
IST-004527 ARTIST2
Network of Excellence
on Embedded Systems Design

Activity Progress Report for Year 3

JPIA-Platform

# Design Tools for Embedded Control

Clusters:

**Control for Embedded Systems**

Activity Leader:

**Professor Martin Törngren (KTH)**

**http://www.md.kth.se/~martin**

*Policy Objective (abstract)*

*The overall purpose is to integrate research efforts on tools for co-design of resource-constrained embedded control systems. A related goal is to bridge the gaps between control systems tools to model-based development tools addressing other concerns of embedded systems such as software design and safety analysis. Providing tools is an important vehicle in bridging theory and practice. Providing integrated tools also contributes to the simplification of the design process for embedded systems.*

# Table of Contents

# 1. Overview of the Activity

The overall purpose is to integrate ongoing research efforts on tools for co-design of resource-constrained embedded control systems. Providing integrated tools provides facilities to handle the gaps between the control community and the embedded system community and contribute to the simplification of the design process for these systems. Providing tools is also an important vehicle in bridging theory and practice.

Traditionally, most of the tools in this area have been developed from the viewpoint of one discipline, thus with little explicit support of co-design. In addition, most of the existing tools are point tools in that they focus on the handling of a few aspects, at one specific level of abstraction.

Embedded control design tools are of relevance to most embedded systems industrial sectors, including but not limited to: avionics, consumer electronics (kitchen appliances, hi-fi/video, wireless communication), space, energy distribution.

## *1.1 ARTIST Participants and Roles*

Prof. Martin Törngren – KTH (Sweden)
*Provides expertise in development methodology, co-design of control and computer systems, model-based development, and model and tool integration approaches.*

Ass. Prof. DeJiu Chen – KTH (Sweden)
*Provides expertise in development methodology, model-based development, and model and tool integration approaches.*

Prof. Karl-Erik Årzen – LTH (Sweden)
*Provides expertise in co-design theory, and the TrueTime and Jitterbug co-design tools.*

Ass. Prof. Anton Cervin – LTH (Sweden)
*Provides expertise in the TrueTime and Jitterbug co-design tools, and co-design theory.*

Ass. Prof. Zdenek Hanzalek – CTU (Czech Republic)
*Provides expertise in the TORSCHE toolbox, and co-design theory*

Prof. Pedro Albertos – UPVLC (Spain)
*Provides expertise in co-design theory*

## *1.2 Affiliated Participants and Roles*

PhD Henrik Lönn. Volvo Technology Corporation (Sweden)
Provides expertise in automotive embedded systems.

PhD Jonas Edén, Scania Corporation (Sweden).
Provides expertise in automotive embedded systems.

Tech Lic. Diana Malvius, Syntell corporation and KTH (Sweden).
Provides expertise in information management tools and systems engineering.

PhD Jakob Axelsson - Volvo Car Corporation (Sweden).
Provides expertise in automotive embedded systems

PhD Ulrich Freund – ETAS Corporation (Germany).
*Provides expertise in commercial development tools for embedded control systems.*

Joachim Stroop – dSPACE (Germany).
*Provides expertise in commercial development tools for embedded control systems.*

PhD Rolf Johansson – Volcano/Mentor Graphics (Sweden and Hungary).
*Provides expertise in commercial development tools for communication technologies for embedded control systems.*

Ass. Prof. Yiannis Papadopolous – Univ. of Hull (UK).
*Provides expertise and tools in the area of safety analysis.*

Mikael Strömberg – Systemite Corporation (Sweden).
*Provides industrial competence in the areas of configuration management, model based development and systems engineering.*

Vladimir Havlena - Honeywell Prague Labs (Cech republic)
*Expertise in industrial control systems.*

Prof. Yves Sorel – Inria (France).
*Development and experiences with the Syndex tool for embedded systems design.*

PhD. Daniel Simon – INRIA (France)
*Development and experiences with the ORCCAD tool for embedded systems design*

Christoff Kirsch, University Salzburg (Switzerland).
*Development and experiences with the GIOTTO tool for embedded systems design.*

## *1.3 Starting Date, and Expected Ending Date*

The activity started September 1, 2004. The nature of this activity, tool integration, makes it relevant that the activity will run over the entire life-time of the network, and most likely also continue after the termination of Artist2. There are plenty of opportunities not only for integration of the tools represented by the cluster members but also in considering broader scale integration that can involve other clusters.

## *1.4 Baseline*

Several tools have already been developed separately by the individual teams, and are briefly described in the following paragraphs. A national Swedish research programme, FLEXCON (http://www.control.lth.se/FLEXCON/) – which ended 2005, included objectives for integrating these tools, and this JPIA builds on this effort.

Two Matlab-based toolboxes, Jitterbug and TrueTime, for analysis and simulation of real-time control systems have recently been developed at Lund University. The tools can be used at early design stages to determine how sensitive controllers are to scheduling-induced delays and jitter. They can also be used at the implementation stage for trade-off analysis between the tasks. Furthermore, TrueTime can be used as an experimental platform for research on flexible scheduling.

At KTH the AIDA toolset has been developed for design of networked embedded control systems. The toolset is based on a modelling framework allowing functional requirements and various implementation abstractions to be represented. AIDA supports end-to-end timing behaviour and facilities for fault injection and robustness experiments. Based on experiences with the AIDA toolset, further work has concentrated on developing a new model and tool integration platform.

At CTU, the Torsche (Time Optimisation of Resources, SCHEduling) MATLAB-based toolbox is being developed with support for scheduling algorithms that can be used for applications such as high level synthesis of parallel algorithms and optimized production of manufacturing lines.

UPVLC has developed several co-design tools to facilitate the embedded control system development. These tools include the schedulability analysis of the system with a partitioned system in order to reduce the jitter, optional activities analysis, dynamic changes of controllers and embedded control system generation. RT-LEAST is a tool to deploy minimal embedded control system for RT-Linux.

## *1.5 Problem Tackled in Year 3*

The long term goal – as stated in the 1st year deliverable - remains valid, that of achieving a platform consisting of a suite of tools, each tailored for one or several tasks in the development process for resource-constrained embedded control systems. The new and unique feature of the tools is that they take control, computing, and communication aspects into account.

