ARTES

Stiftelsen för strategisk forskning

Programme Plan

1998-2002

for

Approved by the ARTES board of directors April 21, 1998

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Preface

The ARTES national network officially started in January 1998, after almost three years of planning. The network has its roots in the Swedish National Association for Real-Time (SNART), which is an association formed in the early 90's to promote real-time systems research and related industry-academia cooperation. The launching of ARTES has been performed in a true SNART-spirit as a process with active involvement of both industry and academia.

Up-until-now, ARTES has sponsored three graduate courses, all given in a distributed fashion with participants from several universities and industry. Also, support for three projects, involving four graduate students has been decided. Additional graduate courses as well as research projects will be initiated during 1998. The purpose of this programme plan is to outline the activities and focus of ARTES during the years 1998–2002.

In addition to ARTES, the programme plan also covers PAMP which is an associated programme that is managed by ARTES. The administrative provisions for handling PAMP is included in this plan, whereas the PAMP research plan is provided separately in Appendix D.

This plan was approved by the ARTES board of directors April 21, 1998.

Bengt Asker
Chairman of the Board

Hans Hansson
Programme Director

Executive Summary

The Swedish Foundation for Strategic Research (Stiftelsen för Strategisk Forskning; SSF) has established the national research programme ARTES (A network for Real-Time research and graduate Education in Sweden). This programme plan presents ARTES activities and goals for the first five year period: 1998-2002. Additionally, a programme plan for the associated programme PAMP (Symmetric Multiprocessors in High-Performance Real-Time Applications) is provided in Appendix D. The PAMP research projects will be treated separately, whereas the PAMP graduate school will be integrated with ARTES. The PAMP administration and relation to ARTES is presented in the main sections of this plan.

ARTES is dedicated to Real-Time Systems research, which is multidisciplinary in that it (at least) includes aspects of Automatic Control, Computer Science, Computer Engineering and Electrical Engineering. There is also a multitude of application areas for Real-Time Systems, ranging from embedded micromechanical systems to world-wide communication systems. The area is of paramount importance to Swedish industry, since many Swedish companies are designing and manufacturing products with real-time systems as vital components.

Several of the strategic research centres supported by SSF (e.g., Computing & Communication Systems, Autonomous Systems, and the Excellence Center in Computer Science and Systems Engineering) have strong real-time orientations. The ARTES national network will complement these and other local programmes as well as strengthen Swedish real-time research in general by strengthening graduate education and providing an infrastructure for national and international cooperation.

The research in the ARTES programme is guided by the following twofold vision:

For the network:

To transfer knowledge and competence to Swedish industry that will allow it to first utilise the latest achievements in real time systems design.

Specifically for the research projects:

To reduce lead times for designing and modifying real time systems by an order of magnitude by year 2005.

Research in component based design together with a network for intense interactions between academic and industrial groups will be instrumental in fulfilling the above vision.

ARTES will be organised as a network of nodes, where each node typically is an academic or industrial research/development group. Presently, ARTES consists of 21 industrial and 11 academic nodes, encompassing more than 40 senior researchers (including 14 professors). The current annual budget for real-time systems related research and graduate education at the academic nodes is in the order of MSEK 60/year. During the planning period this budget is expected to increase to more than MSEK 90/year, partly due to ARTES, but also due to expected increase in funding from other sources.

ARTES will play an important role in coordinating the total educational, research and transfer of technology effort in the real-time systems area, thus guaranteeing synergetic effects among the various efforts, thereby maximising the total yield and nationwide substantially increase the real-time competence.

The goals of ARTES are

- to increase the number of PhDs and Licentiates which play important roles in development of industrial real-time applications and products,

- to increase the efficiency of graduate education,
- active industrial involvement in research and graduate education, as well as academic involvement in industry,
- to maximise synergy between the real-time components in strategic centers supported by SSF, as well as with other efforts in the area,
- to increase national and international cooperation in real-time systems research and education, and
- to provide a broad base for Swedish real-time systems research, and to make Swedish real-time systems research world leading in selected areas.

