The PROGRESS Centre for Predictable Embedded Software Systems

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Half-time report

January 2006 – June 2008

Edited version

10/11/2010

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Executive summary

PROGRESS is a Swedish national strategic research centre at Mälardalen University (MDH) in Västerås. PROGRESS is dedicated to find methods for cost-efficient handling of the increasing complexity of embedded software used in computer-based products. Our focus is on the domains of automation, ground vehicles and telecom; domains of great strategic importance for Swedish economy, and for which the majority of innovation and added value stem from software. Alas, these are also domains where the cost of software is rampaging, and where the necessary quality of software is becoming increasingly difficult to achieve.

Adopting a software-component approach to engineering and re-engineering of embedded software systems, PROGRESS provides theories, methods, and tools that increase quality and reduce life-cycle costs. PROGRESS is focusing its research on development, adaptation and extension of **Component Based Development** (CBD) into a mature engineering discipline for cost-efficient development of embedded software. This includes addressing the specific concerns and requirements of embedded systems, such as real-time requirements, resource consumption, dependability, and life-cycle properties, as well as supporting implementation mechanisms and reuse of legacy software.

Based on a common vision and concept, the PROGRESS research is organized into a set of interrelated **disciplinary research directions**, interlinked via cross-cutting and integrating tool environment and demonstrator projects, as illustrated in Figure 1. The cross-cutting projects are important vehicles for integration of disciplinary research results and provide means for evaluation and verification of the developed technology.

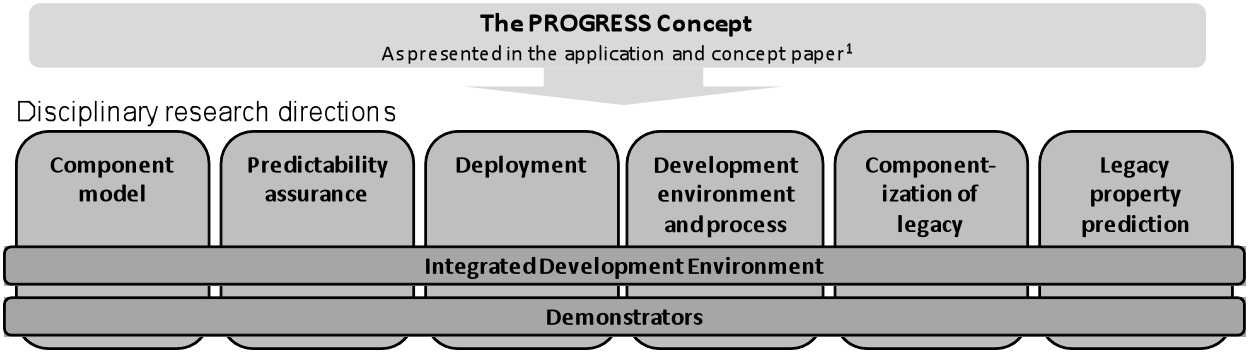

Figure 1: Organization of research in PROGRESS

During the first half of the funding period, 6 professors, 9 senior researchers, and 12 PhD-students have been recruited. Several **important achievements** have been made, including new and improved models and processes for software engineering, advancement of theories for analysis of software, development of run-time support for efficient and predictable execution of components, and more. These results are presented in close to 200 peer-reviewed scientific publications, implemented in prototype tools, or made available in both commercial and free software-engineering tools. Research is progressing at full speed and according to plans. An increasing number of externally funded projects (~30) have been granted – including 8 EU-funded projects. The extensive international and industrial cooperation is manifested by joint publications with 56 international scientists and 41 persons from industry.

To summarize: PROGRESS has had a flying start and is currently producing tangible results to support software development in strategically important business domains. PROGRESS also plays a vital role in MDH's effort in establishing a hub for Swedish research, education, and industry-academia cooperation within the area of embedded systems.

[1] The concept paper "The world according to PROGRESS" presents the technical vision and philosophy of PROGRESS.

1. Involvement in related larger initiatives

The leading PROGRESS researchers are involved in several larger research and educational initiatives related to and supporting PROGRESS. The table below lists these initiatives, where "H", "M", "L", and "-" indicate "High", "Medium"," Low", and "No direct" relevance to PROGRESS, respectively.

Q-Impress, All-Times, and Flexi are **research projects** with participation of several internationally prominent academic and industrial groups. IRIL is an **industrial laboratory** at MDH funded by Ericsson and ABB and equipped with actual industrial development environments and target systems, providing students and researchers with excellent possibilities to study and experiment in real industrial settings. SICS CNS (Centre for Networked Systems) is an **institute excellence centre** for industry-academia research hosted by SICS. Artist-Design and Artist-2 are **European networks of excellence** with participation of leading European researchers in Embedded Systems Design. Save-IT is a **national industrial graduate school** hosted by MDH and with some 20 industrial graduate students doing research related to Embedded Software Development. DICES, SISTER, KISEK, and EURECA are **international research and education projects** aiming at dissemination of results and recruitment of graduate students. Hi5, ISE, PIFF, CUGS, and SWELL are **educational and mobility initiatives** aiming at improving recruitment and mobility of graduate students and researchers, as well as establishing industry-academia exchange and cooperation. All projects mentioned here, as well as several additional related research projects, are further presented in Appendix C, including additional information about relevance for, and relation to, PROGRESS.

						Relation to research directions					
Project	**Funding agency**	**Time-period**	**Principal Investigator (PI) at MDH**	**Total budget (MSEK)**	**Budget MDH (MSEK)**	**Component Model**	**Predictability Assurance**	**IDE and Process**	**Deployment**	**Componentization of Legacy**	**Model Extraction**
Q-IMPRESS	EU FP7	2008-2010	Ivica Crnkovic	31.3	4.7	H	H	-	L	H	H
ALL-TIMES	EU FP7	2008-2010	Björn Lisper	15	3.9	-	H	L	-	-	L
FLEXI	ITEA 2/Vinnova,	2007-2009	Ivica Crnkovic	355	5.5	-	-	H	-	-	-
IRIL	Ericsson, ABB	2006-	Christer Norström	>4	>4	H	H	H	H	H	H
SICS CNS	SSF, KKS, Vinnova	2007-2009	Mats Björkman	19.2	1	-	M	-	-	-	-
ARTIST-DESIGN	EU FP7	2008-2011	Björn Lisper	42.3	0.9	-	H	L	-	-	L
ARTIST2	EU FP6	2004-2008	Björn Lisper	61	1.1	-	H	L	L	-	L
SAVE-IT	KKS	2004-2010	Hans Hansson	20.8	11.3	H	H	H	H	H	H
DICES, SISTER, KISEK, EURECA	EU FP7. EU TEMPUS, EU Erasmus, WorldBank	2008-2011	Ivica Crnkovic, Sasi Punnekkat	47	6	H	H	L	M	-	-
Hi5, ISE, PIFF	Vinnova, KKS,	2008-2011	Ivica Crnkovic	18.7	14.4	H	H	H	H	L	L
CUGS (2)	CUGS	2006-2008	Björn Lisper	45	2.1	L	H	L	-	L	M
SWELL	Vinnova	2008-2011	Kristina Lundqvist	3	0.6	L	M	M	L	M	M

It is particularly satisfying to note that the strategy to increase our involvement in international projects has been successful (including several new EU-projects and international research and education projects).

2. Fulfilment of SSF's vision for strategic research centres

PROGRESS is the collective effort of 7 research groups with complementary competences[2] at MDH, and is Sweden's largest academic research centre with a focus on embedded and real-time software; an area of strategic importance for dominating Swedish industrial sectors. Research is conducted in close

[2] The following research groups at MDH participate in PROGRESS: Industrial Software Engineering, Embedded Systems Software Engineering, Dependable Software Engineering, Programming Languages, Real-Time Systems Design, Real-Time Modeling and Analysis, and Communication Performance and Analysis.

cooperation with both local and national industry, with the involvement and support of more than 40 companies. PROGRESS hosts 12 professors, 19 additional senior scientists and 30 PhD-students, out of which 6 professors, 9 senior researchers, and 12 PhD-students have been recruited as a result of PROGRESS. The centre has a well defined and efficient organization with strong leadership, as detailed in Section 3.

Since the start of PROGRESS, close to 200 scientific papers have been published in peer-reviewed journals and conference proceedings. PROGRESS researchers are highly active in the scientific community, including arrangement of conferences (12 during the initial years), editorial duties for int'l journals (10), being conference program chair (10), members of int'l program committees (>100), as well as some 20 memberships of steering and technical committees. Since 2006, PROGRESS researchers have got in the order of 30 externally funded research projects approved; projects, which in most of the cases are closely related to the research agenda of PROGRESS.

The size of the PROGRESS research centre and the top down articulation of the PROGRESS research program allows for dealing with larger and more complex issues compared to traditional research projects. Stretching over 5 years, the PROGRESS research program includes 14 projects. The program is revised annually, based on achievements, recruitments, and discussions with the board. The integration and synergy between projects in the plan brings extra value that would have been hard to achieve without the PROGRESS research centre. Additionally, 35 related projects contribute both to PROGRESS and to the creative and productive environment at the research centre.

Deployment of PROGRESS research is carried out both in the individual research projects as well as by the PROGRESS integrated project in close cooperation with our network of industrial and academic partners. Bringing results to practical use is supported by infrastructure for establishing and maintaining external contacts, deployment, and commercialization (detailed in Appendix D).

3. Fulfilment of vision in the application

The vision as formulated in the funding application:

"PROGRESS' vision is to be a world-wide recognised centre in software engineering of embedded real-time systems with extensive contacts/exchange with other leading universities, and to be the preferred partner for industry in Sweden and Europe in this growing technology field."

The vision has directed focus to efforts in the following directions:

- **International presence**. We have put substantial efforts to strengthen our role in the international communities. The results include, (i) participation and coordination in more than ten international (mostly EU) projects (detailed in Section 10), (ii) a visible improvement in publications by targeting the most prestigious conferences and journals (reported in Appendix B), as well as (iii) active involvement in organisation of important international conferences (detailed in Section 10).
- **Industrial cooperation**. Based on our already extensive cooperation with Swedish industry, we have intensified cooperative efforts further, including being a catalyst in forming the national industrial network Swedsoft (www.swedsoft.se) and the regional cluster Automation Region (www.automationregion.com), as well as further extending and developing our industrial cooperation (detailed in Section 7).
- **Educational initiatives**. The dominating focus of our educational initiatives is on establishing our software engineering masters program as an internationally recognised program, with strong connections to the PROGRESS research and with clear industrial relevance. We have launched a joint master program in software engineering together with three EU universities (www.gseem.eu), established cooperation with more than 10 international universities for academic staff and students exchange, and, supported by national funding and participating industries, we are recruiting national and international top-talents to a branch of the master program in software engineering that has extensive industrial involvement and industry-sponsored scholarships.

Substantial advances in all these three directions have set PROGRESS on a clear trajectory towards reaching its vision.

4. Leadership and organization

The hosting research unit, MRTC, has a long tradition of industrially relevant research, including extensive cooperation with a wide range of companies. The PROGRESS funding has provided a unique opportunity for consolidation of the scientific basis of the research and for providing synergy and integration between the different research directions. For the sustainability of the research centre, two complementary and equally important aspects are in focus: (1) further development of PROGRESS as a research and education centre of excellence, and (2) providing research results with industrial and academic impact.