As indicated by the work during the second year, an increased emphasis has been placed on model and tool integration considering control systems tools and related embedded systems tools. There are several reasons for this, including industrial relevance and the fact that several interesting research challenges have to be solved to provide satisfactory solutions. Consider for example the design of an embedded automotive ABS braking system. One obvious concern is that of the core motion control functionality, especially the control logic and algorithms and the dynamic behaviour of the system. However, this is only one out of several aspects. Other aspects include safety, security, network communication, mechanical design, IO, power, etc. These aspects and components are typically handled by different specialists, employing different modeling languages and tools. Approaches to support model integration and management therefore become increasingly important.

The work during the period has focussed on

- further development of the individual tools developed by the cluster partners
- development of a demonstrator platform, the Saint truck, which so far has been used to explore complexity management for automotive embedded systems, limitations of Autosar, and model-based development approaches.
- increased efforts for cross-cluster discussions on model and tool integration. Martin Törnren of the Control for embedded systems cluster took the initiative to raise and discuss the needs of ARTIST2 actions dedicated to synchronization between various platforms, models and tools. Following this initiative, two workshops have been carried out during the 3rd year of ARTIST2 with Martin Törngren as a co-organizer.
- further work on model and tool integation considering in particular how UML and safety models/tools can be connected to control systems models/tools. The work includes both the identification of integration scenarios as well as initial integration case studies.
- Interviews and studies of industrial practices in the area of automotive embedded systems area. This work is motivated to better understand the gap between research and industrial practices, what the industrial challenges are, and provides essential information on important aspects when introducing new methods/technologies in industry.
- dissemination of results

There is no major deviation from the work plan.

## *1.6 Comments From Year 2 Review*

### *1.6.1 Reviewers' Comments*

"4.4.7 D23-Control-Y2 Design Tools for Embedded Control (Platform)

ACCEPTED

General comments apply."

### *1.6.2 How These Have Been Addressed*

Several of the "General comments" are on the level of the network management or clusters. We would like to point out that we have addressed in particular the following one:

"The consortium should open itself to external views and additional industries. Today too many stakeholders are left over. We would like to see the number of affiliates growing. Following the recommendations from the last review meeting, we are glad to see that a procedure is in place for this on the website."

We agree with this statement of the reviewers. Supported by other projects and additional informal industrial contacts we have this year had extensive interactions with industry (mainly the automotive, but also telecom and process control) and with academic partners not part of ARTIST2, providing complementary competences – these interactions are briefly described in Secction 2.3.3.

At KTH, an effort has been driven by Prof. Martin Törngren to create an embedded systems centre, enhancing the interactions in education and research among research groups spanning control, robotics, communication, software, electronics, and human machine interaction. This effort has been met very positely by both researchers and industry. We expect the centre to be launched towards the beginning of 2008.

# 2. Summary of Activity Progress

## *2.1 Previous Work in Year 1*

The following is an extract from the last year's deliverable, describing accomplishments the first 12 months.

Work achieved in the first 6 months:

- Development of the TrueTime tool (wireless network blocks, battery-powered devices, ocal clocks with drift and offset) – LUND
- Development of a new tool for model integration and management (Paper to appear in the 31st EUROMICRO conference, 2005, by Jad El-khoury, Ola Redell and Martin Törngren) – KTH
- Started the work on a survey on tools for modelling and design of real-time control systems
- Further developments of the TORSCHE (Time Optimisation of Resources, SCHEduling) MATLAB-based toolbox – CTU. Using the toolbox, one can easily and quickly obtain an optimal code of computing intensive applications running on specific hardware architectures like FPGAs with special purpose macros. The tool can also be used to investigate application performance prior to its implementation and to use these values (e.g. the shortest achievable sampling period of the filter implemented on given set of processors) in the control system design process performed in Matlab/Simulink.
- Further development of the tools from UPVLC - UPVLC

Work achieved in months 6-12:

- Completed the survey on tools for modelling and design of real-time control systems. Existing tools have been categorized. In doing so discussions have taken place with the HRT cluster as well as the Hycon NoE to provide feedback on the types of tools included. Continued development of the TrueTime tool (wireless network blocks, battery-powered devices, local clocks with drift and offset) – LUND
- Development of course and training material for TrueTime – KTH
- Tutorial on TrueTime given at IFAC World Congress, Prague, July 3
- Continued development of a new tool for model integration and management (Paper to appear in the 31st EUROMICRO conference, 2005, by Jad El-khoury, Ola Redell and Martin Törngren) – KTH
- Continued developments of the TORSCHE (Time Optimisation of Resources, SCHEduling) MATLAB-based toolbox – CTU
- Continued development of the tools from UPVLC – UPVLC
- KTH has initated a state of the art survey on approaches for model/tool integration and model management

## *2.2 Previous Work in Year 2*

Technical Achievements, Outcomes and Difficulties encountered are described in the following – extracted from the year 2 deliverable. Note that the cited references refer to those in the year 2 deliverable.

**Achievement: Dissemination of results on design tools to the scientific community**

As part of the dissemination of cluster results in this area, we have organized the following events:

- A graduate school on embedded control systems (Prague, April 3-7, 2006)

http://www.artist-embedded.org/FP6/ARTIST2Events/Events/EmbeddedControl/

- A cluster session on Tools for Co-Design of Control Systems and Their Real-Time Implementation at the IEEE International Symposium on Computer-Aided Control Systems Design (CACSD), Thursday October 5, 2006 (note that the planning for the event took place during the 2nd year of ARTIST2 whereas the event was carried out during the 3rd year).

http://www.elet.polimi.it/conferences/cca06/CACSD_home.htm

The session on "Tools for Co-design of Control Systems and their Real-time Implementation" was prepared by Zdenek Hanzalek, Martin Törngren and Karl-Erik Årzén. The session will be held at the IEEE Conference on Computer Aided Control System Design (CACSD) in Munich, October, 2006.

This session sets the context of embedded control systems development describing what is achievable with current generation tools. The aim of this session is to:

- give overall characteristics of the area
- identify and summarize important co-design tools available
- characterize the state of practice for both industrial and academic tools
- show illustrative case studies
- provoke discussion on integration of these tools.