To reach these goals ARTES has the following four activities on its programme:

Research Projects involving cooperation between industrial and academic network nodes. The projects should tie together research/development at different nodes to maximise synergy, but also concentrate efforts on areas of current and potential high industrial interest. ARTES (including PAMP) plans to finance the graduate studies for 43 students, of which 36 are expected to complete a PhD by 2005.

The ARTES graduate school which is concentrate on nationally providing graduate courses and proposing curricula for real-time related graduate education. A special effort is the annual ARTES *summer school*, which will be both a traditional academic summer school with tutorials and a meeting place for academic and industrial nodes, where projects, other cooperations and general issues are discussed.

A Mobility Programme to increase interaction between industrial and academic network nodes, as well as with internationally leading research groups.

Infrastructure Support to provide information and establishing various types of cooperations involving ARTES nodes, such as support to workshops and establishment of international cooperation.

The below table summarises the budget related to the SSF support for ARTES/PAMP (A/P) during the planning period 1998–2002. It should be noted that the reason for the relative high administrative cost for 1998 is that costs from the actual start of the programme in July 1997 are included.

(MSEK)	1998		1999		2000		2001		2002		Total	
Funding	A	P	A	P	A	P	A	P	A	P	A	P
SSF	5.0	2.0	10.0	4.0	15.0	5.0	15.0	5.0	15.0	5.0	60.0	21.0

Costs	A	P	A	P	A	P	A	P	A	P	A	P
Projects	2.1	1.2	5.8	3.6	9.8	3.7	11.6	3.4	10.4	2.6	39.7	14.5
Grad. Scool	0.8		1.1		1.4		1.9		1.9		7.1	
Mobility	0.4		0.7		0.8		0.8		0.8		3.5	
Infrastructure	0.4		0.6		0.7		0.8		0.8		3.3	
Adm.	1.5		1.1		1.1		1.1		1.1		5.9	
VAT (8%)	0.6		1.1		1.6		1.6		1.6		6.5	
Total	7.0		14.0		19.1		21.2		19.2		80.5	
Funding–Costs	0.0		0.0		0.9		-1.2		0.8		0.5	

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1 Introduction

Real-time systems is an IT area of high relevance for current and emerging Swedish industry. The aim of the ARTES programme is to provide Swedish industry with competence and qualified personnel in this important area by focusing and developing Swedish real-time systems research and graduate education. This is to allow Swedish industry not only to stay competitive, but also to strengthen its competitiveness.

1.1 Real-Time Systems

In many applications, computer systems sense their environment and directly influence it through actions. Such systems are subject to the real-time constraints of the environments in which they operate. For example, an autonomous vehicle needs a control system that responds quickly enough to avoid collisions. This requirement for timely behaviour is the defining characteristic for *real-time systems*. Real-time systems must not only choose appropriate actions but also choose actions at appropriate times. Research in real-time systems addresses precisely this issue by developing methods for guaranteeing timely reaction. Real-time computing is not about building "fast" systems; it is about building systems predictably "fast enough" to act on their environments in well-specified ways.

Real-time systems provide an enabling technology for many important application areas, including: multimedia, telecommunications, robotics, process control, flexible manufacturing, avionics, vehicular systems, air-traffic control, nuclear power plants, medical equipment, and defence applications. In particular, almost all safety-critical systems are real-time systems. ARTES will serve to produce generic results and qualified personnel required in development of all these important applications. The benefits are likely to be immense since the results are potentially usable by so many industries critical to the Swedish economy.

Real-time computing is playing a key role in many sectors of Swedish industry. For instance, the automotive manufacturers can only stay competitive if they incorporate state-of-the-art real-time systems into their vehicles. In the future, distributed real-time control systems will replace and enhance many of the conventional control systems in automobiles, making them more efficient and improving public safety. Before distributed real-time systems can be used there are a number of significant research challenges that must be addressed, e.g. precise real-time response (to the microsecond), fault tolerance under strict timing requirements, maintainability, and testability, all under competitive pricing pressure. ARTES will facilitate the development and transition of current real-time technology in this and other application domains. In particular, the catalytic effects on graduate (and undergraduate) education will help industry solve the critical problem of finding qualified personnel.

