluster is to enable future development of embedded devices to cope with the growing complexity.

In particular, the cluster wants to develop model-driven and component approaches based on rigorous modeling formalisms and supporting validation techniques spanning allowing all relevant aspects of embedded systems (hardware, software and physical environment) to be taken into account. Here, a special challenge is to overcome the current weakness of model-driven development methodologies in dealing with physical constraints and quantitative aspects.

This calls for development of efficient means for analysing and validating such designs, as well as realization of coherent tool chains integrating academic efficient tool components into existing industrial tool chains. The presence of core members of the cluster within the ARTEMIS projects CESAR and MBAT provides unique and golden opportunity for ensure industrial take-up of the most mature formalisms and analysis techniques developed within the cluster.

-- The above is new text, not present in the Y3 deliverable --

4. Cluster Participants

-- Changes in the Cluster Participants wrt Y3 deliverable --

The set of Cluster patners has been stable. The set of associated partners has slightly changed, in fact increased over the years

4.1 Core Partners

Cluster Leader	
	*Professor Kim G Larsen (Aalborg)* *http://www.cs.aau.dk/~kgl/*
Technical role(s) within ArtistDesign	*Leads and coordinates the overall activities in the cluster together with Tom Henzinger; Team Leader for Aalborg. Contributes with expertise on timed automata based models with particular emphasis on extensions with cost, probabilities and multiplayer extensions. Verification, synthesis, performance evaluation and model-based testing.*

Cluster Leader	
	Susanne Graf (VERIMAG) http://www-verimag.imag.fr/~graf/
Technical role(s) within ArtistDesign	Leads and coordinates the overall activities in the cluster together with Kim Larsen; Team Leader for the modelling activities of Verimag. Contributes with expertise on component-based design, the BIP framework, platform-aware implementation of embedded systems, structural verification. Modelling taking into account extra-functional properties.

Team Leader	
	Professor Tom Henzinger (EPFL) http://mtc.epfl.ch/~tah/
Technical role(s) within ArtistDesign	Team Leader for IST Austria. Contributes with expertise on Rich interface theory for component-based design. Quantitative properties for the design of reactive systems with resource constraints. Languages and algorithms for specifying, checking and comparing resource-dependent specifications. Predictability and robustness of embedded systems.

Team Leader	
	Prof.dr. Jozef Hooman (Embedded Systems Institute (ESI) & Radboud University Nijmegen) http://www.cs.ru.nl/~hooman/
Technical role(s) within ArtistDesign	Team Leader for ESI; Contributes with expertise on modelling, compositional validation, and industrial applications.

Team Leader	
	Prof. Dr. Ir. Boudewijn R. Haverkort (Scientific Director of the ESI, The Netherlands) http://www.cs.ru.nl/~hooman/
Technical role(s) within ArtistDesign	Team Leader for ESI; Contributes with expertise on quantitative modelling.

Team Leader	
	Professor Wang Yi (Uppsala) http://user.it.uu.se/~yi/
Technical role(s) within ArtistDesign	Contributes with expertise on Resource modelling and Timing Analysis.

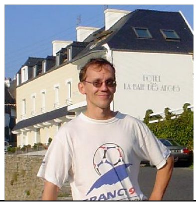
Team Leader	
	Professor Bengt Jonsson (Uppsala) http://user.it.uu.se/~bengt/
Technical role(s) within ArtistDesign	Team Leader for Uppsala. Contributes with expertise on Component Modeling and Verification.

Team Leader	
	Scientific Leader Thierry Jeron (INRIA) http://www.irisa.fr/prive/jeron/
Technical role(s) within ArtistDesign	Team Leader for INRIA. Contributes with his expertise on models with data and time for model-based test selection and coverage criteria, as well as for quantitative verification, control and diagnostics.

Team Leader	
	Scientific Leader Alain Girault (INRIA) http://pop-art.inrialpes.fr/~girault/
Technical role(s) within	Team Leader for INRIA. Contributes with his expertise on *Design*

ArtistDesign	*and modeling for reliability of safety-critical embedded real-time systems. Protocol conversion techniques and discrete. Controller synthesis for component-based real-time systems. Design and programming of predictable embedded architectures*.

Team Leader	
	Dr. Sébastien Gérard, CEA.
Technical role(s) within ArtistDesign	Team Leader for CEA. Contributes with expertise on model-based engineering, specific focus on standard modelling (specially OMG UML, SYSML and MARTE standards) and RT/E (Real-Time/Embedded) domains.

Team Leader	
	Professor Martin Törngren (KTH) http://www.md.kth.se/~martin/
Technical role(s) within ArtistDesign	Team Leader for KTH. Contributes with expertise on Integrated models supporting cross-layer validation. Methods for validation of self-configuring systems.Compositional validation of integrated models/components.

Team Leader	
	Professor Axel Jantsch (KTH) http://web.it.kth.se/~axel/
Technical role(s) within ArtistDesign	Team Leader for KTH. Contributes with expertise on *Integrated models of behaviour, formal analysis and model refinements*.

Team Leader	
	Professor Christoph Kirsch (Salzburg) http://cs.uni-salzburg.at/~ck/
Technical role(s) within ArtistDesign	Team Leader for Salzburg. Contributes with expertise on Compositional timing and reliability modeling in the Giotto family of languages.