The session consists of one survey presentations (Tools supporting the co-design of control systems and their real-time implementation; current status and future directions) plus five presentations oriented towards specific tools and principles (Model based integration from the Royal Institute of Technology, Jitterbug and TrueTime from Lund University, Sweden, TORSCHE from the Czech Technical University in Prague, the schedulability issues from Valencia, the SAE Architecture Analysis & Design Language from Carnegie Mellon Software Engineering Institute, US Army/AMCOM and Honeywell Labs).

As part of an effort to summarize achievements in the Swedish research program on embedded real-time systems – ARTES – a chapter was written jointly by KTH and LTH describing the co-design tools that were partly developed by funding from ARTES [9]. See http://www.artes.uu.se/bok/ for more information about the book.

The work has also been promoted and disseminated through a number of invited talks described in section 2.2.3, in some cases coinciding with invited papers [2, 3].

Output from Achievement: Dissemination

- On-line documentation/presentations including overviews of co-design tools – see

http://www.artist-embedded.org/FP6/ARTIST2Events/Events/EmbeddedControl/links

- The papers produced for the CACSD session – see links above and references to individual papers [4, 6, 7, 8].

Difficulties with Achievement: Dissemination

No difficulties encountered.

**Achievement: Interactions with other ARTIST2 clusters, and a characterization of model and tool integration efforts**

In order to stimulate interactions swith the other clusters, we issued our tool survey for review to other cluster leaders. In addition, discussions and joint work was initated with the real-time components cluster (partners CEA and MDH) and with affiliated partners VTEC and Volvo car, the purpose of which was to achieve a better understanding of different approaches towards model and tool integration. This topic is today addressed by many researchers and companies, spurred by the increasing product complexity and needs to support early integration of models representing different aspects and parts of a product. Several variants of model-based approaches are today advocated to facilitate systems integration. A survey was conducted including a number of representative efforts that address multiple concerns or views including modeling languages such as AADL and EAST-ADL as well as model integration environments such as GeneralStore, ToolNet, and Fujaba.

Part of this work was carried out in connection to the new European research project, ATESST, involving KTH, Volvo (affiliated partner) and CEA (real-time components cluster partner), as well as other automotive companies.

www.atesst.org

Output from Achievement: Interactions and characterization

- An extended tool survey essentially with complementing information from Inria on the Syndex tool and from Univ. of Salzburg on the GIOTTO tool, [5].

- A jointly authored paper surveying different approaches towards model and tool integration, highlighting their commonalities and differences regarding basic integration mechanisms and engineering support, [6].

- A better understanding of the challenges, integration characteristics and types of solutions available with respect to model and tool integration.

Difficulties with Achievement: Interactions with other ARTIST2 clusters

Interactions with other clusters is resource/time demanding because it requires that disciplinary gaps (terminology and mutual understanding) are bridged. This is even more difficult today because people in academia and industry tend to be extremely busy. Therefore, dedicated efforts and resources/time have to be devoted for this purpose. The partial success reported here is due to ARTIST2 as such, already existing connections, and new projects, such as ATESST. We believe there is more potential with this type of interactions.

**Achievement: Tool Integration**

An example of how the to co-design tools TrueTime and Jitterbug from LUND can be combined has been developed. In [1] Truetime is used to, using simulation, derive the sampling jitter distributions and the input-output latency distributions for a controller task set executing in a real-time kernel. These distributions are then used by Jitterbug to analytically evaluate the reaulting control performance.

The tools are interfaced through the Matlab workspace. Another approach to combine the tools is for performance evaluation of nonlinear control loops. Jitterbug is able to analytically evaluate a quadratic control performance function for linear systems. If the control loop under

investigation instead is nonlinear (either the control law or the controlled plant) then the same quadratic control performance can be evaluated by Truetime through simulation.

Based on the experiences of the AIDA toolset, an experimental model integration and management platform has been developed at KTH [11, 13]. Interfaces from Simulink and Dome, representing domain tools (in this case used for function and hardware desin respectively), were implemented to the platform which was also exercised with case studies on architectural design. The corresponding tool integration architecture draws upon experiences from mechanical engineering where product data management tools are used to store design information, and with interfaces and various levels of integration to design tools, e.g. for CAD and CAM. The design and implementation of fine-grained model management of functions, software and hardware turned out to be quite feasible using existing commercial PDM tools, although a complete evaluation including performance, scalability etc. has not been carried out [11, 12].

Output from Achievement: Tool Integration

Apart from the papers mentioned in the previous paragraph, a better understanding of the problems facing tool integration has been achieved during year 1.

Difficulties with Achievement: Tool Integration

The efforts required for actual tool development and integration must not be underestimated. The progress in these areas depends to a large extent on the available research projects that provide explicit funding to these activities.

**Achievement: Further development of individual tools**

Further development of the tools developed by LTH, Jitterbug and Truetime, and by CTU, Torsche. The work at KTH on a model and tool integration platform was reported in the previous paragraphs.

Jitterbug: The development of a graphical user interface for Jitterbug has started. Currently the user interface of Jitterbug is purely text-based. However, Jitterbug is based on block diagrams and state automata, two formalisms for which graphical interfaces are very natural. In the current GUI approach a graphical interactive interface has been developed in Java and Swing. In this interface the user develops the block diagram and state automaton models using mouse-based drag-and-drop techniques. When the user decides to perform a performance evaluation, the user interface models are interpreted and the corresponding text-based Jitterbug Matlab commands are created. These commands are then piped to Matlab, that runs as a compute engine executing the Jitterbug commands and returning the result. The GUI is at the time of writing currently completed to around 80%. With the GUI we expect the usability of Jitterbug to increase substantially.

TrueTime: A new version (1.4) of TrueTime has been released. The version includes support for semaphores (in addition to the already existing mutexes), and blocking mailboxes. The possibility to have user defined radio models for wireless networks has been added. As well as support for implementing ad hoc routing protocols, e.g. AODV. At the time of writing the previous release (1.3) has been downloaded more than 1.900 times.