1.2 Real-Time Systems Research

Real-Time Systems is a multidisciplinary research area, in that it includes (at least) aspects of Automatic Control, Computer Science, Computer Engineering and Electrical Engineering. There is also a multitude of application areas for Real-Time Systems, ranging from embedded micromechanical systems to world-wide communication systems.

2 The ARTES Vision

The research in the ARTES programme is guided by the following twofold vision:

For the network:

To transfer knowledge and competence to Swedish industry that will allow it to first utilise the latest achievements in real time systems design.

Specifically for the research projects:

To reduce lead times for designing and modifying real time systems by an order of magnitude by year 2005.

Research in component based design together with a network for intense interactions between academic and industrial groups will be instrumental in fulfilling the above vision.

It should be noted that, even though the above specific vision is focussed on the timing dimension of real-time systems development (speeding up the development and modification processes), we consider it to also implicitly cover other dimensions, such as

- **the quality/correctness dimension** with its focus on improving the quality of the design and the confidence in the correctness of the designed component/product. A plausible vision in this dimension is *provably correct designs*, meaning mathematical proofs of all relevant aspects of the design, including proving that requirements related to behaviour, timing and reliability of the designed component/product are met.
- **the size dimension** with its focus on handling systems substantially larger than current real-time systems. A possible vision in this dimension is to be able to conveniently design systems that are an order of magnitude larger the systems we are designing today.

One important basis for the ARTES vision is that most industrial real-time systems are built from components of various origin. It is not feasible to build a reasonably sized system with exclusively tailor made components. Some will be purchased, some will be inherited from existing systems, and they will not always make a perfect fit. Hence, industry has an urgent need for a better scientific foundation on how to develop this type of heterogeneous real-time systems.

This leads to a profile for ARTES with emphasis on a building block approach for designing real-time systems. The main problems typically arise in the early and late development phases, i.e. design and integration, respectively. Some relevant questions are:

- How to specify and design a heterogeneous real-time system?
- How to evaluate an early design architecture for a real-time system?
- What is required for the system to be able to grow and change?
- What are the implication for processes, methods and tools for real-time systems?

These problems are not unique for real-time systems, but solutions that are sufficient for other systems may not apply when requirements related to timing guarantees, predictability, availability and reliability are added. Specific aspects/topics that are important to consider include (but are not limited to):

- **Dependability**, which is a key issue in any computer/communication system that controls a critical application. Safety levels of 10^{-10} to 10^{-8} catastrophic failures per hour is often required. Dependability of that order can only be achieved by careful use of methods for errorless design in combination with tolerance and robustness against different types of hardware and software faults. Important research areas include: methods for fault detection, dependability in distributed systems, software fault-tolerance, and dependability validation.

- **Formal methods** are the use of mathematical techniques in the design and analysis of computer hardware and software. Formal methods allow properties of a computer system to be predicted from a mathematical model of the system by calculation. Application areas and research issues of formal methods include: execution-time analysis, schedulability analysis, specification of system requirements and behaviours, automatic code-generation, as well as verification of safety, real-time, and reliability properties.
- **Resource handling** concerns efficient handling of computer system resources to provide progress and proper sharing such that the system requirements are met. This problem is especially difficult for real-time systems, since by sharing (otherwise) unrelated processes may interfere such that their real-time requirements are violated. Resource handling includes both allocation (placement in space) and scheduling (sharing in time). Important research issues include: schedulability analysis, dynamic allocation and load-balancing, handling of overloaded situations, execution-time analysis, distributed and parallel system scheduling and allocation, taking control information into account, operating system support for predictable scheduling and allocation, as well as tool and language issues.
- **Distributed systems** are loosely coupled multicomputer system, geographically as well as logically distributed. A distributed real time system is complicated by the latency in communication, the need for distributed synchronisation, concurrent execution and that some computers may fail during normal operation. Central research in the area focus on how to make a distributed system predictable in the time domain under these complications. This involves both handling soft Quality of Service (QoS) type of requirements and strict hard requirements. Research fields and issues include: real-time and predictable communication systems, distributed scheduling, real-time platforms, dependability and fault-tolerance, formal methods, as well as programming systems for expressing distribution, concurrency, and real time requirements.
- **Real-time databases** are database management systems which in addition to performing normal database functions are required to provide their responses in a timely manner. It is required that the system allows accurate estimates on the average and worst-case time taken to execute queries and operations. Due to the unpredictable behaviour of most database systems, real-time databases are often seen as only suitable in systems with soft real-time requirements. Research issues include: development of database systems that can be used also in systems with a mixture of soft and hard real-time requirements, handling of temporary overloads, increasing predictability (e.g., by distribution and replication), temporal databases for storing values and times, as well as active databases capable of taking actions in response to modifications of data.
- **Implementation of control systems** is the dominating application area for real-time technology. Real-time systems and control has developed into a recognised sub-field of automatic control. Application areas include industrial control systems for the process, manufacturing and power industry, embedded mechatronic systems, vehicular systems and aerospace systems. Research areas and issues include: distributed control systems, scheduling, operating systems and platforms, real-time languages, control that is robust against timing variations, models with both continuous and discrete elements, code generation from high-level specifications, as well as hardware and software architectures that support embedded open and yet efficient control system implementations.