For centre development, the strategy includes recruitment of reputed scientists, career programs and mentoring of post-doctoral (as well as more senior) researchers, encouragement and support for writing funding applications, professionalization of the administrative support, and conscious establishment of a culture emphasising internal and external cooperation, scientific excellence, and industrial impact.

To ensure academic and industrial impact of the research, a substantial effort has been spent on formulating a coherent research program with emphasis on integration and demonstration of research results.

Organization

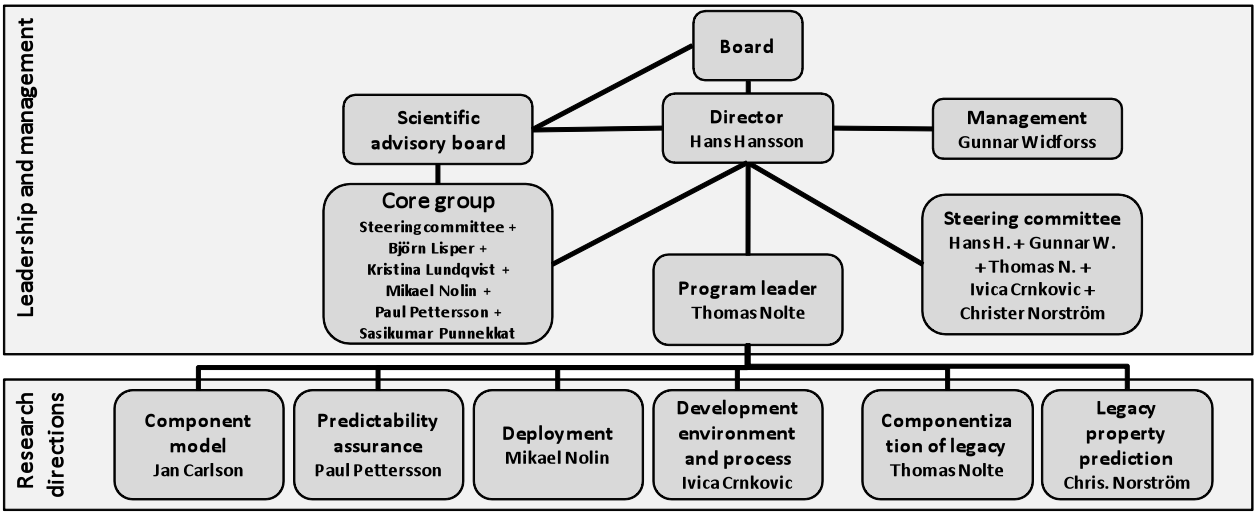

Figure 2: The PROGRESS organization

The main responsibilities of **the board** are to decide on qualitative and quantitative objectives, policies, strategic plans, budget and conditions for the director. Members of the board are:

- Bazmi Husain, Director ABB Corporate Research (chairman of the board)
- Tomas Andersson, CEO, Bombardier Transportation AB
- Erik Hagersten, Prof., Uppsala University
- Jane Walerud, Serial entrepreneur and Angel investor
- Claes Wohlin, Prof., Blekinge Institute of Technology

The **Scientific Advisory Board** (SAB) monitors and evaluates the scientific development and plans of the centre, and provides guidance, suggestions, and constructive criticism to the management and board of PROGRESS. Member of the SAB are:

- Dr. Iain Bate, University of York, UK
- Prof. Paola Inverardi, University of L'Aquila, Italy
- Prof. Raj Rajkumar, Carnegie Mellon University, USA

Competent advice and constructive discussions with the SAB have been of great help in formulating plans and sharpening the focus of PROGRESS. In particular, the SAB has been instrumental in motivating us to provide a clear top-down articulation of the PROGRESS research.

The **centre director** (Prof. Hans Hansson) is the scientific and administrative leader of PROGRESS. The director has appointed Prof. Ivica Crnkovic and Prof. Christer Norström as his deputies. The

program leader (Dr. Thomas Nolte) assists the director in coordinating the research, and a research coordinator (Gunnar Widforss) is responsible for the daily **management**. The director, deputy directors, program leader, and research coordinator form a **steering committee** responsible for the operation of the centre. For strategic discussions, the steering committee is extended into the **"core-group"** by participation of leading researchers from all involved groups.

The PROGRESS research is organised in the following **research directions**[3]:

- **The component model (CM) research direction** has the main responsibility for developing the framework of component models. This framework provides a basis on which (essentially) all PROGRESS activities build on.
- **The predictability assurance (PA) research direction** develops the theories, methods, algorithms and tools essential for reasoning about the predictability attributes that have been identified to be in focus, since they are important for the considered application domains.
- **The deployment research direction** provides mappings and translations from the software design to executing code on particular target platforms, as well as models of realizations that are needed in making resource related analysis within predictability assurance.
- **The development environment and process research direction** provides a tool infrastructure with a set of basic tools and support for integration of other tools (provided by PROGRESS or externally), as well as guidelines for component-based development processes, and techniques for integrating such development in existing processes.
- **The componentization of legacy research direction** provides methods and techniques that assist in integrating legacy code in the component-based development, and in providing faithful execution of legacy code in the new component-based setting.
- **The legacy property prediction research direction** provides methods for analysis and model extraction needed by the componentization of legacy research direction, as well as tools and techniques for software maintenance in general.

5. Added value

The PROGRESS research is organized as a large coordinated project aiming at integrating results from its parts, i.e., the fact that PROGRESS is a single "centre" is essential for reaching the objectives. Without PROGRESS, the integration would not have taken place, and less coordination would have given more scattered research efforts; deployment and demonstration of industrial value would have been more difficult. The coordination and integration has increased cooperation within the centre, and provided synergies that have resulted in an increasing number of joint publications (with 53 inter research group publications in 2006-2008) and applications (15 of the 34 current externally funded projects involve multiple research groups), as well as increased interactions also between projects outside the PROGRESS core. PROGRESS is providing important coordination, focus, and synergies in research at the entire hosting MRTC research centre.

From a relevance perspective, the tight coordination of PROGRESS makes it possible to combine competences, thereby being able to address larger and from an industrial perspective more relevant problems. Furthermore, the branding of PROGRESS is increasing the attractiveness to our industrial partners, as well as to international researchers and students that are provided the opportunity to use and participate in the development of the PROGRESS component model and IDE. Thus, PROGRESS provides additional opportunities for international cooperation and exchange at all levels.

PROGRESS has also given us unique opportunities to make strategic recruitments of senior researchers (e.g. Kristina Lundqvist from MIT and Paul Pettersson from Uppsala Univ.), as well as coordinated international recruitments of Post Docs and graduate students.

[3] We are using the term "research direction" for these groupings of research (and researchers), since there is not a 1-to-1 mapping between research directions and the research groups at MRTC, and since each research direction is responsible for a specific aspect/direction of research within PROGRESS.

6. Scientific achievements

This section presents the top 10 scientific highlights of PROGRESS during the first years, followed by an overview of scientific results in relation to the plan presented in the original PROGRESS application.

Top 10 scientific highlights

The order of presentation follows the order of the corresponding research directions in the organization chart in Section 4, and is not a ranking of relative importance. The referred publications are listed in Appendix B. Note that, though there are, in most cases, multiple associated publications, we are only referencing the listed ones in this report. A complete list of publications is available at www.mrtc.mdh.se/progress/.

1. The ProCom component model (Component model research direction)

A component model defines the nature of components, e.g., how they interact with each other, how they are specified and implemented, and how they can be composed into complex systems. The ProCom component model is developed for i) scalable design of embedded systems, ii) integration of different models for prediction and analysis of components and system properties, and iii) allowing resource-efficient realizations at run-time. The desired characteristics have been obtained by designing a two-layered component model where the lower layer strictly defines the execution semantic and enables efficient timing and resource analysis, while the top level enables a variety of component designs and styles of communication.

ProCom [30], including its predecessor SaveCCM [6], has been well received, and there is currently a growing international research community involved in development of tools and using the component model in research[4]. Furthermore, the commercial potential has already been demonstrated by the improved version of the RUBUS component model[5], which to a large extent is based on our research.

2. Partial order verification (Predictability Assurance Research Direction)

Scalability is a main challenge for automated formal verification. By taking advantage of information about the structure of component-based systems, we have been able to improve the time to perform model checking with up-to several orders of magnitude [44]. More specifically, we have developed an efficient formal verification technique for real-time component models, which is based on partial order reduction. The technique has been implemented in the tool UPPAAL Port (www.uppaal.org/port/) and a graphical user interface for modeling, simulation, and verification is provided in the PROGRESS IDE. We have also validated the techniques and the tool in a case-study, in which functional and timing requirements of an industrial production system are verified.

3. Advanced flow analysis (Predictability Assurance Research Direction)

High quality execution time estimates for code fragments are needed for accurate prediction of safety-critical real-time systems. To obtain such estimates, the possible execution paths (program flows) must be determined. Most existing execution time analysis tools perform only a rudimentary flow analysis, which gives poor precision and necessitates manual provision of program flow information. We have developed advanced methods for flow analysis, including infeasible path detection [19] and fast methods for loop bounds detection [28] [50] (**Best Paper Award**). The methods have been verified against industrial real-time production code generated from the RUBUS component model [26], and they are implemented in our Worst-Case Execution Time (WCET) analysis tool SWEET.

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[4] The component model is used in the EU project Q-Impress, the DICES project, and independently; including use by researchers at University of Queensland, Australia (Dr. Lars Grunske), RMIT University Melbourne, Australia (Prof. Heinz Schmidt), Charles University, Czech Republic (Prof. Frantisek Plasil), Sofia University, Bulgaria (Dr. Sylvia Ilieva), University of Zagreb, Croatia (Prof. Mario Zagar), Karlsruhe University, Germany (Prof. Ralf Reussner), L'Aquila University, Italy (Dr. Henry Muccini), and Thessaloniki University, Greece (Prof. Katsaros Panagiotis).

[5] We have supported Arcticus Systems AB in their development of the new improved version of the RUBUS component model [49], which essentially is a simplified and adapted version of SaveCCM.

4. Context aware execution-time estimation (Predictability Assurance Research Direction)

One of the major challenges in providing component-based software engineering for embedded real-time systems is to achieve performance efficiency and predictability while maintaining reusability of software components. We have developed a contract-based approach for dealing with the WCET of a component [35] (**Best Paper Award**). This approach calculates the actual WCET of a component taking its actual usage into consideration, thereby greatly reducing the risk of over-provisioning CPU resources while still guaranteeing accurate WCET estimates for the components. The applicability of the approach has been shown in an industrial case-study.

5. Reliability assurance and error models (Predictability Assurance Research Direction)

Embedded systems are typically characterized by high dependability requirements, where fault tolerance in both value and time domains plays an important role, though researchers have traditionally treated them independently. We have developed novel fault-tolerance techniques, which extend the state-of the art in both time and space dimensions, as well as techniques that consider both dimensions in combination to ensure better predictability of developed systems [48]. Another salient contribution is a technique that maximizes the fault-tolerance capabilities of fixed priority systems, which we show to be superior to other well-known techniques [34].

