ARTIST 2

Network of Excellence

IST-004527 ARTIST2:
Embedded Systems Design

Activity Progress Report for Year 2

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 ongoing research efforts on tools for co-design of resource-constrained embedded control systems. Providing tools is an important vehicle in bridging theory and practice. Providing integrated tools also 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

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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: automotive, aerospace, consumer electronics (kitchen appliances, hi-fi/video, wireless communication), energy distribution.

1.1 ARTIST2 Participants: Expertise and Roles

Prof. Martin Törngren – KTH (Sweden)
development methodology, co-design of control and computer systems, the AIDA2 co-design tool, and model and tool integration approaches.

Pdh. DeJiu Chen – KTH (Sweden)
development methodology, and model and tool integration approaches.

Pdh. Jad El-Khoury – KTH (Sweden)
model and tool integration approaches, and the AIDA2 co-design tool.

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

Ass. Prof. Anton Cervin – LTH (Sweden)
TrueTime and Jitterbug co-design tools, and co-design theory

Ass. Prof. Zdenek Hanzalek – CTU (Czech Republic)
TORSCHE toolbox, and co-design theory

Prof. Pedro Albertos – UPVLC (Spain)
co-design theory

1.2 Affiliated Participants: Expertise and Roles

PhD Henrik Lönn, Magnus Hellring and Jonas Edén - Volvo Technology Corporation (Sweden)
automotive embedded systems

PhD Jakob Axelsson - Volvo Car Corporation (Sweden)
automotive embedded systems

Joachim Stroop – dSPACE (Germany)
commercial development tools for embedded control systems.

Vladimir Havlena - Honeywell Prague Labs (Cech republic)
industrial control systems

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

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 2006, 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 Year2

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.

The work during the period has focussed on

- further development of the individual tools developed by the cluster partners

- initial work on the integration of these tools
- a broader contextual study on how tool integration can be accomplished in a systematic way
- dissemination of the results from the first year of ARTIST2

There is no major deviation from the work plan. It should however be noticed that the effort for tool integration is considerable. The survey on approaches towards tool integration has revealed a large number of potential topics for further work and for interactions with other clusters. Interactions with other clusters and affiliated partners have been initiated and some achievements are reported for the work during the second year.

1.6 Comments From Previous Review

1.6.1 Reviewers' Comments

The following is a copy of the reviewer's comments from year 1.

4.10 Control for Embedded Systems cluster deliverables

Four deliverables were due from this cluster at the end of Y1:

• Deliv-JPIA-a-Control-Y1

• Deliv-JPRA-NoE Integration-c-Y1 (this cluster's contribution as planned in the DoW.)

• Deliv-JPRA - Cluster Integration – Control for Embedded - a -Y1

• Deliv-JPRA - Cluster Integration – Control for Embedded - b -Y1

The deliverables were of uniformly excellent quality. The deliverable documents themselves described the problem to be addressed, the current state of the art, what was achieved using ARTIST2 funds in the past year, and natural integrative next steps for the coming 12/18 months. Where Roadmaps (or other collateral documents) were developed as part of a particular task, such documents were succinctly summarized in the deliverable, with pointers to the more complete document for the interested reader.

4.10.1 D2.6 Platform: Design Tools for Embedded Control: ACCEPTED

This task is focused on integration of ongoing research efforts on tools for co-design of resourceconstrained embedded control systems. The primary work item for Y1 was to complete a survey of tools for modelling and design of real-time control systems. The full survey appears as Appendix A of the deliverable document.

1.6.2 How These Have Been Addressed

Since the reviewer's were very positive we have tried to continue along the same lines as previous year. One goal has been to disseminate the material collected in the tool survey in a wider circle and to stimulate interactions with other clusters. Efforts have also been initiated to bridge the gap between the OMG-related modelling approaches and the control and computer science oriented ones traditionally dealt with by with this cluster. More information on these efforts and corresponding achievements is given in section 2.

2. Summary of Activity Progress

2.1 Previous Work

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

3.1 Work achieved in the first 6 months

- *Development of the TrueTime tool (wireless network blocks, battery-powered devices, local 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*

3.2 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 Current Results

2.2.1 Technical Achievements / Outcomes / Difficulties encountered

- **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

  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 and 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 2,000 times.