Torsche: The development of a simulation and implementation support for DSP applications in TORSCHE has started providing several case-studies. Further, TORSCHE has been extended by a simple response time analysis for the set of periodic tasks running under operating system with fixed priority preemptive kernel. Therefore one set of input parameters (computation times, periods, priorities) may be used to run simulation in True Time and response time analysis in TORSCHE. A new version (0.2) of TORSCHE has been released. The version includes new scheduling algorithms (Horn, List scheduling with various parameters, Scheduling with start

time related deadlines, Cyclic scheduling), support for random generation of test cases, graph algorithms and interface to ILP solvers.

Output from Achievement: Further development of individual tools

- Jitterbug: http://www.control.lth.se/~lincoln/jitterbug/
- Truetime: http://www.control.lth.se/truetime/
- Torsche: http://rtime.felk.cvut.cz/scheduling-toolbox/

Difficulties with Achievement: Further development of individual tools

No difficulties encountered

## *2.3 Current Results*

The technical achievements in terms of NoE integration include sharing of tools with other partners (in particular the Truetime tool developed by LTH), joint development of model integration platforms (KTH, CEA, Volvo), interactions with international partners (UIUC), joint cross-cluster efforts on workshops to share viewpoints and identify openings for the various platforms/models/tools developed by different clusters, and finally, also interactions with other communities and industries not part of ARTIST2. These interactions are further elaborated in sections 2.3.1, 2.3.3 and 2.3.5.

### *2.3.1 Technical Achievements*

**Achievement: Developments of individual tools/platforms developed by cluster partners (all partners)**

LTH has developed the TrueTime simulation toolbox in a number of directions. In September 2006 Version 1.4 was released. It contained the following new features:

- support for semaphores (previously only monitors were supported) and for blocking reads and writes to mailboxes
- the possibility to user-defined path-loss models for the wireless network blocks
- the addition of an AODV ad hoc routing protocol example
- improved execution speed of more than 100% for the real-time kernel blocks

In January 2007 Version 1.5 was released. It contained the following new improvements::

- major performance improvements for the network blocks
- new network interface blocks which make it possible to use the network blocks standalone, without any real-time kernel blocks, something that is of interest in certain networked control applications

Each version is downloaded by between 1,000 – 1,500 user over the course of a year (version 1.5 has been downloaded 963 times since its release in January 2007). During the year we have also learned about several new users. For example at Universite d'Evry Val d'Essonne TrueTime is used in the final project course in control. In this control the students apply all the theory they have learned in earlier courses on a distributed control example where an inverted pendulum controller is closed over a CAN network. Before the students are allowed to try their design on the real physical system, they must develop a TrueTime model that verifies that their design works. The same university have also used TrueTime in several master thesis projects with French industry, including PSA and GM. The number of Artist2 partners who are using

TrueTime increases steadily. Some of these that we are aware of are Aveiro, SSSA/Pisa and TU Vienna.

A drawback with TrueTime is that it is based on Matlab/Simulink. In a master thesis project (Kusnadi 2007) we have successfully shown that it is possible to port TrueTime to Scilab/Scicos. We have also evauated that it is possible to use multi-threading to simulate the different user threads in a real-time kernel model. In the current TrueTime version multi-threading is emulated which implies that context switching also must emulated. Using the new approach would greatly simplify the implementation of the kernel blocks in future releases. It would also make it easier to port production C code into TrueTime.

In (Gonzalo et al 2007) the possibility to include TrueTime in the EJs (Easy Java Simulation) simulation toolbox has been evaluated. This has been done in cooperation with UNED, Madrid.

KTH, an ARTIST2 and Control for embedded systems partner, has been using Truetime. In work at KTH, modeling and simulation concepts for dynamically configurable systems have been studied. In particular, the use of Truetime as a basis this has been evaluated. Certain abstractions, such as memory, and modelling of dynamic configurations are not explicitly support by Truetime and are the subject of further work [Naseer et al., 2007].

Achievement: Development of TORSCHE (CTU). The CTU tool called TORSCHE Scheduling Toolbox for Matlab has adopted several extensions and changes (see [Sucha et al (2006) and Kelbel and Hanzalek (2006)] and http://rtime.felk.cvut.cz/scheduling-toolbox/). Beside of development of new scheduling algorithms, the integration with Truetime has been shown on typical examples of DSP algorithms implemented on FPGAs where Torsche profits from cycle-exact simulation executed by Truetime. Coupling of Truetime and Torsche was demonstrated during labs of Graduate Course on Embedded Control Systems, May 7-11, 2007, Lund, Sweden. Further we finished a work on graph editor and web based production of scheduling results in Gantt charts written in Perl and Metapost.

Feature screen casts were published 15-Jun-2007. The screen casts have been developed in order to simplify the use of scheduling algorithms within Matlab environment. The screen casts focus on the following problems: How to create Scheduling objects. How to solve a optimization problem. How to work with Graph object. How to write an easy scheduling algorithm (Earliest Release Time algorithm). How to implement a simple algorithm (Minimum spanning tree).

**Achievement: The TrueTime RUNES demonstrator (LTH, KTH, UIUC)**

During the year most of the TrueTime development has been funded by the EU/IST project RUNES. In RUNES a large demonstrator involving wireless networks and autonomous mobile robots that are used as mobile network routers has been developed [Årzén et al 2007a,b]. In parallel with the physical scenario a large TrueTime model of the scenario has been developed [Årzen et al 2007]. The TrueTime model includes models of heterogeneous mobile robots consisting of both AVR microcontrollers and Tmote Sky “motes”, and of stationary sensor network nodes. The model further includes ultrasound-based localization and data fusion using Extended Kalman filters. The movement of the robots and the connectivity status of the sensor network are animated dynamically. The developed model is most likely one of the largest TrueTime models ever developed. Our international partner UIUC has been involved in the implementation of the TrueTime model of the AODV protocol.