6. Stack-sharing in component-based systems (Deployment Research Direction)

Random Access Memory (RAM) is a scarce and expensive resource in many embedded systems. RAM is needed for storing the dynamic state of a system, and is particularly needed for storing the stack. We have developed a technique for stack-sharing that reduces the amount of required stack-memory. The core of the approach is an analysis technique to calculate bounds on the stack usage [20]. The technique has been integrated in an existing component-model to allow stack-sharing between components [25]. Furthermore, the result has been incorporated in the tool-suite Rubus-ICE and is already commercially available.

7. Software development process (Development Environment and Process RD)

Research and practice in CBD have achieved significant results in different technologies, but in general there is a lack of identification of CBD development processes. We have developed component-based software development process that distinguishes component development, component selection, and system development, and analyzed its application in different development models (Waterfall, V model, and Agile methods). Through several case studies at Ericsson, ABB and Philips we have provided clear evidence that CBD is a sound approach in distributed development of high-volume and many-variant products. We have also identified that it is necessary to change the emphasis in the development process from intensive development activities to intensive specification and verification activities [40]. Based on the case studies we have proposed improvements in particular development phases important in CBD [9, 12, 23].

8. The IDE (Development Environment and Process Research Direction)

The purpose of the PROGRESS Integrated Development Environment (IDE) is to support design, analysis, and realization of components and component-based systems using different tools integrated in a common environment. The novel CBD process is enabling a seamless integration of, and interaction between, different phases in the process, which traditionally are performed as a sequence of isolated activities. For example, our approach enables incremental and concurrent modeling and deployment, a combination of reuse of existing components and development of new ones, or a combined deployment on virtual and physical nodes. A first version of the IDE was released in December 2007 [22]. The development of the IDE is, together with related component-model research, performed at universities and research centers world-wide, as described in Highlight 1 above.

9. Faithful execution of legacy code (Componentization of Legacy Research Direction)

Predictable reuse of legacy software is substantially facilitated if the legacy code is executed in the same (or very similar) way as in the original system. To support such faithful execution of legacy components and subsystems, we have developed operating system mechanisms using a hierarchical scheduling approach. We have improved these mechanisms in several steps, including adaptation to new (multicore) architectures [24] (**Best Paper Award nomination**), development of a resource

efficient synchronization protocol [27, 46], and development of efficient algorithms for constructing resource efficient systems [18] (**Best Paper Award nomination**). Several mechanisms have been implemented under the commercial operating system VxWorks.

10. Extraction of models from legacy code (Legacy Property Prediction Research Direction)

Many industrial software systems are too large and complex for a single person to comprehend, since they contain millions of lines of code and are the result of hundreds of people working for many years. For such systems, it is too time-consuming and error-prone to manually reverse-engineer the type of detailed model that are required for accurate timing analysis. We have developed a modeling process that makes model extraction practical for very large systems [39] (**Best Paper Award**). The process is supported by two complementary methods for automated and semi-automated model extraction. A case-study at ABB Robotics shows the applicability of the approach to large and complex software systems.

Scientific results

The plan of activities, as originally outlined in the PROGRESS application (enclosure 2, section 5.5), is annually revised, refined, and detailed. The revised plan covers all main intentions and expectations of the original PROGRESS application. The table below provides a high level summary of research performed by PROGRESS in relation to the original PROGRESS goals. For each expected result, the current status, actual outcome, and possible remaining plans are indicated.

In addition to what is explicitly articulated in the table, important achievements targeting predictability assurance have been made, including those presented in scientific highlights 2 to 6 above.

Expected results from original application	Status	Outcome
Specification of architecture and functional properties of generic component-model syntax and semantics.	Completed	Analysis of the feasibility of generating generic component models; journal paper submitted.
Component model syntax and semantics, considering timing and resources.	Completed	The ProCom component model. See highlights 1 and 4 for more information.
Syntax and semantics of component model, additionally considering reliability and safety.	Ongoing (as planned)	Initial results with respect to predictability assurance; integration into component model starts in 2009.
Prototype CBD design tool.	Completed	The SaveCCM component model and demonstrator.
Industrial case-study: CBD development.	Completed	Case-study on the management of component evolution at CC-systems.
Exploitation of component model (from SAVE, with Volvo and CC-Systems).	Completed	Improved version of RUBUS component model based on SaveCCM; used at Volvo CE, Alvis Hägglunds and others.
Component Model – distributed RT systems.	Completed	The ProSys part of ProCom.
Evaluation and exploitation: Timing analysis of control systems at ABB Robotics.	Completed	Successful evaluation (see highlight 10) and exploitation of the Tracalyzer tool.
Technique for instrumentation and extraction of approximate model of monolithic legacy software.	Completed	Techniques for extraction and validation of models (see highlight 10 and PhD thesis of Joel Huselius).
Validation of extracted models, considering behaviour, timing, and context.	Completed	See PhD thesis of Joel Huselius.
Industrial case-study: Remodeling of an industrial real-time system including model validation.	Completed	See Highlight 10.
Method for adaption of legacy components to fit our CBD technology.	Ongoing (as planned)	ProSys part of ProCom, together with run-time mechanisms for execution of legacy components (Highlight 9).
Prototype tool for model extraction and legacy adaptation.	Ongoing (as planned)	Model extraction: the MASS and Tracalyzer tools. Legacy adaption: planned for 2009-2010.
Performance and execution time extraction and impact analysis at ABB Robotics.	Ongoing (as planned)	Initial study completed (Highlight 10). Further experiments planned for 2009.

Expected results from original application	Status	Outcome
CBD processes - case studies.	Completed	Two case studies; at Philips in 2006 and at ABB Substation Automation in 2007.
CBD processes - models for integration activities improvements.	Completed	Three case studies; reported in the PhD thesis of Stig Larsson and Highlight 7.
Infrastructure support - case studies, analysis.	Completed	Multiple case-studies reported in the PhD thesis of Rikard Land + Highlight 7.
Infrastructure support - integration and industrial evaluation.	Canceled	This activity has been cancelled. Related activities are performed in Flexi.
Componentisation process - case studies.	Completed	Case-study for transformation to product line development at ABB.
Development of Integrated Development Environment (IDE) - integration framework.	Ongoing (as planned)	Prototype completed; increased emphasis on the IDE, with additional resources through 2010. Highlight 8.
Development of IDE - instantiations of component models and transformation tools.	Ongoing (as planned)	Component models and transformation tools implemented in the IDE. Highlight 8.
Development of IDE - advanced component and assemblies repositories management.	Ongoing (as planned)	To be completed in 2009.
IDE development for SaveCCM Component Model – exploitation with CC Systems.	Completed	Two case-studies; a demostrator on component evolution and an IDE demonstrator; repository in use at CC-Systems.

7. Relevance

According to statistics from SCB[6], more than 50% of the Swedish product exports in 2007 are due to computer-based products. Continued development of Swedish expertise in this area is a key strategic issue for dominating industrial sectors, including automotive, telecom and automation. The issue is equally important for Sweden as a nation, to ensure that industry remains in Sweden, and to make Sweden more attractive for top talents and to the globalised engineering industry.

The relevance of PROGRESS is captured by our *grand challenge* in the original application:

> *The PROGRESS grand challenge is to provide the tools and techniques necessary for cost-efficient development of future computer controlled products, with 100 times increased functionality, developed in one 10th of the time, with increased and predictable quality, while keeping the costs under control. While being novel and innovative, these tools and techniques should allow to be gradually incorporated in today's processes and tool chains, and support seamless integration of legacy as well as newly developed software.*

The mission of PROGRESS is to (i) act as a catalyst and to strengthen Swedish competence in the development of embedded software for products, (ii) to advance the state-of-the-art in engineering of embedded software, (iii) to be a partner for industry pointing out technical opportunities and providing methods and tools to help mastering current and emerging challenges in embedded software development, and (iv) to be instrumental in international recruitment of highly skilled engineers and researchers.

Industrial cooperation and relevance

One of the cornerstones of the centre is the extensive and close industrial cooperation. An account of our industrial cooperation and disseminations conveys the industrially strategic relevance of PROGRESS, as well as our impact on Sweden's industrial competence in development of embedded systems.

Almost all projects and activities at the centre include industrial partners. The basic reason for this quite extensive range of collaboration is our partners' appreciation, not only of our competence, but also of our senior researchers' thorough understanding of industrial problems; based on many years of close cooperation, and not least, many years of industrial experience[7].

[6] http://www.scb.se/Statistik/HA/HA0201/2008M08D/HA0201_2008M08D_DI_01_SV_expSPIN.xls

[7] E.g., Jakob Axelsson, Ivica Crnkovic, Magnus Larsson, Mikael Nolin, Christer Norström, and Sasikumar Punnekkat each have more than 5 years of relevant industrial experience.

We have adopted a strategy for our industrial cooperation in which we aim for establishing more long-term bilateral cooperation with our main industrial partners. This cooperation includes a portfolio of activities, such as projects, case-studies, funding of PhD-students, and courses, as well as persons responsible for maintaining the portfolio. Currently we have strategic long-term co-operations with seven companies: ABB Corporate Research, ABB Robotics, Arcticus Systems, Bombardier Transportation, CC-Systems, Ericsson, and Volvo Construction Equipment. In recent years, the cooperation has been extended to international subsidiaries and partners of these companies. In addition to this strategic cooperation we have cooperation also with several other Swedish and international companies[8].

Our strategy has resulted in substantial industrial support, including a 9.6 MSEK donation from ABB, close to 30 graduate students funded by industry, an industrial lab (currently been set up in cooperation with Ericsson and ABB), a top-talent program for recruitment of international master level students, as well as a large number of national and international joint research projects.

The most important "output" of the centre is, however, the large number of graduate students that play important roles in the development of science, technology, and society. The following table is an illustration of the careers of our PhDs; listing the current occupation of our 10 most recent PhDs.

Name	Year	Title of thesis	Current occupation
Markus Lindgren	2008	A capability model for SW release planning	Engineer at ABB
Johan Fredriksson	2008	Improving Predictability and Resource Utilization in Embedded Component-Based Real-Time Systems (RTSs)	Engineer at ENEA
Mikael Åkerholm	2008	Reusability of Software Components in the Vehicular Domain	Engineer at CC-Systems
Kaj Hänninen	2008	Efficient Memory Utilization in Resource Constrained RTSs	Engineer at CC-Systems
Sundmark, Daniel	2008	Structural System-Level Testing of Embedded RTSs	Senior researcher MDH (ITEA project in cooperation with ABB)
Carlson, Jan	2007	Event Pattern Detection for Embedded Systems	Senior Researcher MDH
Fröberg, Joakim[9]	2007	Engineering Automotive Electronic Systems: Decision Support for Successful Integration	Engineer/Researcher Volvo CE
Huselius, Joel	2007	Reverse Engineering of Legacy RTSs: An Automated Approach Based on Execution-Time Recording	Engineer at Combitech/Ericsson
Johnsson, Andreas	2007	Modeling, Implementation and Evaluation of IP Network Bandwidth Measurement Methods	Researcher, Ericsson Research
Larsson, Stig[9]	2007	Key Elements of Software Product Integration Processes	Researcher ABB

Another important indicator of our industrial relevance is our track record of successful commercialization of research results, including the Rubus component framework of Arcticus, the real-time debugging technology commercialized by the spin-off company Zealcore (now acquired by ENEA), the HW-accelerator technology commercialized by the spin-off company RealFast (later acquired by Prevas), and the real-time database technology commercialized by Mimer.