Team Leader	
	Professor Alberto L. Sangiovanni-Vincentelli (Parades) http://www.eecs.berkeley.edu/Faculty/Homepages/sangiovanni-vicentelli.html
Technical role(s) within ArtistDesign	Team leader for Parades. Contributes with expertise on Platform-Based Design, the Metropolis and COSI frameworks, industrial applications and international activities.

	Prof. Roberto Passerone (Uni. Trento, Italy)
Technical role(s) within ArtistDesign	*Formal analysis of heterogeneous composition, abstract algebra, and metamodeling*.

Team Leader	
	Joseph Sifakis (VERIMAG) http://www-verimag.imag.fr/~sifakis/
Technical role(s) within ArtistDesign	Team Leader for Verimag. Contributes with expertise on component-based design, the BIP framework, platform-aware implementation of embedded systems, structural verification. Context-based analysis.

Team Leader	
	Oded Maler (VERIMAG) http://www-verimag.imag.fr/~maler/
Technical role(s) within ArtistDesign	Team Leader for Verimag. Contributes with expertise on timed and hybrid models and alidation methods.

Team Leader	
	Saddek Bensalem (VERIMAG) http://www-verimag.imag.fr/~bensalem/
Technical role(s) within ArtistDesign	Team Leader for Verimag. Contributes with expertise on compositional modelling and verification

4.2 *Affiliated Industrial Partners*

	Dr Henrik Lönn, Volvo Technology
Technical role(s) within ArtistDesign	*System engineering and modelling at Volvo. Leading the effort in developing the EAST-ADL modelling language for automotive embedded systems, through the series of projects EAST-EAA, ATESST and ATESST2.*

	Jacques Pulou (France Telecom R&D, France)
Technical role(s) within ArtistDesign	*Component behaviour modeling, Component Based OS construction.*

4.3 Affiliated Academic Partners

Team Leader	
	Prof. Dr. Bernhard Josko (OFFIS) http://www.offis.de
Technical role(s) within ArtistDesign	Team Leader for OFFIS. Contributes with expertise on component-based design and semantic foundation, in particular non-functional aspects as real-time and safety.

	Prof. Albert Benveniste (INRIA Rennes, France)
Technical role(s) within ArtistDesign	*Interfaces and modal automata*

	Prof. Roderick Bloem (TU Graz, Austria)
Technical role(s) within ArtistDesign	*Game models for the synthesis problem.*

	Prof. Pierre Wolper (CFV, Belgium)
Technical role(s) within ArtistDesign	*Computer-aided verification*
	Prof. Yiannis Papadopolis, Univ. Of Hull (UK)
Technical role(s) within ArtistDesign	*Compositional safety analysis and design optimization w.r.t. safety.*

	Ahmed Bouajjani - LIAFA (France)
Technical role(s) within ArtistDesign	*Real-time and hybrid model checking*

	Peter Habermehl - LIAFA (France)
Technical role(s) within ArtistDesign	*Real-time and hybrid model checking*

	Stavros Tripakis – Cadence Research lab (USA)
Technical role(s) within ArtistDesign	*Monitoring and test of real-time properties*

	Jean-Francois Raskin (CVF – Belgium);
Technical role(s) within	*Efficient Model-checking of linear-time properties.*

ArtistDesign	*Verification and synthesis for reactive systems. Timed and hybrid automata.*

	Joost-Pieter Katoen (Aachen – Germany)
Technical role(s) within ArtistDesign	*Model checking of quantitative system properties. Verification of (continuous-time) probabilistic and stochastic systems.*

	Holger Hermanns (Saarlandes U – Germany);
Technical role(s) within ArtistDesign	*Probabilistic and stochastic model checking.*

	Christel Baier (Dresden – Germany);
Technical role(s) within ArtistDesign	*Probabilistic and stochastic model checking*

	Patricia Bouyer, Nicola Markey and Phillippe Schnoebelen (LSV Cachan – France),
Technical role(s) within ArtistDesign	*Decidability and algorithms for priced timed automata and games. Algorithms for solving games of imperfect information*

	Prof. dr. ir. Wil van der Aalst, professor at Eindhoven University of Technology, The Netherlands
Technical role(s) within ArtistDesign	*Information System. Affiliated participant in the ESI Octopus project.*

	Prof. dr. Mehmet Aksit, professor at Twente University, The Netherlands.
Technical role(s) within ArtistDesign	*Software Engineering. Affiliated participant in the ESI Darwin project.*

	Prof. dr. Sandro Etalle, professor at Eindhoven University of Technology, The Netherlands.
Technical role(s) within ArtistDesign	*Security. Affiliated participant in the ESI Darwin project.*

	Prof. dr. Arjen van Gemund, professor at Delft University of Technology, The Netherlands. Embedded Software Laboratory.
Technical role(s) within ArtistDesign	*Affiliated participant in the ESI projects Trader and Octopus.*

	Prof. dr. Frits Vaandrager, professor at Radboud University, The Netherlands.
Technical role(s) within ArtistDesign	*Formal methods. Affiliated participant in the ESI Octopus project.*

4.4 Affiliated International Partners

	Sandeep Shukla (Virginia Tech, USA and INRIA Rennes, France)
Technical role(s) within ArtistDesign	*Modeling of embedded and synchronous systems*

	Stavros Tripakis – Cadence Research lab (USA)
Technical role(s) within ArtistDesign	*Monitoring and test of real-time properties*

5. Internal Reviewers for this Deliverable

- Bruno Bouyssounouse (Verimag)