**Achievement: The Saint demonstrator (KTH with Scania and Enea)**

The KTH Saint demonstrator (http://www.md.kth.se/saint/) and model integration and management platform. The Saint demonstrator, which has been developed in cooperation with Scania, constitutes a scale-model truck including mechanics, sensors, actuators and distributed control system. It incorporates a simple static middleware and advanced configuration environment which enables a user to configure which functions (e.g. adaptive cruise control and collision avoidance by braking) to be included. The configuration tool will then based on information stored in a product data management system, identify the corresponding software components and perform and suggest an intelligent allocation of software components to hardware nodes, build the complete (or partial) system and download it to the truck. The demonstrator illustrates the limitations of middleware approaches that do not explicitly consider real-time behaviour. It also provides a foundation for futher experiments with life-cycle model-based information management and domain tool/aspect integration encompassing mechanics, software and electronics, [Larses et al (2007), Axelsson et al (2007).

**Achievement: Developments of integrated environment for embedded control systems (CTU with UNIS Ltd. and 1Czech Academy of Sciences)**

The motivation of our work (for more details see Bartosinski et al (2006) and Bartosinski et al (2007)]) is to make a Matlab/Simulink compatible design tool for embedded control systems compliant with HIS and AUTOSAR. The tool is based on Processor Expert (http://www.processorexpert.com/ ), a component oriented development environment supporting several hundreds of microcontrollers, and Matlab/Simulink (http://www.mathworks.com/ ) which is the de-facto standard in the rapid prototyping of the control applications but it does not have an adequate HW support. The objective is to provide an integrated development environment for embedded controllers having distributed nature and real-time requirements. Therefore we discuss the advantages of using an automatically generated code in the development cycle of the control embedded software. We present a developed block set and Processor Expert Real-Time Target for Matlab Real-Time Workshop Embedded Coder. The case study shows a development cycle for a servo controller.

**Achievement: Model-based embedded systems engineering (KTH, Volvo, CEA, other ATESST partners and the Univ. of Hull)**

In connection to the ATESST project (www.atesst.org) KTH has been investigating model transformations between UML, Simulink and safety analysis tools. In the ATESST project, a UML profile for automotive embedded systems modelling is developed. The goal is to provide support for coherent systems level modelling, while enabling integration with domain tools.

UML-Simulink. A new UML tool environment, Papyrus, developed by CEA is used to demonstrate the concepts, but the idea is that the profile should be useful in commercial UML tools. During this year scenarios (providing motivation) and ways of performing structural and behavioural transformations between UML and Simulink have been investigated. The work has been promising but there are several outstanding research topics which will be dealt with in the subsequent work [Shi et al (2007), Cuenot et al (2007a)], one being to what extent the UML can be formalized using its available extension mechanisms and current definition of behavioural models. There are also several technological issues involved, such as how well UML tools support profiling (this is important given the interest in developing profiles).

Continuous-time modelling in SysML/UML2. Related to the above effort, KTH has been investigating the possibilities for continuous-time modelling in SysML/UML2. This type of modelling can in principle be performed on different levels of abstraction, and using different types of diagrams such as parametric and acitivity diagrams; we have performed an initial

investigation of different approaches, found a limitation in the parametric diagrams and concerns when using the activity diagrams – these are subject for further work [Sjöstedt et al (2007)].

UML-Safety modelling and analysis. Safety analysis for embedded control systems, including analysis at functional as well as implementation level have been investigated. A new fault/error/failure modelling concept linked to systems level modelling is being developed, partly in cooperation with the Univ. of Hull. The approach builds on model-based embedded systems engineering integrated with extensions of classical safety analysis techniques such as failure-mode and effects analysis and fault-tree analysis [Cuenot et al (2007a), Cuenot et al (2007b)].

**Achievement: Better understanding of industrial practices in automotive embedded systems model based development (KTH)**

Interviews and studies of industrial practices in the area of automotive embedded systems area have been carried out. This work is motivated by the need to better understand the gap between research and industrial practices, what the industrial challenges are, and to provided insight into how systematic approaches to model-based development can be introduced in industry. The studies have provided several important insights regarding the consideration of process and organizational constraints when introducing new methods/tools, and how model-based development supports product/process/organization integration [Adamsson (2007), Malvius (2007)].

**Achievement: Higher level of interaction between clusters and industry on model-based development (all partners)**

Martin Törngren of the Control for embedded systems cluster took the initiative to raise and discuss the needs of ARTIST2 actions dedicated to synchronization between various platforms, models and tools. This initiative received a positive response from the other ARTIST2 clusters, resulting in two ARTIST2 workshops during the 3rd year, one collocated with the DATE conference, and the other one collocated with the CAV conference.

http://www.artist-embedded.org/artist/-ARTIST2-Workshop-at-Date-07-.html

http://www.artist-embedded.org/artist/-Tool-platforms-for-modelling-.html

The workshops served both as dissemination and for discussing design flows, methodology, tools and modelling approaches for embedded systems (see the dissemination achievement for the links). The workshops were successful but more efforts in this direction are needed; it takes time and resources to bridge disciplinary gaps.

A larger KTH/Industry seminar was organized on Aug. 30th at KTH to discuss embedded systems challenges, industry/academia interactions, and activities of the forthcoming KTH embedded systems centre cooperation. The European commission was represented at the meeting and provided a talk on joint technology initiatives, focusing on ARTEMIS.

http://www.md.kth.se/RTC/KTH_es_seminar2007.html

### *2.3.2 Individual Publications Resulting from these Achievements*

The work during this third year of ARTIST2 has involved extensive cooperation. As a result, a large number of the publications are joint ones.

**Partner Name**
List of Publications

**CTU**

Sucha et al (2006). Šůcha, P. - Kutil, M. - Sojka, M. - Hanzálek, Z.: TORSCHE Scheuling Toolbox for Matlab. In IEEE Symposium on Computer-Aided Control System Design 2006. Piscataway: IEEE, 2006, s. 50-52. ISBN 0-7803-9797-5.

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**LTH**

(Årzén et al 2007c) Karl-Erik Årzén, Martin Ohlin, Anton Cervin, Peter Alriksson, Dan Henriksson: "Holistic Simulation of Mobile Robot and Sensor Network Applications Using TrueTime", European Control Conference, Kos, July 2007.

(Cervin et al 2007a) Anton Cervin, Martin Ohlin, Dan Henriksson: "Simulation of Networked Control Systems Using TrueTime", In Proc. 3rd International Workshop on Networked Control Systems: Tolerant to Faults, Nancy, France, June 2007. Invited talk.