8. Exploitation

The centre has a history of bringing research results into practical use[10]. Commercialization activities have been quite successful so far, yet based on individual initiatives. In cooperation with Idélab[11], a special unit at MDH dedicated to idea generation and commercialization, PROGRESS will professionalize its commercialization efforts by developing a supporting infrastructure for innovation, aiming at transferring research results to commercial value for existing or start-up companies. In strengthening the industrial impact, the large number of alumni PhDs working in industry will be engaged.

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

[9] Has together with two other of our PhDs received support from the KK-Foundation to pursue research in synergy between industry and academia.

[10] Several examples are given in Section 3 of the development plan in Appendix D.

[11] Idélab has an impressive track-record; approximately 40 companies are started annually as a result of the incubator activities.

A concrete activity initiated in 2008 is the engagement of an experienced business developer that in close cooperation with the research leaders and external domain experts will review all research projects at the centre, with the purpose to identify the most promising projects and individuals with respect to commercialization potential. In a second phase, development of the identified ideas into innovations and products will be promoted. These commercialization efforts will include active involvement of the PROGRESS board. Further details and plans are provided in Appendix D.

9. Graduate education and recruitment

One of the main outcomes of PROGRESS in terms of graduate education has been the opportunity to professionalize, broaden, and internationalize the PhD student recruitment. As an example, among the 14 PhD students funded by PROGRESS, 10 have an international undergraduate degree. This is a major step forward, compared to previous recruitments dominated by master students from our own ranks.

In order to handle a more ambitious graduate education and recruitment, the PROGRESS funding has allowed for a strengthened administrative support in these areas. One of the research coordinators is director for the post graduate education, and monitors all parts of the PhD studies. In addition to administrative support to supervisors and students, the task is focussed on quality assurance and development, including review of student progress, counselling, and supervisor training.

Beside this, the PROGRESS students benefit from the PROGRESS seminar series with frequent international speakers, an annual planning week with intensive scientific discussions, participation in international summer schools and national graduate schools, courses on scientific methods in general and specifically on how to apply the appropriate methods in the own research, as well as frequent conference trips, international visits and participation in international projects.

Furthermore, PROGRESS has played a seminal role in establishing the Vinnova-funded Hi5 research school, which provides new instruments for industrial cooperation, not only at PhD education level, but also at the pre-PhD education and post-doc levels. Hi5 organizes mobility of PhD students/post-docs and senior researchers; outgoing (to industry or international academia) as well as incoming international or industrial participants (PhD students/post-docs). Hi5 extends and complement the existing infrastructure at the centre for cooperation with industry and international research environments. As a result, recruitment of researchers and PhD students is facilitated.

10. International cooperation

PROGRESS has a substantial international presence, manifested by 35 articles co-authored with international academic and industrial scientists, 11 international projects (as shown in the table below; with further details in Appendix C), permanently 3-5 international visitors, extensive involvement in the international research community[12], as well as cooperation with international subsidiaries and partners of our regional multinational industrial partners. The latter is currently increasing, with a main focus on recruitment and education of international top-talents that are expected to play important future roles for our industrial partners, as well as strengthening our international and industrial links.

Project	Industrial partners	Academic partners	Countries (in addition to Sweden)
Q-IMPRESS	4	4	4 (Italy, Czech Republic, Germany, Croatia)
ALL-TIMES	4	2	3 (UK, Austria, Germany)
ARTIST-2			
ARTIST DESIGN	0	40	11 (Portugal, Italy, France, United Kingdom, Netherlands, Germany, Spain, Switzerland, Austria, Denmark, Belgium)

[12] Members of the PROGRESS staff have during 2006-2008 participated (as general chair, local chair etc.) in the organization of 10 international conferences and workshops, including top events such as ESEC/FSE and CBSE, been associate editors, members of editorial boards and guest editors of 10 reputed international journals, including Springer's Real-Time Systems Journal and IEEE Transactions on Industrial Informatics, been program chair of 10 international conferences, including Euromicro SEAA and CBSE, participated as program committee members of more than 100 international conferences and workshops, including top events such as ICSE, RTSS, CBSE, EMSOFT, LCTES, and ECRTS. Moreover, PROGRESS staff is participating and/or chairing some 20 steering and technical committees, including committees of ACM, IEEE and Euromicro.

Project	Industrial partners	Academic partners	Countries (in addition to Sweden)
KISEK	4	5	2 (Croatia, Germany)
FLEXI	25	10	6 (Belgium, Finland, Ireland, Israel, Netherlands, Norway, Spain)
GSEEM	0	4	3 (UK, Italy, Germany)
EURECA	0	16	11 (Bulgaria, Germany, Finland, Ireland, Italy, Netherlands, UK, India, Nepal, Pakistan, Sri Lanka)
DICES	1	3	1 (Croatia)
SISTER	0	6	5 (Spain, Netherlands, UK, Italy, Bulgaria)
MOMENT	4	8	7 (Spain, Italy, Austria, Hungary, Greece, Israel, Switzerland)

The centre provides support to enable international cooperation. There is a structure of 4 qualified research coordinators (PhD-level), out of which one is dedicated for the PROGRESS centre. There is a continuous survey for adequate research calls from the EU, as well as from other international funding sources, such as Nordforsk, ESF, Eureka, and US federal research grants etc. There are also pointed alerts to research leaders to start application processes, and support for their work. As a result the number of submitted and granted applications is steadily increasing.

The research coordinators also provide project management support, especially for European research projects, from the negotiation process with the EC and consortia, over deliverables and reports, until the final audit; and there is an infrastructure to facilitate visiting researchers travel, accommodation and cost management, as well as flats available for visiting researchers and PhD students.

The support and coordination in PROGRESS has been instrumental for the increased international involvement. The international presence is an indispensable asset in the development of the research and centre, simply because the research is international, and since the international community stimulates and challenges us to improve.

11. Gender equality

There has been an improvement in gender balance at the hosting research centre MRTC, to a large extent due to the recruitments resulting from the PROGRESS grant. The following table presents the gender balance at MRTC before PROGRESS (2005) and after the initial years of PROGRESS (June 2008):

	2005				2008				Increase
Category	Total	Male	Female	%Female	Total	Male	Female	%Female	%Female
Professors	7	7	0	0%	13	12	1	8%	+∞
Senior researchers	13	12	1	8%	17	14	3	18%	+200%
PhD-students	38	32	6	16%	41	32	9	22%	+50%
Total	58	51	7	12%	71	58	13	18%	+ 86%

The table shows that there has been a substantial increase in the number and fraction of females in all categories. It is particularly satisfying to note the increase among senior researchers and professors.

To further increase awareness of gender aspects and promote improved gender balance, a gender project – GENIUS – is currently under way. A planning grant has been received from Vinnova and a final application submitted. Regardless of the outcome of this application we intend to initiate activities targeting the GENIUS objectives:

- To integrate gender perspectives in the formulation, implementation and evaluation of research and cooperation projects.
- To increase the gender awareness among all participants in PROGRESS.
- To increase the number of female participants in research, cooperation, and innovation projects.

12. Planned activities

PROGRESS research is conducted in 6 interrelated research directions, as illustrated in Figure 3.

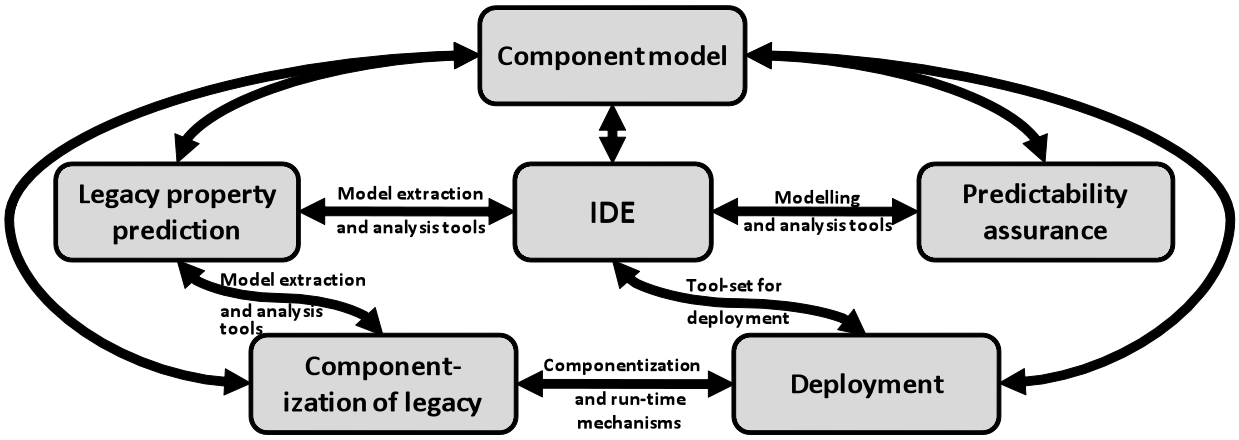

Figure 3: The integrating aspect of PROGRESS: dependencies among research directions.

Detailed planning for 2009-2010 is outlined in "The PROGRESS Activity Plan"[13] which is revised in November annually. Below, the content of this activity plan is summarized, listing the main future research activities for each research direction.

1. **Component model research direction** – further development of the component model; looking at applicability of the component model in the targeted application domains (vehicular, automation, telecom); major revision of the component model targeting the telecom domain, which has some unique requirements compared to the other two application domains.
2. **Predictability assurance research direction** – disciplinary research into formal modeling, static analysis, and dependability for CBD has been performed during the first half of PROGRESS. Efforts now include: implementation of results in tools; integration of tools in the IDE; and integration of results in the component model.
3. **Deployment research direction** – continued research on synthesis and model transformations, applying advanced state-of-the-art optimization techniques; development of models of realizations making it possible to reason about deployment related properties of the system without having to undergo all steps in the deployment.
4. **Development environment and processes research direction** – IDE refinement, making it suitable for a wider domain of applications; research and development of workflows for using the IDE; perform simulation of processes as the basis for selecting appropriate process; integration of CBD and agile methods.
5. **Componentization of legacy research direction** – development of techniques for wrapping of legacy systems; implementation of more advanced functionality, such as synchronization protocols, in the legacy run-time environment; adaption of run-time environment to more advanced architectures including multicore and distribution.
6. **Legacy property prediction research direction** – increased efforts on model validation to ensure that the models extracted and constructed from a legacy system are sufficiently accurate representations of the real legacy system.

[13] "The PROGRESS Activity Plan" is an annually revised 50+ page document with detailed plans for the PROGRESS disciplinary and cross-cutting projects.

Appendix A List of researchers

The table below presents the staff active within PROGRESS in June 2008, followed by a table listing the PhD-students active within PROGRESS and associated projects. The first table additionally indicates the amount of research time, and in the case when the person has been recruited as a result of PROGRESS, the previous organizational affiliation is listed. Note that recruitments from "MDH" indicate that the person previously had a different position at MDH, or was a student at MDH.

For students, the second table lists the university where the qualifying degree was awarded. Students partially or fully funded by PROGRESS are additionally indicated.