3 Objectives

The objective of ARTES is to substantially increase the Swedish competence in real-time systems by strengthening real-time systems graduate education and research. The graduate students

should acquire knowledge in the multitude of aspects of real-time systems, including both theoretical and practical aspects, as well as skills in applying this knowledge in industrial type projects.

The specific goals of ARTES are

- to increase the number of PhDs and Licentiates which play important roles in development of industrial real-time applications and products. Concretely, the long term goal is 50 graduate degrees per year in ARTES related areas (current level is about 20 degrees per year), and that at least 80% of the graduates start an industrial career.
- to increase the efficiency of graduate education. The goal is that no ARTES graduate student should have a study-time exceeding the nominal times of 2 years for a licentiate and 4 years for a PhD (compensating for departmental duties and periods of industrial work).
- active industrial involvement in research and graduate education, as well as academic involvement in industry. Concretely, each ARTES supported project should have at least one active cooperation activity, e.g., in the form of an industrial engineer participating in the project, or a graduate student performing parts of his/her research in industry.
- to maximise synergy between the real-time components in strategic centers supported by SSF, as well as with other efforts in the area. Concretely, at least 50% of the ARTES supported projects should have a formalised or informal cooperation (e.g., in terms of joint papers) with related national programmes.
- to increase national and international cooperation in real-time systems research and education, and
- to provide a broad base for Swedish real-time systems research, and to make Swedish real-time systems research world leading in selected areas.

4 Impact

There is a substantial amount of real-time related research already in progress in Sweden, frequently involving close industrial cooperation (e.g., the initial ARTES application listed 150 active cooperations). However, these activities are only to a limited degree coordinated and their impact on graduate and undergraduate education is not matching the industrial demand for qualified personnel.

ARTES will be instrumental in achieving the necessary coordination between ongoing and planned real-time systems efforts, thereby achieving synergy which substantially increases the total yield. In particular, ARTES is focussed on coordinating graduate education, to provide industry with personnel qualified for the advanced technical development that will be required on the competitive markets of tomorrow.

The ARTES supported graduate education will be attractive to a wide group of students, not only to those that are primarily interested in academic research. Students interested in industrial careers will be attracted by the focus on industrial cooperation and industrially relevant research, together with the support and mechanisms provided for students to complete their graduate studies in time.

The coordination mechanism implemented by ARTES will give an outstanding platform for the ambition to identify uncovered research areas of strategic importance and accordingly establish

activities in these areas. The ARTES vision and profile will act as a basis for guiding and identifying required research.

ARTES also has a potential to be instrumental in the establishment of new industries. For instance, based on the yearly review of ongoing research, ARTES will identify research results which are commercially promising, and then assist in establishing contacts between the researchers and the appropriate financiers, industrialists and entrepreneurs to facilitate the creation of new ventures in the real-time systems area.

5 The ARTES Programme

ARTES is a network of nodes. As such, the main objective of ARTES is to play a catalytic role in stimulating cooperation. To ensure this, all ARTES activities are required to involve at least two nodes.

The ARTES programme is partitioned into the following four interrelated and mutually supportive sub-programmes:

1. Research Projects
2. The ARTES Graduate School
3. The ARTES Mobility Programme
4. Infrastructure support

5.1 Research Projects

An ARTES research project requires cooperation between individuals from different nodes, with the important objective to maximise synergy between local activities. Equally important is to provide relevant research problems and environments for graduate students.