(Ohlin et al 2007) Martin Ohlin, Dan Henriksson, Anton Cervin: "TrueTime 1.5—Reference Manual", Department of Automatic Control, Lund University, Sweden, January 2007.

(Kusnadi 2007) Daniel Kusnadi: "TrueTime in Scicos", Master Thesis, Department of Automatic Control, Lund University, June 2007

(Cervin et al 2007b). Anton Cervin, Martin Ohlin, Dan Henriksson: "Simulation of Networked Control Systems Using TrueTime", Real-Time in Sweden Symposium (RTiS), August 2007

(Ohlin et al 2006). Martin Ohlin, Dan Henriksson, Anton Cervin: "TrueTime 1.4—Reference Manual", Department of Automatic Control, Lund University, Sweden, September 2006

(Farias et al 2007) G. Farias, K-E Årzén, A. Cervin, S. Dormido, F. Esquembre: "Real-Time Control Systems in Easy Java Simulations" In submission to the IFAC World Congress, Seoul, 2008

KTH: THESES related to ARTIST2 work at KTH

Malvius, D. Information Management for Complex Product Development. Licentiate thesis, TRITA-MMK 2007:09, ISSN 1400-1179, Department of Machine Design, KTH, August 2007.

Adamsson, N., 2007, Interdisciplinary integration in complex product development - Managerial implications of embedding software in manufactured goods. PhD Thesis, TRITA – MMK 2007:04, ISBN 978-91-7178-610-4.

### 2.3.3 Interaction and Building Excellence between Partners

Supported by other projects and additional informal industrial contacts we have this year had extensive interactions with industry (including ABB, Ericsson, Mecel/Delphi, Scania and Sun) and academic partners, including ARTIST2 partners and affiliated partners. Several bilateral smaller meetings with industries have been organized in terms of smaller workshops for discussing cooperation and/or to discuss certain dedicated themes such as testing and product life cycle management.

We have also had interactions with several academic partners not affiliated with ARTIST2 representing the following complementary competences; safety analysis (Univ. of York – Ass. Prof. Yiannis Papadopoulos), policy based computing (Ass. Prof. Richard Anthony, Univ. of Greenwich), variability and product lines (Affiliated Prof. Mathias Weber, Technical Univ. of Berlin, formerly with Daimler, now with Carmeq), model driven engineering (Prof. Dov. Dori, Technion, Israel) and the Architecture and Analysis Description Language Dr. Peter H. Feiler (CMU-SEI, USA).

Interactions with ARTIST2-teams include

- Cooperation with MDH in the SAVE++ project in integrating software component modeling with other embedded systems modeling approaches. In particular, an investigation on how to provide a bridge from Simulink to the component models developed in the SAVE project has been performed.
- Cooperation within the ATESST project with Volvo Technology, Volvo car, CEA (including several other automotive related companies: Volcano/Mentor graphics, ETAS, Daimler-Chrysler, Carmeq, Mecel and Siemens-VDO), in developing an automotive embedded systems domain model and its UML profile implementation [Cuenot et al. (2007a), Cuenot et al (2007b), Shi et al (2007), Sjöstedt et al (2007), Törngren et al (2007)]
- Cooperation within the Dyscas project on architecture and methods for dynamically configurable automotive embedded systems with Daimler, Bosch, Volvo Technology, Enea, Univ. of Greenwich, Univ. of Paderborn, SME's Movimento and Systemite. In particular, modelling and simulation techniques for dynamically configurable systems have been investigated, and discussed in cooperation with Lund.
- Cooperation with other ARTIST2 clusters in planning and performing the joint workshops on model-based development.

Preparations for joint proposals have been carried out with Volvo and CEA. A prolongation proposal for the SAVE project together with MDH, UU and LIU from Sweden was accepted by the Swedish Strategic Foundation(SSF) for research.

During 2006 Martin Törngren was invited to write a chapter entitled Model based development, for the forthcoming handbook Automotive Embedded Systems. This chapter has been co-authored with Dr. Jakob Axelsson from Volvo car who is also adjunct professor at MDH, Västerås in Sweden, and with two collegues from KTH. The book chapter has been written during the 3rd year of ARTIST2.

### 2.3.4 Joint Publications Resulting from these Achievements

Naser et al (2007). Tahir Naseer Qureshi, DeJiu Chen, Magnus Persson and Martin Törngren. Simulation Tools for Dynamically Reconfigurable Automotive Embedded Systems - An evaluation of TrueTime. Real-Time in Sweden 2007 (RTiS2007), August 21-22, Västerås, Sweden.

Sjöstedt et al (2007). Carl-Johan Sjöstedt, DeJiu Chen, De-Jiu Chen, Phillipe Cuenot, Patrick Frey, Rolf Johansson, Henrik Lönn, David Servat, Martin Törngren. Developing Dependable Automotive Embedded Systems using the EAST-ADL; representing continuous time systems in SysML. In Proc. of EOOLT'2007. 1st Int. Workshop on Equation-Based Object-Oriented Languages and Tools.

Shi et al (2007). Jianlin Shi, Martin Törngren, David Servat, Carl-Johan Sjöstedt, DeJiu Chen, Henrik Lönn. Combined usage of UML and Simulink in the Design of Embedded Systems: Investigating Scenarios and Structural and Behavioral Mapping. To appear in Proc. of OMER 4 workshop on Object-oriented modeling of embedded real-time systems, Oct. 30-31, 2007.

Cuenot et al (2007a). Philippe Cuenot, DeJiu Chen, Sébastien Gérard, Henrik Lönn, Mark-Oliver Reiser, David Servat, Ramin Tavakoli Kolagari, Carl-Johan Sjöstedt, Martin Törngren, Matthias Weber. Managing Complexity of Automotive Electronics Using the EAST-ADL. Accepted for the 2nd Int. UML&AADL Workshop (UML&AADL'2007) at the 12th Int. Conf. On Engineering of Complex Computer Systems, Auckland, New Zealand, July 11 - 14, 2007.