Name	Title/Rôle	Recruited from	Employed	Research
BJÖRKMAN MATS	Professor/Co-applicant		100%	40%
CRNKOVIC IVICA	Professor/Co-applicant; Deputy Director; Cluster leader; Research Direction Leader		100%	85%
HANSSON HANS	Professor/Applicant; Director		100%	100%
LISPER BJÖRN	Professor/Co-applicant		100%	75%
LUNDQVIST KRISTINA	Professor	MIT, USA	100%	100%
NOLIN MIKAEL	Professor/Co-applicant; Research Direction Leader	MDH/CC-Systems	75%	75%
NORSTRÖM CHRISTER	Professor/Co-applicant; Deputy Director; Cluster leader; Research Direction Leader		50%	50%
PETTERSSON PAUL	Professor/Research Direction Leader	Uppsala Univ.	100%	95%
PUNNEKKAT SASI	Professor/Co-applicant	MDH	100%	90%
AXELSSON JAKOB	Adjunct professor/Co-applicant		20%	20%
LARSSON MAGNUS	Adjunct professor	ABB	30%	30%
SCHMIDT HEINRICH	Adjunct professor	Monash U. Aus.	25%	25%
GUSTAFSSON JAN	Docent/Senior Lecturer		100%	30%
THANE HENRIK	Docent/Senior Lecturer		35%	15%
ERMEDAHL ANDREAS	Docent/Senior Lecturer		100%	90%
ISOVIC DAMIR	PhD/Senior Lecturer		100%	20%
MÄKI-TURJA JUKKA	PhD/Senior Lecturer		100%	50%
SANDSTRÖM KRISTIAN	PhD/Senior Lecturer		38%	38%
LAND RIKARD	PhD/Senior Lecturer	MDH	100%	40%
LÜDERS FRANK	PhD/Senior Lecturer	MDH	100%	25%
CARLSON JAN	PhD/Senior Researcher; Research Direction Leader	MDH	100%	100%
DOBRIN RADU	PhD/Senior Researcher	MDH	100%	100%
NOLTE THOMAS	PhD/Senior Researcher; Program Leader; Research Direction Leader	MDH	100%	100%
NYSTRÖM DAG	PhD/Senior Researcher	MDH	50%	50%
SECELEANU CRISTINA	PhD/Senior Researcher	Åbo Akademi	100%	100%
SUNDMARK DANIEL	PhD/Senior Researcher	MDH	100%	100%
FRÖBERG JOAKIM	PhD/Industrial Post Doc (Volvo)			40%
LARSSON STIG	PhD/Industrial Post Doc (ABB)			40%
WALL ANDERS	PhD/Industrial Post Doc (ABB)			50%
BURES TOMAS	PhD/Post Doctoral Fellow	Charles U. CZ	Post Doc	100%
SHIN INSIK	PhD/Post Doctoral Fellow	U. Pen. USA	Post Doc	50%
WIDFORSS GUNNAR	Research Coordinator		100%	100%
FLEMSTRÖM DANIEL	Research Engineer	ABB	100%	100%
PETTERSSON ANDERS	Research Engineer	MDH	100%	100%

Name	Rôle	Undergrad. degree from	Funded by PROGRESS
AYSAN HUSEYIN	PhD-student	Istanbul Technical University	X
BEHNAM MORIS	PhD-student	MDH/U. of Technology Baghdad	X
BJÖRNANDER STEFAN	PhD-student	Umeå U.	X
BOHLIN MARKUS	Industrial PhD-stud. (SICS)	MDH	X
BRANGER PER	Industrial PhD-stud. (ABB)	Uppsala University	
BYGDE STEFAN	PhD-student	MDH	X
CAUSEVIC ADNAN	PhD-student	University of Sarajevo	
CAUSEVIC AIDA	PhD-student	University of Sarajevo	X
EKMAN MATHIAS	Ind. PhD-stud. (Bombardier)	MDH	
ELD SIGRID	Industrial PhD-stud. (Ericsson)	Uppsala University	
FREDRIKSSON JOHAN	Ind. PhD-stud. (CC-Systems)	MDH	
GUSTAFSSON HÅKAN	Industrial PhD-stud. (Scania)	KTH	
HJERTSTRÖM ANDREAS	PhD-student	MDH	X
HÄNNINEN KAJ	Industrial PhD-stud. (Arcticus)	MDH	
JOHNSSON STEFAN	Industrial PhD-stud. (Level21)	Linköping University	
KRAFT JOHAN	PhD-student	MDH	
LINDGREN MARKUS	Industrial PhD-stud. (ABB)	MDH	
LU YUE	PhD-student	U. of Southern Denmark/Beijing University of Technology	X
NEMATI FARHANG	PhD-student	Uppsala U./Univ. Of Teheran	X
NI PENGPENG	Industrial PhD-stud. (Ardendo)	MDH	
PEI-BREIVOLD HUNGYU	Industrial PhD-stud. (ABB)	Northeast University of Technology, Shenyang, China	
SANDBERG CHRISTER	PhD-student	MDH	
SANTOS MARCELO	PhD-student	Chalmers/Federal University of Rio Grande do Sul, Brazil	X
SENTILLES SEVERINE	PhD-student	University of Pau, France	X
SRINIVASAN JAYAKANTH	PhD-student	MIT, Boston, USA	X
STOLL PIA	Industrial PhD-stud. (ABB)	Lund University	
SURYADEVARA JAGADISH	PhD-student	Jawaharlal Nehru Technological University, India	X
WALLIN PETER	PhD-student	MDH	
WALLNAU KURT	Ind. PhD-stud. (SEI/CMU US)	Villanova U./USA	
VULGARAKIS ANETA	PhD-student	SS Cyril and Methodius University, Macedonia	X

Appendix B Publications

Below, we present 50 publications, selected from the 215 PROGRESS publications in 2006-2008. The total number is distributed over different types of publications according to the following:

Publication type	Amount
Books	2
Journal articles	18
Conference articles	146
Articles in collections	5
Technical reports	25
PhD-theses	13
Licentiate theses	5

These articles frequently have co-authors with affiliation outside MDH. The following statistics for the articles from 2006-2008 illustrates the level of national and international cooperation:

Number of articles with co-authors from	
National academia	21
International academia	32
National industry	74
International industry	3

Number of co-authors from	
National academia	13
International academia	56
National industry	35
International industry	6

For a complete and up-to-date account of PROGRESS publications we refer to our publication database available at http://www.mrtc.mdh.se/progress/.

Please note that, the tradition within the scientific areas of PROGRESS is to mainly publish full papers in peer-reviewed conferences, and that acceptance ratios for the leading conferences normally are substantially lower than those for the journals.

Top-50 publications

Peer-reviewed journal articles

1. **The Worst-Case Execution-Time Problem - Overview of Methods and Survey of Tools**. Reinhard Wilhelm (Saarland University, Germany), Jakob Engblom (Virtutech AB), Andreas Ermedahl, Niklas Holsti (Tidorum Ltd., Finland), Stephan Thesing (Saarland University, Germany), David Whalley (Florida State University, USA), Guillem Bernat (Rapita Systems, Ltd.), Christian Ferdinand (AbsInt Angewandte Informatik), Reinhold Heckmann (AbsInt Angewandte Informatik), Tulika Mitra (National University of Singapore), Frank Mueller (North Carolina State University, USA), Isabelle Puaut (IRISA, France), Peter Puschner (TU Vienna, Austria), Jan Staschulat (TU Braunschweig, Germany), Per Stenström (Chalmers University of Technology), *ACM Transactions on Embedded Computing Systems*, vol. 7, nr 3, pp. 1-53, ACM, April, 2008.

2. **Efficient Implementation of Tight Response-times for Tasks With Offsets**. Jukka Mäki-Turja, Mikael Nolin, *Real-Time Systems*, vol. 40, nr 1, pp. 77-116, Springer Netherlands, February, 2008.

3. **Data cache locking for tight timing calculations**. Xavier Vera, Björn Lisper, Jingling Xue (University of New South Wales, Australia), *ACM Transactions on Embedded Computing Systems*, vol. 7, nr 1, pp. 4:1-4:38, ACM, December, 2007.

4. **Task Automata: Schedulability, Decidability and Undecidability**. Elena Fersman (Ericsson Research), Pavel Krcal (Uppsala University), Paul Pettersson, Wang Yi (Uppsala University), *International Journal of Information and Computation*, vol. 205, nr 8, pp. 1149-1172, Elsevier, August, 2007.

5. **Key Factors for Achieving Project Success in Integration of Automotive Mechatronics**. Joakim Fröberg, Mikael Åkerholm, Kristian Sandström, Christer Norström, *Journal of Innovations in Systems and Software Engineering*, vol. 3, nr 2, pp. 141-155, Springer, June, 2007.

6. **The SAVE Approach to Component-based Development of Vehicular Systems**. Mikael Åkerholm, Jan Carlson, Johan Fredriksson, Hans Hansson, John Håkansson (Uppsala University), Anders Möller, Paul Pettersson, Massimo Tivoli (University of L'Aquila, Italy), *Journal of Systems and Software*, vol. 80, nr 5, pp. 655-667, Elsevier, May, 2007.

7. **Software Configuration Management**. René Krikhaar (Vrije Universiteit, The Netherlands), Ivica Crnkovic, *Science of Computer Programming*, vol. 65, nr 3, pp. 215-221, Elsevier, April, 2007.

8. **Component-Based Software Engineering of Trustworthy Embedded Systems**. Ivica Crnkovic, Heinz Schmidt, Judith Stafford (Tufts University, USA), George Heineman (Worcester Polytechnic Institute, USA), Kurt Wallnau (SEI, Carnegie Mellon University, USA), *Journal of Systems and Software*, vol. 80, nr 5, pp. 641-642, Elsevier, January, 2007.

9. **Software Systems In-House Integration: Architecture, Process Practices and Strategy Selection**. Rikard Land, Ivica Crnkovic, *Journal of Information and Software Technology*, vol. 49, nr 5, pp. 419-444, Elsevier, September, 2006.

10. **Code Analysis for Temporal Predictability**. Jan Gustafsson, Björn Lisper, Raimund Kirner (Technische Universität Wien, Austria), Peter Puschner (Technische Universität Wien, Austria), *Journal of Real-Time Systems*, vol. 32, nr 3, pp. 253-277, Springer-Verlag, March, 2006.

11. **Managing Redundancy in CAN-based Networks Supporting N-Version Programming**. Julian Proenza (Universitat de les Illes Balears, Spain), José Miro-Julia (Universitat de les Illes Balears, Spain), Hans Hansson, to appear in *Journal of Computer Standards and Interfaces*, Elsevier. Available online December 3, 2007.

12. **Software Product Integration: A Case Study-Based Synthesis of Reference Models**. Stig Larsson, Petri Myllyperkiö (ABB Distribution Automation, Finland), Fredrik Ekdahl (ABB Robotics), Ivica Crnkovic, to appear in *Information and Software Technology,* Elsevier.

Invited tutorials

13. **Testing Real-time Systems Using UPPAAL**. Anders Hessel (Uppsala University), Kim Guldstrand Larsen (Aalborg University, Denmark), Marius Mikuèionis (Aalborg University, Denmark), Brian Nielsen (Aalborg University, Denmark), Paul Pettersson, *Formal Methods and Testing*, Springer-Verlag, December, 2007.