A typical project includes at least one industry and several academic nodes. It typically considers several research areas, but is focussed on one application area. Preferably, the project applies research results to real industrial problems, or develops results conforming to industrial requirements.

The main evaluation criteria for a project are:

- The industrial relevance
- Its academic qualities
- How well it supports the ARTES vision and current profile
- The synergy it provides
- The degree of research cooperation with other SSF funded research programmes

The profile, which will develop as the network evolves, is an important mechanism for guiding and focussing the research to keep up with (and take a lead in) national and international industrial and academic developments.

5.1.1 Project requirements

An ARTES research project involves at least two ARTES nodes (where a node should be interpreted as a group active in the real-time systems area) of which at least one is industrial and at least one is academic. The industrial participation can take various forms, the major point being that the research is guaranteed to be industrially relevant and that exploitation possibilities are handled timely and effectively. Examples of industrial participation are:

- providing case studies and requirements,
- forming reference groups,
- active research work,
- providing equipment, and
- direct financing.

Projects are planned for 2 or 2+2 years, corresponding to the timing of licentiate and doctoral degrees. Since all projects are true collaborative efforts special emphasis is to be put on project leadership and organisation.

Project support is provided in *graduate student units*, one unit corresponding to the annual (marginal) cost for one full time graduate student including supervision, currently kSEK 500.

In order to consent to the 20-25% department duty rule for doctoral students at most universities the project application and later plans may include a time schedule taking department duty into account. This implies up to six months of delay per two year period.

All projects are presented annually to the ARTES network at the ARTES summer school and/or ARTES/SNART conference. All projects provide continuously updated project descriptions on the web.

5.1.2 Evaluation of Projects

Project applications are, as the general rule, evaluated by external experts and the ARTES board. In addition, there is a yearly review of projects and control points as outlined in Appendix A.

The following criteria are used in the evaluation of both the application and the results:

- scientific merits,
- industrial relevance, experience, participation and synergy,
- conformity with the ARTES vision and the real-time profile of the current call,
- mobility; both academia/industry and international,
- amount of interdisciplinary research,
- degree of research cooperation with other SSF funded research programmes,
- exploitation expectations,
- complementary activities and financing, critical mass,
- project management,

- multi node publications,
- case studies, application of research results,
- quality of presentations, and
- matching of objectives and resources.

The evaluation of a project application may result in approval, rejection or reformulation by the ARTES board. The latter meaning that the applicants are asked to reformulate their application. This is one of the ways in which the ARTES board can coordinate, synchronise and optimise activities within the network.

The process for ARTES projects is described in Appendix A.

5.1.3 Current projects

As a result of the first call for project proposals (with a November 10^{th} 1997 deadline) support to the following three projects have been decided:

- *Integrated Control and Scheduling*
  Supported with 2 graduate student units (initially for 2 years).
  Project leader: Karl-Erik Årzén, Control Engineering, LTH.

  This project is a cooperation between Automatic Control and Computer Science at Lund Institute of Technology, Sigma Exallon Systems AB, DDA Consulting AB, and Software Engineering Institute at Carnegie Mellon University.

  The focus of the project is practical management of hard real-time demands in embedded software for real-time control. The project is based on two key ideas. The first idea is to combine control theory and scheduling theory in such a way that the nominal requirements on hard deadlines for control systems can be relieved. The approach taken is based on using dynamic feedback from the scheduler to the controllers and from the controllers to the scheduler. The second, complementary, idea is to use attribute grammars and incremental semantic analysis to carry out on-line interactive analysis of the worst-case timing of the software and generation of exception handling code for coping with unexpected delays. Combining these ideas forms a more complete and practical methodology than available today. The results will be packaged in tools that can be evaluated in industrial applications by the industrial partners.

- *Hardware Software Co-design*
  Supported with 1 graduate student unit (initially for 2 years).
  Project leader: Zebo Peng, Computer and Information Science Linköping University.