Larses et al (2007). Ola Larses, Carl-Johan Sjöstedt, Martin Törngren, Ola Redell. Experiences from Model supported Configuration Management and Production of Automotive Embedded Software. In Proceedings of the SAE World Congress, In-Vehicle Software session, Detroit, USA, 2007.

Cuenot et al (2007a). Philippe Cuenot, DeJiu Chen, Sébastien Gérard, Henrik Lönn, Mark-Oliver Reiser, David Servat, Ramin Tavakoli Kolagari, Carl-Johan Sjöstedt, Martin Törngren, Matthias Weber. Managing Complexity of Automotive Electronics Using the EAST-ADL. In Proc. of the 2nd Int. UML&AADL Workshop (UML&AADL'2007) at the 12th Int. Conf. On Engineering of Complex Computer Systems, Auckland, New Zealand, July 11 - 14, 2007.

Axelsson et al (2007). Martin Axelsson, Magnus Eriksson, Thomas Francke, Felix Hammarstrand, Andreas Lindell, Oskar Nyqvist, Erik Persson, Martin Svensson, Christoffer Strömberg, Niklas Thörnqvist, Magnus Persson, Martin Törngren. The Saint3 automotive embedded systems demonstrator. Technical report, Department of Machine Design, KTH, 2007 (in print).

Cervin et al (2006). Anton Cervin, Karl-Erik Årzén, Dan Henriksson, Manuel Lluesma Camps, Patricia Balbastre, Ismael Ripoll, Alfons Crespo: Control Loop Timing Analysis Using TrueTime and Jitterbug, In Proceedings of the 2006 IEEE Computer Aided Control Systems Design Symposium, October 2006.

Årzén et al (2007a). Karl-Erik Årzén, Antonio Bicchi, Gianluca Dini, Stephen Hailes, Karl Henrik Johansson, John Lygeros, Anthony Tzes: "A component-based approach to the design of networked control systems" In Proceedings of the European Control Conference, July 2007

Årzén et al (2007b). Karl-Erik Årzén, Antonio Bicchi, Gianluca Dini, Stephen Hailes, Karl Henrik Johansson, John Lygeros, Anthony Tzes: "A component-based approach to the design of networked control systems", European Journal of Control, 13:2-3, 2007 (extended version of (Årzén et al 2007a))

INVITED BOOK CHAPTERS

Cuenot et al (2007b). Philippe Cuenot, DeJiu Chen, Sébastien Gérard, Henrik Lönn, Mark-Oliver Reiser, David Servat, Ramin Tavakoli Kolagari, Martin Törngren, Matthias Weber. Improving Dependability by Using an Architecture Description Language. Accepted book chapter contribution for the forthcoming book Architecting Dependable Systems IV. Editors: Rogerio de Lemos, Cristina Gacek, Alexander Romanovsky. Springer series: Lecture Notes in Computer Science, Vol .4615, 2007. ISBD 978-3-540-74033-9.

Törngren et al. (2007). Törngren Martin, DeJiu Chen, Diana Malvius, Jakob Axelsson. Model based development of automotive embedded systems. Invited chapter in the forthcoming Automotive Embedded Systems Handbook. Editors Nicolas Navet and Francoise Simonot-Lion. Taylor and Francis CRC Press - Series: Industrial Information Technology. ISBN: 9780849380266. Publication Date: 1/30/2008.

Web links to the corresponding books:

http://www.crcpress.com/shopping_cart/products/product_detail.asp?id=&parent_id=&sku=8026&isbn=9780849380266&pc=

http://www.springer.com/west/home/computer?SGWID=4-146-22-173752106-0

### *2.3.5 Keynotes, Workshops, Tutorials*

**Invited lectures**

- Model based development of Automotive embedded systems. Electronics in Vehicles (IBC Euroforum conference), April 17-18, Gothenburg By Martin Törngren
- Challenges for automotive embedded systems. Enea Automotive Systems Meeting, March 22, Stockholm By Martin Törngren
- Real-Time Aspects in Control, ANIPLA, November 15, Rome. By Karl-Erik Årzén
- Simulation of Networked Control Systems Using TrueTime, 3rd International Workshop on Networked Control Systems: Tolerant to Faults, Nancy, France, June 2007. By Anton Cervin
- Jitterbug and TrueTime: MATLAB tools for Analysis and Simulation of Controller Timing, Plenary lecture at the Mexican National Congress of Automatic Control, Mexico City, October 2006. By Anton Cervin

**Workshops**

- A cluster session on Tools for Co-Design of Control Systems and Their Real-Time Implementation at the IEEE International Symposium on Computer-Aided Control Systems Design (CACSD), Thursday October 5, 2006, with representatives from industry (e.g. the Mathworks) and several academic communities (including AADL).
- The KTH/Industry Embedded systems seminar, August 30th, 2007. http://www.md.kth.se/RTC/KTH_es_seminar2007.html
- Towards a Systematic Approach to Embedded System Design April 20th, 2007 – Workshop at the DATE conference. http://www.artist-embedded.org/artist/-ARTIST2-Workshop-at-Date-07-.html
- Tool Platforms for ES Modelling, Analysis and Validation July 1-2, 2007 - satellite event of CAV 2007, Berlin, Germany. http://www.artist-embedded.org/artist/-Tool-platforms-for-modelling-.html
- The Tool Exhibition organized by SNART (Swedish National Real-Time Association) (chaired by Anton Cervin of LTH) as part of the Real-Time in Sweden Symposium,

Västerås, August 2007. In this exhibition several of the tools developed for embedded system design within Artist2 were presented, including the LTH and KTH tools.

**Graduate courses**

Graduate Course on Control for embedded systems (Lund, May 2007). http://www.control.lth.se/user/karlerik/ArtistEmbedded/

Autumn 2006: Design of Embedded Real-time Systems: a graduate course given within the Artes++ graduate school – with invited speakers from Artist2 affiliated industries (Volvo, Daimler-Chrysler, Saab), with in total 20 participants including PhD students and industrial participants. http://www.md.kth.se/RTC/Derts06/index.html

Four lectures on “Control for Embedded Systems - Introduction and Motivation” within the Artist2/UNU-IIST School, Suzhou, August 2007. By Karl-Erik Årzén

Graduate course on Embedded Control Systems, UNED, Madrid, April 2007. By Karl-Erik Årzén

Jitterbug and TrueTime: MATLAB tools for Analysis and Simulation of Controller Timing, Pre-congress graduate course, National Autonomous University of Mexico (UNAM), Mexico City, October 2006. By Anton Cervin.