14. **Execution Time Analysis for Embedded Real-Time Systems**. Andreas Ermedahl, Jakob Engblom (Virtutech), *Handbook of Real-Time Embedded Systems*, pp. 35.1-35.17, Chapman & Hall/CRC - Taylor and Francis Group, August, 2007.

15. **Evaluating Dependability Attributes of Component-Based Specifications**. Ivica Crnkovic, Lars Grunske (University of Queensland, Australia), *International Conference on Software Engineering (ICSE),* pp. 157-158, IEEE, May, 2007.

16. **Trends in Timing Analysis**. Björn Lisper, *From Model-Driven Design to Resource Management for Distributed Embedded Systems*, pp. 85-94, Springer Boston, 2006.

17. **Component-based Software Engineering for Embedded Systems**. Ivica Crnkovic, *From MDD Concepts to Experiments and Illustrations*, pp. 71-90, ISTE Ltd, 2006.

Peer-reviewed conference articles

18. **Synthesis of Optimal Interfaces for Hierarchical Scheduling with Resources**. Insik Shin, Moris Behnam, Thomas Nolte, Mikael Nolin, to appear in Proceedings of the 29th IEEE International Real-Time Systems Symposium (RTSS'08), December, 2008, IEEE. (Acceptance ratio: 23%; **BEST PAPER AWARD NOMINATION,** decision pending)

19. **Automatic Derivation of Loop Bounds and Infeasible Paths for WCET Analysis using Abstract Execution**. Jan Gustafsson, Andreas Ermedahl, Christer Sandberg, Björn Lisper, In Proceedings of the 27th IEEE International Real-Time Systems Symposium (RTSS'06), pp. 57-66, December, 2006, IEEE. (Acceptance ratio: 24%)

20. **Determining Maximum Stack Usage in Preemptive Shared Stack Systems**. Kaj Hänninen, Jukka Mäki-Turja, Markus Bohlin, Jan Carlson, Mikael Nolin, In Proceedings of the 27th IEEE Real-Time Systems Symposium (RTSS'06), pp. 445-453, December, 2006, IEEE. (Acceptance ratio: 24%)

21. **The TASM Toolset: Specification, Simulation, and Verification of Real-Time Systems**. Martin Ouimet (MIT, USA), Kristina Lundqvist, In Proceedings of the 19th International Conference on Computer-Aided Verification (CAV'07), pp. 126-130, July, 2007, Springer LNCS vol. 4590. (Acceptance ratio: 24%)

22. **Save-IDE – An Integrated development environment for building predictable component-based embedded systems**. Séverine Sentilles, John Håkansson (Uppsala University), Paul Pettersson, Ivica Crnkovic, In Proceedings of the 23rd IEEE/ACM International Conference on Automated Software Engineering (ASE'08), September, 2008, ACM. (Acceptance ratio: 12%)

23. **Driving the Selection of COTS Components on the Basis of System Requirements**. Vittorio Cortaliessa (University of L'Aquila, Italy), Ivica Crnkovic, Pasqualina Potena (University of L'Aquila, Italy), Fabrizio Marinelli (Laboratoire d'Informatique de l'Ecole Polytechnique, France), In Proceedings of the 22nd IEEE/ACM International Conference on Automated Software Engineering (ASE'07), pp. 413-416, November, 2007, ACM. (Acceptance ratio: 12%)

24. **Hierarchical Scheduling Framework for Virtual Clustering of Multiprocessors**. Insik Shin, Arvind Easwaran (University of Pennsylvania, USA), Insup Lee (University of Pennsylvania, USA), In Proceedings of the 20th Euromicro Conference on Real-Time Systems (ECRTS'08), pp. 181-190, July, 2008, IEEE. (Acceptance ratio: 29%, **BEST PAPER RUNNER UP**)

25. **Bounding Shared-Stack Usage in Systems with Offsets and Precedences**. Markus Bohlin, Kaj Hänninen, Jukka Mäki-Turja, Jan Carlson, Mikael Nolin. In Proceedings of the 20th Euromicro Conference on Real-Time Systems (ECRTS'08), pp. 276-285, July 2008, IEEE. (Acceptance ratio: 29%)

26. **Evaluation of Automatic Flow Analysis for WCET Calculation on Industrial Real-Time System Code**. Dani Barkah (Volvo CE), Andreas Ermedahl, Jan Gustafsson, Björn Lisper, Christer Sandberg, In Proceedings of the 20th Euromicro Conference of Real-Time Systems (ECRTS'08), pp. 331-340, July, 2008, IEEE. (Acceptance ratio: 29%)

27. **SIRAP: A Synchronization Protocol for Hierarchical Resource Sharing in Real-Time Open Systems**. Moris Behnam, Insik Shin, Thomas Nolte, Mikael Nolin, In Proceedings of the 7th ACM and IEEE International Conference on Embedded Software (EMSOFT'07), pp. 279-288, October, 2007, ACM. (Acceptance ratio: 22%)

28. **Faster WCET Flow Analysis by Program Slicing**. Christer Sandberg, Andreas Ermedahl, Jan Gustafsson, Björn Lisper, In Proceedings of the 2006 ACM SIGPLAN Conference on Languages, Compilers and Tools for Embedded Systems (LCTES'06), pp. 103-112, June, 2006, ACM. (Acceptance ratio: 25%)

29. **Scheduling Timed Modules for Correct Resource Sharing**. Cristina Seceleanu, Paul Pettersson, Hans Hansson, In Proceedings of the 1st IEEE International Conference on Software Testing, Verification and Validation (ICST'08), pp. 102-111, April, 2008, IEEE. (Acceptance ratio: 20%)

30. **A Component Model for Control-Intensive Distributed Embedded Systems**. Séverine Sentilles, Aneta Vulgarakis, Tomas Bures, Jan Carlson, Ivica Crnkovic, to appear in Proceedings of the 11th International Symposium on Component-Based Software Engineering (CBSE'08), October, 2008, Springer LNCS. (Acceptance ratio: 29%)

31. **Structural Testing of Component-Based Systems**. Daniel Sundmark, Jan Carlson, Sasikumar Punnekkat, Andreas Ermedahl, to appear in Proceedings of the 11th International Symposium of Component Based Software Engineering (CBSE'08), October, 2008, Springer LNCS. (Acceptance ratio: 29%)

32. **A Prototype Tool for Software Component Services in Embedded Real-Time Systems**. Frank Lüders, Daniel Flemström, Anders Wall, Ivica Crnkovic, In Proceedings of the 9th International Symposium on Component-Based Software Engineering (CBSE'06), pp. 222-237, June, 2006, Springer LNCS vol. 4063. (Acceptance ratio: 29%)

33. **A Metaheuristic Approach for Best Effort Timing Analysis targeting Complex Legacy Real-Time Systems**. Johan Kraft, Yue Lu, Christer Norström, Anders Wall, In Proceedings of the 14th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS'08), pp. 258-269, April, 2008, IEEE. (Acceptance ratio: 25%)

34. **Maximizing the Fault Tolerance Capability of Fixed Priority Schedules**. Radu Dobrin, Sasikumar Punnekkat, and Hüseyin Aysan, In Proceedings of the 14th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA'08), pp. 337-346, August, 2008, IEEE. (Acceptance ratio: 26%)

35. **Contract-Based Reusable Worst-Case Execution Time Estimate**. Johan Fredriksson, Thomas Nolte, Mikael Nolin, Heinz Schmidt, In Proceedings of the 13th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA'07), pp. 39-46, August, 2007, IEEE. (Acceptance ratio: 29%; **BEST PAPER AWARD**)

36. **COTS Selection Best Practices in Literature and in Industry**. Rikard Land, Laurens Blankers (Logica, the Netherlands), Michel Chaudron (Technical University Eindhoven, the Netherlands), Ivica Crnkovic, In Proceedings of the 10th International Conference on Software Reuse (ICSR'08), pp. 100-111, May, 2008, Springer LNCS vol. 5030. (Acceptance ratio: 35%)

37. **A Case Study of Issues Related to Automotive E/E System Architecture Development**. Peter Wallin, Jakob Axelsson, In Proceedings of the 15th Annual IEEE International Conference and Workshop on the Engineering of Computer Based Systems (ECBS'08), pp. 87-95, March, 2008, IEEE. (**BEST PAPER AWARD**)

38. **Evaluating the Quality of Models Extracted from Embedded Real-Time Software**. Joel Huselius, Johan Kraft, Hans Hansson, Sasikumar Punnekkat, In Proceedings of the 14th Annual IEEE International Conference and Workshop on the Engineering of Computer Based Systems (ECBS'07), presented at the 5th Workshop and Session on Model-Based Development of Computer Based Systems, pp. 577-585, March, 2007, IEEE.

39. **Extracting Simulation Models from Complex Embedded Real-Time Systems**. Johan Andersson, Joel Huselius, Christer Norström, Anders Wall, In Proceedings of the 2006 International Conference on Software Engineering Advances (ICSEA'06), October, 2006, IEEE. (Acceptance ratio: 37%; **BEST PAPER AWARD**)

40. **Component-based Development Process and Component Lifecycle**. Ivica Crnkovic, Michel Chaudron (Eindhoven University of Technology, the Netherlands), Stig Larsson, In Proceedings of the 2006 International Conference on Software Engineering Advances (ICSEA'06), October, 2006, IEEE. (Acceptance ratio: 37%)

41. **Analyzing Software Evolvability**. Hongyu Pei-Breivold, Ivica Crnkovic, Peter Eriksson (ABB Robotics), In Proceedings of the 32nd Annual IEEE International Computer Software and Applications Conference (COMPSAC'08), pp. 327-330, July, 2008, IEEE. (Acceptance ratio: 31%)

42. **Towards a Capability Model for the Software Release Planning Process - Based on a Multiple Industrial Case Study**. Markus Lindgren, Rikard Land, Christer Norström, Anders Wall, In Proceedings of the 9th International Conference on Product-Focused Software Process Improvement (PROFES'08), pp. 117-132, June, 2008, Springer LNCS vol. 5089. (**Among best papers** – invited for submission to a special issue of the journal *Software Process: Improvement and Practice*)

43. **Component Testing is Not Enough - A Study of Software Faults in Telecom Middleware**. Sigrid Eldh, Sasikumar Punnekkat, Hans Hansson, Peter Jönsson (Combitech Systems), In Proceedings of the 19th IFIP International Conference on Testing of Communicating Systems/7th International Workshop on Formal Approaches to Testing of Software (TestCom/FATES'07), pp. 74-89, June, 2007, Springer LNCS vol. 4581.

44. **Partial Order Reduction for Verification of Real-Time Components**. John Håkansson (Uppsala University), Paul Pettersson, In Proceedings of the 5th International Conference on Formal Modeling and Analysis of Timed Systems (FORMATS'07), pp. 211-226, October, 2007, Springer LNCS vol. 4763.

45. **Evaluating Flexibility in Embedded Automotive Product Lines Using Real Options**. Håkan Gustavsson, Jakob Axelsson, In Proceedings of the 12th International Software Product Line Conference (SPLC'08), pp. 235-242, September, 2008, IEEE. (Acceptance ratio: 30%)

46. **Scheduling of Semi-Independent Real-Time Components: Overrun Methods and Resource Holding Times**. Moris Behnam, Insik Shin, Thomas Nolte, Mikael Nolin, In Proceedings of the 13th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA'08), September, 2008, IEEE. (**Among best papers** – invited to submit to a special section of the IEEE Transactions on Industrial Informatics)

47. **Design-Time Management of Run-Time Data in Industrial Embedded Real-Time Systems Development**. Andreas Hjertström, Dag Nyström, Mikael Nolin, and Rikard Land. In Proceedings of the 13th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA'08), September, 2008, IEEE.