  This is a project which is carried out at the Embedded Systems Laboratory (ESLAB), Linköping University. The project deals with system-level design methods and tools for mixed hardware/software systems, with special emphasis on real-time issues. Methods and tools for analysis of a given design based on a given architecture will be developed, as will methods for modifying a given architecture to obtain an optimal design of the system specification. The final objective is to develop techniques and tools to allow the designers to quickly explore different design alternatives and find cost-effective solutions of mixed hardware/software implementations.

  The project will be performed in close cooperation with industry, including Saab Dynamics AB, Saab AB and Volvo Technological Development.

- *Incremental Static Scheduling*
  Supported with 1 graduate student unit (initially for 2 years).
  Project leader: Gerhard Fohler, Computer Engineering, Mälardalen university

  This is a project performed at the Centre for Real-Time Systems at Mälardalen university college. The goal is to develop methods and interactive tools that allow incremental extension of existing trusted schedules. By this modular construction of schedules, component-based design and design modifications are facilitated, since adding or modifying tasks will not require reconstruction of the entire schedule.

  The project is performed in cooperation with Volvo Construction Equipment Components.

5.2 The ARTES Graduate School

The purpose and ambition of the ARTES graduate school is twofold

- To offer a sufficient number of graduate courses nationwide to allow graduate student at all participating nodes to compose individual study programmes that will enable them to complete their graduate courses in 1-2 years, and

- To provide graduate students with industrially relevant and scientifically challenging theses topics, to be worked upon under competent supervision in stimulating academic and/or industrial environments.

It is worth pointing out that an additional important (but secondary) effect of the proposed concentrated graduate education effort will be that the real-time component in undergraduate education will be substantially strengthened. The reson for this is both that the interest, competence and awareness of the area will increase at universities, and that introductory graduate courses are expected to evolve into advanced uhndergraduate courses.

The graduate school will not be formally organised as a separate entity. Instead it will be built on increased utilisation and coordination of local courses offered, including those created through local graduate schools in related programmes supported by SSF. The obtained leverage will both increase quality in local programmes and improve cost effectiveness.

5.2.1 The Real-Time Graduate Student Network

An important task of the ARTES graduate school is to support interaction among graduate students and provide meeting places (e.g., the summer school) for discussions. To this end a *graduate student network* is formed. This network will be instrumental in strengthening the national real-time community, thereby providing a basis for continued long-term development in the real-time area. The network is built by admitting *Real-Time graduate students*.

A Real-Time graduate student is a PhD or licentiate student at a Swedish university which has applied to and been accepted by ARTES. The thesis subject of a Real-time graduate student is typically computer science, computer engineering, computer systems, industrial control systems, mechatronics, or automatic control. The thesis topic will be assessed by ARTES to have a strong connection to the real-time area. It is also expected that Real-time graduate students shall be well motivated to work in cooperation with industry during the education and have an ambition to work in industry after the education.

A Real-Time graduate student will have the possibility to be financially supported by ARTES by, for example, grants for travel and other purposes, and the possibility to be funded via ARTES-projects. He or she will also have priority admittance to ARTES-courses and other

common activities within ARTES. Thirdly, by being a Real-time graduate student, special supervision support can be arranged in an interdisciplinary way using the ARTES network

Acceptance to be an Real-Time graduate student is only possible if the candidate already has been admitted to a local licentiate or PhD programme at a Swedish university. Applications to and possible exclusions from being a Real-time graduate student within ARTES are handled by the ARTES board.

5.2.2 Real-Time Curricula

Graduate Education in ARTES is distributed on several traditional subjects - like automatic control, computer engineering or computer science. It is important that ARTES in connection with the Graduate School establishes areas of competence for real-time system professionals. This will simplify the recruitment of people in industry and the selection of subject areas/projects for academic research.

Establishing real-time curricula by describing competence areas will give a contributing support for the research and educational plans of graduate students in the real-time area

A final goal is to establish real-time systems as a new subject area at university level.

5.3 The ARTES summer school

A special and very important effort in establishing and maintaining the ARTES network will be the annual ARTES *summer school*. The summer school is not only a traditional academic summer school with tutorials given by internationally leading scientists, but it also provides a natural meeting place for academic and industrial nodes, where current and emerging ARTES projects and other cooperations are discussed, together with general discussions/presentations of issues of common interest, such as industrial needs and requirements. Additionally, representatives from related SSF-programmes are invited to discuss cooperation and other issues of mutual interest. The summer school will also provide opportunities for venture capitalists and start-up experts to discuss commercialisations with researchers and industrial partners.