Graduate course on “Embedded Control - Controller Implementation with ResourceLimitations”, Aalborg University, January 2007. By Karl-Erik Årzén.

Summer School – Embedded RTLinux Intro 2007, CTU Prague, Czech Republic, June 18th – 22nd, 2007, http://rtime.felk.cvut.cz/rtlinuxss07/

# 3. Future Work and Evolution

## *3.1 Problem to be Tackled over the next 12 months (Sept 2007 – Aug 2008)*

The current 18 month plan states the following:

- Further development of partner individual tools
- Further work on model and tool integration including
  - Development of integration scenarios
  - Case studies involving integrating of tool functionalities developed by cluster partners
  - Case studies providing integration with UML tools
  - Case studies providing integration with tools for system safety analysis
- Further dissemination of results

To create a better cross-cluster understanding, and map of tools for embedded systems development, it is our opinion that a joint tool/platform meeting involving all the clusters should be organised within Artist2.

This overall plan remains valid. We will in particular address

- UML-Simulink transformations, continuing the earlier work on structural and behavioral mappings.
- Safety modeling in the EAST-ADL language, with an industrial case study and implementing a transformation, also further investigating the UML specification and the level of formality possible.
- An investigation of how requirements can be formalized and integrated with industrial model-based development will be performed in cooperation with Scania.
- Middleware abstractions will be implemented in Truetime in cooperation between KTH and LTH, where scenarios such as load balancing, software download, connecting external devices pose challenges for modeling and verification.
- The design of a reference implementation of the Dyscas middleware will be initiated for the Saint demonstrator (www.dyscas.org).
- Extensions of TrueTime so that it will be able to model and simulate multicore platforms. This will be performed within the new EU/IST FP7 STREP project ACTORS and within an anticipated new national project (pending proposal)
- Extensions of Torsche - version 0.4.0 will be released in September 2007, so that it is ready for distribution with the book by Michael Pinedo: Scheduling: Theory, Algorithms, and Systems (Third Edition) as requested by the author of this widely used book. Currently we are working on extension of our tool towards graph algorithms in order to have better coverage of general optimization and decision problems ( e.g. routing in sensor networks, scheduling of TDMA slots in Profinet).
- It is possible that we will also find the time and resources to investigate the connections between systems level modeling and software/hardware component modeling (as manifested by for example Autosar).

## *3.2 Current and Future Milestones*

Existing milestones - Year1-2: Identification of which of the existing tools that will be included in the platform, and specification of their interfaces.

*Comment: The tools developed by the cluster have been investigated and compared. Functionalities represented by other discipline's tools have also been investigated. Interfaces have been described at a high level of functionality. Different approaches to model and tool integration have been investigated. The individual tools have been further developed and disseminated. One prototype tool integration platform has been developed.*

Exisiting milestone - Year3: Develop the necessary interfaces that allow the individual tools to be used together.

- Development of integration scenarios

- Performed several case studies on model and tool integration, involving tools specific to the cluster as well tools typically dealt with by other research communities (clusters)

*Comment: Integration scenarios have been developed and have been partly documented/published during this year ([Shi et al (2007), Törngren et al (2007)]). Further documentation and published will take place during the 4th year. Several case studies have been initiated and will be continued in the following year, and new ones will start. Increased interactions with other clusters through a series of workshops have been performed. Cooperation with non-ARTIST2 communities through other research projects have been initiated, primarily related to safety analysis and AI approaches to dynamic configurations.*

Existing milestone - Year4: Usage of the tools in new co-design based research activities, adoption in industrial case studies.

**Updated Milestones for Year 4:**

**Updated milestone - Year4: At the end of ARTIST2, a much improved understanding of the kinds of platforms and industrial needs for future embedded control systems will have been established and communicated within the ARTIST2 NoE. Some of the tools developed by our cluster are already widespread, others are looking towards more comprehensive future platforms that enable handling multiple concerns or views. Future embedded systems also require a more systematic approach to deal with systems with changing configurations (be it for reliability, flexibility or functionality reasons). This calls for new tools where the dynamic envelope of such dynamically configurable systems can be designed, and where the corresponding embedded systems platform require mechanisms and policies to ensure proper on-line configuration. At the end of ARTIST2 we plan to have extended some of our traditional tools for static systems to cope with such dynamic systems.**

## *3.3 Indicators for Integration*

Interactions within the cluster, with other clusters as well as with other relevant academic communities and industries, measured in terms of the number of joint publications, jointly organized events, joint projects, and adoption of tools. Other important measures for integration include the development of open/published case studies, demonstrators and problem formulations/roadmaps.

### *3.4 Main Funding*

The approximate level of funding is given in parenthesis.

International:

RUNES, Integrated Project, European Commission, IST program, FP6 (http://www.istrunes.

org/) (60 kEuro/year during 2006/2007 for the LTH and KTH)

SOCRADES, Integrated Project, European Commission, IST program, FP6

DYSCAS, STREP, European Commission, IST program, FP6 (www.dyscas.org). [For KTH, approx. 150 Euro/year 2006-2007].

ATESST, STREP, European Commission, IST program, FPS (www.atesst.org). [For KTH, approx. 150 KEuro/year 2006-2008].

National:

SAVE++, Swedish Strategic Research Foundation – approx. [For KTH, approx. 150 KEuro/year 2006-2007. Funding also goes to MDH, LIU and UU part of ARTIST2].

FRAMES, Swedish national project funded by the Swedish Governmental Agency for Innovation Systems (Vinnova) [For KTH, approx. 100 KEuro/year 2006-2007].

SESAP – Integration of Processor Expert with Matlab/Simulink following Autosar, Czech national project funded by the Czech Academy of Sciences for IST [For CTU, approx. 120 KEuro/year 2005-2007].

# 4. Internal Reviewers for this Deliverable

:

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