48. **VTV – A Voting Strategy for Real-Time Systems**. Hüseyin Aysan, Sasikumar Punnekkat, and Radu Dobrin, to appear in Proceedings of the 14th Pacific Rim International Symposium on Dependable Computing (PRDC'08), December, 2008, IEEE.

49. **The Rubus Component Model for Resource Constrained Real-Time Systems**. Kaj Hänninen, Jukka Mäki-Turja, Mikael Nolin, Mats Lindberg (Arcticus Systems), John Lundbäck (Arcticus Systems), Kurt-Lennart Lundbäck (Arcticus Systems), In Proceedings of the 3rd IEEE International Symposium on Industrial Embedded Systems (SIES'08), pp. 177-183, June, 2008, IEEE.

50. **Loop Bound Analysis based on a Combination of Program Slicing, Abstract Interpretation, and Invariant Analysis**. Andreas Ermedahl, Christer Sandberg, Jan Gustafsson, Stefan Bygde, Björn Lisper, In Proceedings of the 7th International Workshop on Worst-Case Execution Time Analysis (WCET'07), pp. 63-68, July, 2007. (**one of two BEST PAPERS**)

Appendix C Additional funding

The table below lists the current externally funded projects at the centre, together with projects that terminated in 2006-2007. Brief presentations of the projects, including description of their relevance for PROGRESS, are appended at the end.

Project	Funding agency	Time-period	Main grantee	Total Amount (MSEK)		Amount MRTC (MSEK)	
				Grant	In-kind	Grant	In-kind
Current projects (2008-)							
Q-IMPRESS	EU FP7 STREP	2008-2010	Ivica Crnkovic	31.3		4.7	
ALL-TIMES	EU FP7 STREP	2008-2010	Björn Lisper	15		3.9	
ARTIST DESIGN	EU FP7 NoE	2008-2011	Björn Lisper	42.3		0.9	
ARTIST 2	EU FP6 NoE	2005-2008	Björn Lisper	61.1		1.3	
MOMENT	EU FP7 STREP	2008-2010	Mats Björkman	26.6	10.5	(2.9)	(0.7)
KISEK	EU Tempus	2007-2009	Ivica Crnkovic	2.8		0.6	1
SISTER	EU Tempus	2008-2011	Ivica Crnkovic	2.0		0.2	
ABV	EU FP7 (People IRG)	2007-2010	Kristina Lundqvist	0.9		0.9	
EURECA	EU EMECW	2008-2011	Sasi Punnekkat	41.0		4.5	
HISCORE	VR	2008-2011	Thomas Nolte	4.1		4.1	
CARTCOM	VR, CC-Systems	2006-2011	Mikael Nolin	1.4		0.4	1.0
SAVE	SSF	2003-2008	Hans Hansson	26		12	
SAVE-IT	KKS (ABB, Arcticus, CC-Systems, Ericsson, Scania & al)	2004-2010	Hans Hansson	21	21	15	15
SW-Release	KKS, ABB	2005-2008	Christer Norström	0.8	0.8	0.2	1.4
PASAS	KKS, ABB		Christer Norström	1.6	1.6	0.8	2.8
RT Mediaediting	KKS, Ardendo AB	2005-2009	Gerhard Fohler	1.6	1.6	1.6	1.6
EXTRACT	KKS, ABB, Bombardier	2006-2008	Christer Norström	2.5	2.5	2.5	2.5
MultEx	KKS, CC-Systems, Arcticus, Volvo CE	2006-2008	Mikael Nolin	2.9	2.9	2.9	2.9
WCET	KKS, CC-Systems, Arcticus, IAR Systems	2006-2008	Björn Lisper	1.9	1.9	1.9	1.9
FLEXI	ITEA, Vinnova, ABB	2007-2009	Ivica Crnkovic	5.5	11	5.5	11
FFP(Cosy)	Vinnova, Volvo	2006-2008	Jakob Axelsson	1.6		1.6	
Hi5	Vinnova	2008-2011	Ivica Crnkovic	10.0		10.0	
SWELL	Vinnova		Kristina Lundqvist	3.0		1.3	
GENIUS	Vinnova	2008	Ylva Bäcklund	0.3		0.3	
ISE	KKS, ABB, Ericsson, CC-systems, Volvo CE	2008-2010	Ivica Crnkovic	1.5	1.5	1.5	
DICES	World Bank, Croatian Government, Ericsson Croatia	2008-2011	Ivica Crnkovic	2. 2		0.5	
PIFF	HNSU	2008-2009	Gordana Dodig-Crnkovic	2		0.7	
BARTAP	Vinnova	2008-2010	Mats Björkman	3.2		3.2	
Open Innovation	Ericsson	2008-	Christer Norström	0.4		0.4	
Ericsson lab	Ericsson	2006-	Daniel Flemström	3		3	
CUGS (2)	CUGS	2006-2008	Björn Lisper	1.9		1.9	
PLEX	Ericsson	2006-2009	Björn Lisper	2.1		2.1	
SICS CNS	SSF, KKS, Vinnova	2007-2009	Mats Björkman	19.2		1	

Project	Funding agency	Time-period	Main grantee	Total Amount		Amount	
Funding expired 2006-2007							
BETSY	EU FP6 STREP	2004-2007	Gerhard Fohler	24.3		2.4	
Softin	EU Obj 2	2006-2007	Ivica Crnkovic	1		1	
Evalunet 1	Vinnova, Ericsson, SICS	2003-2006	Mats Björkman	4.5		4.5	
ARTES	SSF	1998-2006	Hans Hansson	95		23	
DRIVE	KKS, Volvo CE	2001-2007	Christer Norström	3	3	3	3
Evalunet 2	KKS, Ericsson Gatorhole	2004-2006	Mats Björkman	2	2	2	2
Testing of Real-Time Systems	VR	2005-2007	Paul Pettersson	1.8		0.4	

Current projects

ABV – Enabling Architecture Based Verification and Validation of Mission-Critical Systems – an EU FP7 International Re-Integration project. The high level objective of this project is to reduce the cost and schedule dimensions of mission critical systems development, while at the same time increasing confidence in the implemented system.

Relation to PROGRESS: The supported cooperation and exchange with MIT in Boston, as well as the content and technical objectives, are very much in line with the ambitions of PROGRESS.

ALL-TIMES – An EU FP7 project coordinated by MDH with focus on integrating different technologies for timing analysis. Other partners: TU Vienna (Austria), Rapita Systems (Great Britain), Gliwa (Germany), Symtavision (Germany), AbsInt (Germany). This project provides funding for further development of the WCET analysis tool SWEET, and in particular its interfaces. SWEET is used as an experimental platform within PROGRESS. The interfaces will be of direct use when integrating SWEET in the PROGRESS tool chain.

Relation to PROGRESS: The development of timing analysis methods and tools, and tool interfaces are of relevance for PROGRESS.

ARTIST DESIGN – An EU FP7 Network of Excellence, follow-up to ARTIST2. The main topic is still embedded and real-time systems, but the focus has shifted towards the forthcoming MPSoC and multicore computer achitectures.

Relation to PROGRESS: Predictability of future Multicore/MPSoC execution platforms is of relevance to the PROGRESS Deplyoment and Predictability Assurance research directions.

BARTAP – Bandwidth Available in Real-Time Aplications – the project is funded by Vinnova and proposes application of methods for computer network performances. A key point of the project is to prove the feasibility of BART (see EvaluNet) in commercial products.

Relation to PROGRESS: BARTAP aims at evaluating tools for network performance prediction. Tools from BARTAP can be used to assess network characteristics of distributed platform networks in PROGRESS.

CARTCOM – Monitoring and Probabilistic Analysis of Component-Based Embedded Control Systems – aims at developing novel methods for surveillance of software components used in embedded control systems. The project is funded by CC Systems and VR. CartCom concretely deals with reusability of components in predictable embedded systems. In these systems, not only the functionality of a component should be reused, but also the results from previous experiences and analysis of the component. In CartCom we focus on reuse of worst-case execution time-analysis, developing models to represent different execution times for different usage-profiles of a component.

Relation to PROGRESS: CartCom is directly addressing key predictability assurance issues in PROGRESS.

CUGS – The Swedish National Graduate School in Computer Science, hosted by Linköping University, where MDH is partner. CUGS is one of the sixteen national graduate schools that were launched in 2001. Other partners: Skövde University, Örebro University, Växjö University, Lund University. CUGS currently provides support for one PhD student working on parametric WCET analysis, which is directly applicable to timing analysis of reusable components.

Relation to PROGRESS: One PROGRESS PhD student participates in the research school. Another PhD student funded by CUGS (until 2008) is working within PROGRESS.

DICES – Distributed component-based embedded systems. The project aims for building technology for development of distributed embedded systems with characteristics of reusing components and predictions of system attributes that are important for embedded systems.

Relation to PROGRESS: DICES is using results from PROGRESS for modelling and predictability assurance, but uses different component deployment mechanisms since DICES is aimed for soft real-time systems.

Ericsson lab – Collaboration between MRTC and Ericsson AB including a lab for common research projects. The purpose of the lab is to create an innovative environment with sophisticated telecom hardware and software, together with a software development environment. The lab is supported by experts from Ericsson AB and Mälardalen University.

Relation to PROGRESS: The lab will be used as a platform for validation of some of the PROGRESS results. In addition, by attracting new master students and Post Docs from international research centres, the lab is becoming an important mean for the recruitment.

EXTRACT – A project with the objective to increase productivity of old legacy systems by automatically creating analyzable models. These models can then be used for analysing the impact of a change in the system. The project is a collaboration project between ABB, Bombardier and MDH funded by KKS.

Relation to PROGRESS: PROGRESS benefits significantly from EXTRACT, since the model extraction tools in development there can be utilized in legacy componentization and reuse, and since important industrial needs are collected in EXTRACT.

EURECA – This project aims to establish a Eurasian academic mobility network, for achieving excellence in research and education, with special focus on information technology, engineering, and management in a global context, by identifying key themes for cooperation, leveraging on the complementary competencies and providing synergies. The consortium consists of 16 premier educational institutions (9 from Europe and 7 from Asia) and MDH is the coordinator. As part of this program, MDH will be receiving researchers and students at various levels who will be working on projects closely related PROGRESS.

Relation to PROGRESS: Projects related to dependability assurance and IDE will be strengthened by the incoming researchers and faculty under EURECA. Higher dissemination and internationalization of PROGRESS results are also expected.

FFP (Cosy – Cost Engineering and System Architecture from an Automotive Perspective) – This project aims at developing methods for handling the early phases of development for automotive electronic systems. These phases are characterized by a high level of uncertainty, and at the same time the solutions must be able to live and evolve over a number of years. The project is a co-operation with Volvo Cars, Volvo 3P, Volvo CE and Chalmers, and is financed by Vinnova and the industrial partners.

Relation to PROGRESS: The project brings valuable insights into the automotive domain.