In August 1997 ARTES organised the *Real-Time week* in cooperation with SNART. The programme for this week consisted of a one day tutorial introduction to real-time systems and research by Prof. Jack Stankovic, the *ARTES kick-off* which was a one day presentation/discussion of ARTES, and the two day bi-annual SNART symposium. The RT-week was quite successful, in that close to 200 persons attended (almost 50% from industry).

The first real ARTES summer school will take place outside Stockholm, August 17-21, 1998. The programme includes, in addition to presentations/discussions of the ARTES programme, three tutorial introductions (on reliability theory, formal methods, and real-time and control), together with presentation/discussions of the ARTES projects and PAMP, as well as discussions on industrial problems and issues. Also, representatives of related SSF programmes will be invited to present their programmes and discuss possible cooperations.

5.3.1 Supported courses

ARTES supports graduate courses in the area of real-time systems. The courses should be organised in a form which simplifies national participation. Four courses have been supported so far within ARTES:

1. *Design of Software for Embedded Real-time Control Systems* (KTH), December 1997 - February 1998.

2. *Distributed Real-Time Systems* (HIS), September 1997 - January 1998.
3. *Modelling and Analysis of Real-Time Systems* (UU), November 1997 - February 1998
4. *Hardware/Software Co-design* (LiTH), Starts March 25, 1998

In these courses we have used different means to allow participation from geographically distributed nodes. The first course used web-techniques, the second teleconferencing, and the third was concentrated to a few meetings. An evaluation of using these different models for teaching these type of courses is underway.

Current plans for course autumn 1998 include courses on *Multiprocessing* and *Real-Time and Control*.

5.4 The ARTES Mobility Programme

The purpose of the mobility programme is to increase interactions between (industrial and academic) network nodes, as well as with internationally leading research groups. The mobility programme provides grants that facilitate different types of personal mobility, in particular it supports:

- Graduate student mobility
  - Industrial participation in graduate education ("industridoktorander").
  - Graduate student involvement in industrial projects ("doktorandindustrialister")
  - Scholarships for graduate education at internationally leading graduate schools
- Senior researcher mobility
  - To industry. Truly industrially relevant academic research requires leading researchers to have good knowledge and understanding of industrial problems and cultures.
  - To internationally leading research groups
- Academic fellowships (adjoint professorships) for senior industrialists.
- Research fellowships, to allow the invitation of
  - Post docs
  - Visiting professors
- Mobility between nodes, to encourage visits at other nodes.
- Travel grants.

ARTES has decided to give priority to mobility between industry and academia, and to give low priority to individual travel grants (since such support is available in most research projects).

5.4.1 Supported activities

This far, support with kSEK 150 for arranging a seminar and mobility in conjunction with a Nutek supported research project at KTH, Chalmers and LTH has been decided.

5.5 Infrastructure

The infrastructure activities aim at providing information and establishing various types of cooperations involving ARTES nodes, in particular the following is supported:

- Information about ARTES activities, which needs to be spread both within the network and externally. This is achieved by a the Web-site (URL: http::/www.docs.uu.se/artes/), pamphlets, seminars and advertisements. As a special service to industry ARTES will provide a catalogue on current real-time activities and competences, as well as information about students that are about to graduate.
- To allow new nodes to enter the network, and to facilitate interaction with smaller companies, support for the academic part of *feasibility studies* is provided. Such a grant makes an academic available, free of charge for the company, during a shorter period (e.g. a couple of weeks). The feasibility study should typically lead to some concrete cooperation, either within ARTES or in some other form. These grants will motivate new companies to enter the network and substantially facilitate cooperation. This is especially valuable for small and medium sized companies, as they seldom have the resources (or contacts) to consult qualified senior academics/researchers.
- Workshops and conferences, including organisation of an annual ARTES conference. In contrast with the summer school, this conference will have the form of a regular academic conference with paper submissions, reviews etc., but be dedicated to presentations of research results from the ARTES network (and related efforts). All graduate students supported by ARTES are expected to submit papers to this conference. The first ARTES conference is planned for 1999. Additionally, support will be given to workshops on specific topics and international workshops/conferences held in Sweden.
- Establishment of international cooperation. Support will be provided for preparation of cooperation with internationally leading research groups, as well as for initiating international, e.g., within the forthcoming EU Framework 5 programme.