Torsche: The development of a simulation and implementation support for DSP applications in TORSCHE has started. As far as for the input side of TORSCHE, we have designed a language, compatible subset of Matlab, suitable for description of DSP algorithms. The parser of this language, generating the graph of precedence relations from the language description, has been designed in BISON and FLEX. 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 simple illustration of this work will be presented in [7]. 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

2.2.2 Publications Resulting from these Achievements

A complete list of publications produced by the cluster, with downloads available for most of the papers, is available here: http://www.md.kth.se/RTC/ARTIST2/publications.html

1. 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. Accepted for publication.
2. Karl-Erik Årzén. Timing Analysis and Simulation Tools for Real-Time Control.In Paul Pettersson, Wang Yi (Eds.): Formal Modeling and Analysis of Timed Systems, volume 3829, Springer, September 2005. Extended abstract in the Proceedings of FORMATS 2005, Uppsala. Invited Talk.
3. Dan Henriksson, Anton Cervin, Martin Andersson, Karl-Erik Årzén. TrueTime: Simulation of Networked Computer Control Systems. In Proceedings of the 2nd IFAC Conference on Analysis and Design of Hybrid Systems, Alghero, Italy, June 2006.(Extended abstract)
4. Martin Törngren, Dan Henriksson, Karl-Erik Årzén, Anton Cervin, Zdenek Hanzalek. Tools Supporting the Co-Design of Control Systems and Their Real-Time Implementation; Current Status and Future Directions. To appear in the Proc. of the 2006 IEEE Computer Aided Control Systems Design Symposium. Oct. 2006.
5. Martin Törngren, Dan Henriksson, Ola Redell, Christoph Kirsch, Jad El-Khoury, Daniel Simon, Yves Sorel, Hanzalek Zdenek and Karl-Erik Årzén. Co-design of Control Systems and their real-time implementation - A Tool Survey. Technical Report. Dept. of Machine Design, KTH – Royal Institute of Technology August 2006. TRITA-MMK 2006:11, ISSN 1400-1179. ISRN/KTH/MMK/R-06/11-SE.
6. DeJiu Chen, Martin Törngren, Jianlin Shin, Henrik Lönn, Sebastien Gerard, Mikael Strömberg, Karl-Erik Årzén. Model Based Integration in the Development of Embedded Control Systems – A Characterization of Current Research Efforts. To appear in the Proc. of the 2006 IEEE Computer Aided Control Systems Design Symposium. Oct. 2006.
7. Sucha Premysl, Kutil Michal, Sojka Michal, Hanzalek Zdenek. TORSCHE Scheduling Toolbox for Matlab. To appear in the Proc. of the 2006 IEEE Computer Aided Control Systems Design Symposium. Oct. 2006.
8. Crespo Alfons, Albertos Pedro, Balbastre Patricia, Valles Marina, Lluesma Camps Manuel, Simo Jose. Schedulability Issues in Complex Embedded Control Systems.

To appear in the Proc. of the 2006 IEEE Computer Aided Control Systems Design Symposium. Oct. 2006.

9. Dan Henriksson, Ola Redell, Jad El-Khoury, Anton Cervin, Martin Törngren, Karl-Erik Årzén. Tools for Real-Time Control Systems Co-Design. In Hans Hansson (Eds.): ARTES – A network for Real-Time research and graduate Education in Sweden 1997–2006, Department of Information Technology, Uppsala University, Sweden, March 2006.
10. Martin Törngren, DeJiu Chen, Ivica Crnkovic, Component based vs. Model based development: A comparison in the context of Vehicular Embedded Systems. In Proc. of 31st EUROMICRO conference on Software Engineering and Advanced Applications, Porto/, Portugal, August 30th- Sept. 3rd, 2005
11. Jad El-khoury. PhD thesis. A Model Management and Integration Platform for Mechatronics Product Development. ISBN: 91-7178-268-0, Serie: Trita-MMK, ISSN 1400-1179 ; 2006:03, Department of Machine Design, KTH, May 2003.
12. Ola Larses. PhD thesis. Architecting and Modeling Automotive Embedded Systems. Dept. of Machine Design, Royal Institute of Technology, Stockholm. TRITA – MMK 2005:31, ISSN 1400-1179, ISRN/KTH/MMK/R-05/31-SE, Nov. 2005.
13. Jad El-khoury, Ola Redell, Martin Törngren. A Model and Tool Integration Platform for Multidisciplinary Development. In Proc. of 31st EUROMICRO conference on Software Engineering and Advanced Applications, Porto/, Portugal, August 30th-Sept. 3rd, 2005.

2.2.3 Keynotes, Workshops, Tutorials

Keynote : Karl-Erik Årzen - Timing analysis and simulation tools for real-time control. International Conference on Formal Modelling and Analysis of Timed Systems (FORMATS'05), [2], Uppsala, Sweden, – *September 26 - 28, 2005*

http://www.it.uu.se/formats05/

Invited Presentation: Anton Cervin - TrueTime: Simulation of Networked Computer Control Systems. Presented at an invited session on hybrid simulation tools at ADHS'06 (2nd IFAC Conference on Analysis and Design of Hybrid Systems) in Alghero, Sardinia, June 2006, [3]. **Invited Tutorial:** Karl-Erik Årzen. TrueTime was presented within the tutorial Advances in Networked Autonomous Vehicles: Technologies, Tools, and Cases at ICRA 2006 (IEEE Conference on Robotics and Automation), Orlando, May 2006

Invited Presentation: Martin Törngren – Challenges for PLM of Mechatronic Systems. PLM Forum 2006, Stockholm, May 10, 2006.

http://www.technia.com/templates/Page____1787.aspx

Invited Presentation: Martin Törngren – Cost-efficient and systematic verification of embedded control systems. Invited Lecture at Mecel (a Swedish subsidiary of Delphi), June 14, 2006, performed at the occasion of starting a new national project between Mecel and KTH.