FLEXI – Flexible Global Product Development and Integration – The goal of FLEXI is to offer means to realise high performance business: From idea to product in six months time.

Relation to PROGRESS: FLEXI studies and defines agile methods in a scale which enables agility and flexibility even in large, possible distributed projects. Results from FLEXI in the area of development process are in PROGRESS combined with the component-based approach.

GENIUS – Gender aspects in collaborative research and development projects. The planning phase of project has been funded by Vinnova and the project will start in July 2008. The aim is to, by using gender theory; analyze what happens in the process of formulating and implementing research projects in applied technical research, especially in collaboration with industry and society. One aim is also to increase the gender awareness amongst researchers from both academy and industry but also to enable a change in action and an integration of gender aspects when formulating research projects within MRTC.

Relation to PROGRESS: GENIUS is targeting gender awareness and improved gender balance in PROGRESS.

Hi5 – A Holistic and Improved Infrastructure for Increased Industrial Impact of research – a complementary structure for the industrial research schools managed by MRTC. Hi5 contains three innovative intruments for further development of cooperation between MRTC and industry. The project is funded by Vinnova, ABB, CC Systems, Ericsson, Prevas and Volvo CE.

Relation to PROGRESS: The purpose of Hi5 is to increase excellence and industrial relevance. Hi5 provides PROGRESS with means for better recruitments and closer relations to industry.

HISCORE – A four-year VR project aiming at developing and generalizing hierarchical scheduling frameworks allowing for semi-independent subsystems, thus making hierarchical scheduling frameworks suitable for deployment in complex (real) architectures, such as those encountered in the automation, telecom, and vehicular domains.

Relation to PROGRESS: This project directly complements the legacy runtime activities in the componentization of legacy research direction of PROGRESS.

KISEK – An EU Tempus project with the aim to establish infrastructures in Croatia for cooperation in education and research within the field of software engineering. The project is coordinated by the University of Paderborn and MDH participates together with the Croatian universities of Zagreb, Split and Osijek as well as several companies including Ericsson Croatia and ABB.

Relation to PROGRESS: KISEK expands the international network and increases dissemination.

ISE – Industrial Software Engineering Master Program. The goal of the project is to develop a set of master programs in software engineering in cooperation with industry.

Relation to PROGRESS: Increasing industrial relevance. The aim is to build up a program that is close to industrial needs.

MOMENT – MOnitoring and MeasuremENT – is an EU FP7 STREP project concerning monitoring and measurement of large networks. The aim is to create a common platform for monitoring and measurement, building on the results of several EU FP6 projects. Swedish partners in MOMENT are Ericsson Research and SICS AB. MDH is in MOMENT acting as the equivalent of a subcontractor to SICS. In the table above, the MDH resources are roughly estimated as half of the resources allocated to SICS in MOMENT.

Relation to PROGRESS: The common platform for measurement and monitoring created in MOMENT can be used directly in distributed PROGRESS platforms where network performance should or must be controlled.

MultEx – The MultEx project studies how software development processes for embedded real-time control systems can be made more efficient, with respect to development time, achieved software quality and hardware utilization. MultEx is a cooperation between Arcticus Systems, Volvo Construction Equipment, and MDH.

Relation to PROGRESS: In MultEx we have developed a limited version of the ProSave component model together with the Swedish tool vendor Arcticus. Since the component model is limited we have been able to incorporate it in the existing tool-suite Rubus ICE where also advanced timing and memory analysis techniques from PROGRESS has been included.

Open Innovation in the development of Complex Industrial Systems – Aims at developing a conceptual tool-box including methods for introducing "open innovation" in the development process of complex industrial systems. This project is fully funded by industry and conducted in close cooperation with several companies who all develop complex industrial systems within telecommunications, automotive and automation.

Relation to PROGRESS: The main challenge is what, and how, to open up the currently closed development process and architecture, and to balance the needs for intellectual property management, quality control, and openness. From an architectural point of view this project is strongly related PROGRESS.

PASAS – Prioritizing Business Goals and System Quality Attributes in Software Architecture Solutions – The objective of this project is to develop a method for analyzing the stakeholders' concerns systematic and for prioritizing business goals and system quality attributes for the achievement of a software architecture where the stakeholders' concerns are satisfied. The project is a collaboration project between ABB and MDH and supported by KKS via the industrial research school RAP.

Relation to PROGRESS: PASAS provides complementary views on architecture and component models from the requirements perspective that are of value to PROGRESS.

PIFF – Improving management of master theses in the area of software engineering. After Bologna systems the fifth year of education offers master theses to students. The project develops methods and builds up experience how to define and supervise the master thesis which is closer to research, or to industry.

Relation to PROGRESS: Increasing educational excellence and relevance.

PLEX – an in-house language at Ericsson for programming AXE telephone exchanges. Project purpose is to prepare for efficient parallel execution in the future parallel AXE processor.

Relation to PROGRESS: PLEX software is structured into blocks, which really are components. Thus, research on parallelization of PLEX is likely to be relevant also for other component-based systems.

Q-IMPRESS – Quality Impact Prediction for Evolving Service-oriented Software – A medium-sized focused research project (STREP) funded under the EU FP7. The project aims to bring service orientation to critical application domains, such as industrial production control, telecommunication and critical enterprise applications, where guaranteed end-to-end quality of service is particularly important.

Relation to PROGRESS: The PROGRESS component model is used in Q-Impress as one of the models on which quality analysis will be performed. Q-Impress is similar to PROGRESS as it aims for predictability for quality attributes. The difference is that the quality attributes are related to service-oriented systems. PROGRESS will benefit from Q-Impress as it can include results from Q-Impress. Q-Impress is also an excellent mean for building up networking and dissemination.

RT Media Editing – A research project aimed to support effective and quick browsing of multimedia content over network through full Video Cassette Recording (VCR) functionality in applications such as Video-On-Demand systems and video editing programs. KKS funded project with an industrial PhD student co-supervised by MDH and Ardendo, Sweden (industrial partner).

Relation to PROGRESS: No direct link to PROGRESS, though related scheduling techniques are used.

SAVE – Component-based design for safety-critical vehicular systems – Cooperation with KTH, Uppsala University, and Linköping University. The project includes development of an initial component model for Embedded Computer Software Systems (ESW).

Relation to PROGRESS: SAVE is a predecessor of PROGRESS – many results from SAVE, such as the Save component model and timing analysis have been included into PROGRESS as staring points.

SAVE-IT – An industrial graduate school, scientifically linked to SAVE with a research focus upon real-time- and safety-critical systems. The school, which contains 21 PhD students, is funded by KKS and coordinated by MDH. Additional partners include Linköping University (IDA/RTSLAB), KTH (DAMEK), Uppsala University (IT/UppAal), and currently the following industries: ABB Research, ABB/Robotics, Bombardier Transportation, Ericsson, Saab, and Volvo CEC.

Relation to PROGRESS: Several of the PhD-projects within SAVE-IT are highly relevant for PROGRESS, and SAVE-IT brings additional and strengthens existing industrial and academic networks.

SICS CNS – SICS Center for Networked Systems – The aim of this project is to create an internationally leading center of knowledge in the area of Networked Systems. The project is funded by Vinnova, SSF and the KK foundation.

Relation to PROGRESS: MDH participates in CNS mainly in the area of network performance prediction, an area that contributes to the ability in PROGRESS to incorporate distributed platforms.

SISTER – An EU Tempus project with the aim to establish infrastructures in Bulgaria for cooperation regarding education and research within the field of software engineering. The project is coordinated by the University of Sofia and MDH participates together with several other EU universities.

Relation to PROGRESS: Dissemination, recruitments, and outsourcing of development of parts of the PROGRESS IDE.

SWELL – Swedish software Verification & Validation ExceLLence – a Swedish top-level research school in the area of Software Verification and Validation funded by Vinnova. MDH is one of four nodes together with Blekinge Institute of Technology, Lund University and the IT University in Göteborg.

Relation to PROGRESS: Dissemination and increase of excellence in research education of the PROGRESS research centre.

SW-Release – The aim of the project is to develop a framework, presumable extending existing research in the area, which helps define a release plan, including architectural modifications, resulting in lowered production costs while at the same time keeping customer satisfaction at an acceptable level. The project is a collaboration project between ABB and MDH and supported by KKS via the industrial research school RAP.

Relation to PROGRESS: Release planning is an important life-cycle process activity of relevance for the PROGRESS process activities.

WCET – The project concerns automatic flow analysis for safe execution time estimations, and involves evaluation of analysis techniques of code from the industrial partners Arcticus, CC-Systems, and IAR.

Relation to PROGRESS: Relates directly to the efforts in the PROGRESS predictability assurance research direction on timing analysis.

Funding expired 2006-2007

ARTES – A national Swedish strategic research initiative in Real-Time Systems. ARTES forms a network of academic and industrial groups, with the ambition to strengthen the Real-Time Systems competence nationwide. Main focus is on graduate education and cooperation between industry and academia.

Relation to PROGRESS: Supplies PROGRESS with a network to Swedish academy and industry in the area of real-time and embedded systems research and development.

ARTIST2/**ARTIST2-JPASE** – An EU FP6 Network of Excellence with around 40 partners, collecting the main European research expertise in embedded and real-time systems.

Relation to PROGRESS: The development of a common European timing analysis platform is of relevance for PROGRESS.

BETSY – An EU project focusing on handling of multimedia streams on wireless hand-held devices seamlessly adapted to fluctuating network conditions and available terminal resources while reducing the energy consumption of the stream processing. EU-project with partners: IMEC, Belgium, University of Cyprus, Cyprus, C-LAB, Germany, Universität Stuttgart, Germany, Industrial System Institute, Greece, Philips Research, Netherlands, Technische Universiteit Eindhoven, Netherlands CSEM, Suisse.

Relation to PROGRESS: The research proposed in the PEACE project will be partially based on adaptation mechanisms and trade-off analysis techniques developed in BETSY.

DRIVE – A collaboration project between Volvo CE and MRTC, with focus on providing guidance for design of architecture, selection of technology and methods for designing automotive on-board electronics.

Relation to PROGRESS: The study of supplier and OEM relationship with respect to integration of mechatronic components has provided important domain insights.

EvaluNet 1/EvaluNet 2 – Projects focused on methods for traffic characterization in data communication networks.

Relation to PROGRESS: The BART tool, developed in the EvaluNet projects, is able to predict network performance in real time. BART is an input to BARTAP and SICS CNS (see above), and can also be utilised directly in PROGRESS distributed implementations where network performance need to be assessed.

Softin – Aiming to increase the competence in software development and maintenance at participating regional companies. Based on studies of current state-of-art and state-of-practice, improvements in development processes for regional SMEs have been proposed and their deployment supported.

Relation to PROGRESS: Provides channels for dissemination of research results.

Testing of Real-Time Systems - Theory and Tool – A three year VR project aiming for development of theory and tools for validation and verification of real-time and embedded systems by testing. The project resulted in a new formal technique and a tool for model-based testing, including a formal specification language for coverage criteria, techniques for automated test-case generation for real-time systems, automatic synthesis of executable test programs, and the testing tool UPPAAL Cover (www.uppaal.org/cover).

Relation to PROGRESS: Results of this project will be applied and further developed in the proposed testing project MB-Test, which aims at developing model-based testing techniques and tools for the PROGRESS component model.