Invited Presentation: Martin Törngren – Automotive Embedded Systems; characteristics, trends and challenges", May 17, 2006. Invited Lecture at Enea embedded technology, Sweden.

Invited Presentation: Martin Törngren – Model based development. Invited lecture at Scania "samverkansforum", Nov. 14, 2005, Scania, Sweden.

3. Future Work and Evolution

3.1 Problem to be Tackled over the next 18 months (Sept 2006 – Feb 2008)

The planned work for the coming 18 months includes the following parts

- 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.

Future developments of Torsche (CTU)

Currently we are working on the DSP code generator, which transforms a schedule produced by TORSCHE either to the code to be simulated in TrueTime or to the Handel C to be implemented in FPGAs. The code generator is based on XSLT transformation. Fully automated version of the code generator will be finished during one year.

A new version (0.3) of TORSCHE will be released in October. The version will include XML support, new graph algorithms, interface to SAT solvers, examples of interconnection with TrueTime and response time analysis. Further we will work on graph editor and web based production of scheduling results in Gantt charts written in Perl and Metapost.

Future TrueTime Developments

A drawback with the current version of Truetime is that it is not possible to simulate production code directly. Instead the code for each task must be manually translated into the code-segment structure of TrueTime. During the year preliminary investigations have been made on how this problem can be solved. The solution that is currently discussed is based on the possibility to have multi-threaded code in Matlab S-functions (using MEX-files). It appears to be possible to derive a solution that does not require any manual code tranformation at all. This opens up intersting possibilities. For example, it would then be possible to start by simulating a controller in Simulink againat a Simulink model of the plant. When that performs according to specifications, an existing tool such as Real-Time Workshop could be used to generate C code for this controller. This C-code could then be simulated executing as a task in a TrueTime real-time kernel together with the other tasks, and the true timely behavior of the control loop could be investigated. Another issue that has been investigated is the possibility to have hierarchically structured code functions. This will be investigated during the coming year.

Future KTH tool developments

The design of advanced embedded control systems requires a systematic approach in handling their increasing complexity and in particular integration of the different system aspects supported by different modeling languages and tools. The work on the model and tool integration platform will continue. In particular emphasis will be placed on linking

Matlab/Simulink with UML environments. While Matlab/Simulink has its emphasis on control and functional design, the UML environments enables a representation of overall system architecture that is compatible to an architecture description language currently under development. There are several parts of this work, including identifying the needs and usages of the various UML models, and the definition of suitable mappings (transformations) from Simulink to the selected UML representations. In developing prototype tools practical issues such as model and exchange formats, and tool APIs have to be considered.

Given the time and resources (depending on complementary funding/projects), the following work will also be performed in the coming period:

- Integrating a suitable UML tool with the integration platform previously developed.
- Providing facilities to integrate formal analysis tools for timing analysis and logical correctness (model checking) with Simulink/UML models.
- Extending the previously developed tool integration platform to handle not only development but also software production and maintenance for distributed embedded systems, e.g. allowing a system configuration to be defined, built and downloaded to a target, dealing with software allocation to the different nodes subject to established configuration rules and optimization criteria.

3.2 Current and Future Milestones

<u>Existing milestones - Year1-2:</u> 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 disciplines tool's 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.

<u>Exisiting milestone - Year3:</u> 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: As a basis for tool integration, it is important to clarity the relevant usage scenarios, i.e. how the tool integration supports the various design activities. Moreover, systems design is not limited to just the aspects traditionally dealt with by this cluster. Therefore it is important to carry out case studies that illustrate tool integration also considering other relevant aspects. This update of the Year 3 milestone is also supported by the previous 18 month plan..

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

3.3 Indicators for Integration

Involvement of several research groups, usage of the tools in new co-design based research activities, adoption by other research groups, adoption in industrial case studies.

3.4 Main Funding

International:

RUNES, Integrated Project, European Commission, IST program, FP6 (http://www.ist-runes.org/)

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

DYSCAS, STREP, European Commission, IST program, FP6 (www.dyscas.org)

ATESST, STREP, European Commission, IST program, FPS (www.atesst.org)

National:

SAVE++, Swedish Strategic Research Foundation

FRAMES, Swedish national project funded by the Swedish Governmental Agency for Innovation Systems (Vinnova)

3.5 Internal Reviewers for this Deliverable

Anton Cervin, LUND

Alfons Crespo, UPVLC