5.5.1 Topical Networks

An important objective of the ARTES network is to extend and strengthen the network itself. This will be done both by extending the size of the network and by forming sub-networks with specific interests in a particular topic.

One such topical sub-network is being formed for the topic *worst-case execution time analysis*. This network currently consists of a research group at DoCS in Uppsala and CUS in Västerås with funding from the Nutek-supported competence center ASTEC, a group at Computer engineering at Chalmers active in the PAMP programme, and the ARTES-supported *integrated control and scheduling* project in Lund. Current plans include to associate leading European and international groups to this topical sub-network.

Additional topical networks, e.g. in the areas of *real-time scheduling* and *real-time and control* are expected to be formed shortly.

6 Milestones

The most important milestones of the ARTES programme are the licentiate and PhD exams that will be completed, as outline in the table below (where A and P denotes ARTES and PAMP, respectively).

	1998		1999		2000		2001		2002		2003		2004		2005		Tot.	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P
Admit. stud.	7	6	10	4	10	0	6	0	0	0	0	0	0	0	0	0	33	10
Stud. in pgm.	7	6	17	10	27	9	31	8	26	6	19	5	12	2	5	0	33	10
Lic. level	0	0	0	1	7	4	8	5	8	0	6	0	4	0	0	0	33	10
PhD exams	0	0	0	0	1	0	3	1	5	1	7	3	6	2	6	1	28	8

For the real-time systems area as a whole, we estimate currently approximately 75 graduate students, 20 licentiate degrees and 10 PhD degrees (1998). Corresponding estimates for 2000 (including the effects of ARTES) are 110, 40 and 20. See also the table on page 16.

Note that even though the table above only indicates the number of students that reach the licentiate level, we expect that most students will complete a licentiate exam., and we assume that approx. 80% of the students continue towards a PhD.

Specific technical milestones are given as an integrated part of the plans for the individual projects.

7 Schedule of Events

The below table presents scheduled ARTES-events, including announcements of call for project proposals.

Date	**Activity**
August 1997	ARTES kick-off meeting in Lund.
November 1997	Deadline for first call for project proposals (CFP).
March 1998	Start of first project.
May 1998	Deadline for first PAMP and second ARTES CFP.
June 1998	Decision related to 1st PAMP and 2nd ARTES CFP.
August 1998	ARTES summer school. Evaluation of first round of graduate courses.
Autumn 1998	Preliminary review/evaluation of ARTES. Graduate course 5-7. Third CFP (second PAMP CFP), including evaluation and decision.
Spring 1999	First ARTES evaluation. First ARTES conference.
Autumn 1999	ARTES summer school (in August). Annual review of project progress. Fourth CFP (third PAMP CFP). First review of ARTES and PAMP.
Spring 2000	Second ARTES conference.
Autumn 2000	ARTES summer school (in August). Annual review of project progress. Fifth CFP (fourth PAMP CFP).
Spring 2001	Second review of ARTES and PAMP. Third ARTES conference.
Autumn 2001	ARTES summer school (in August). Annual review of project progress. Sixth CFP.
Spring 2002	Fourth ARTES conference.
Autumn 2002	ARTES summer school (in August). Annual review of project progress. Seventh CFP. Third review of ARTES and PAMP.

8 Review and Evaluation

To assure and improve quality the ARTES programme, as well as individual ARTES activities, should be evaluated regularly. The following evaluation are planned:

1. A bi-annual evaluation of the entire programme, performed by external experts in cooperation with SSF. A first such evaluation is planned for in January 1999.
2. The research projects will be evaluated as outlined in Section 5.1.2 and Appendix A.
3. The Graduate School, Mobility Programme and Infrastructure Support is, in addition to bi-annual external evaluation, annually evaluated by the ARTES board.

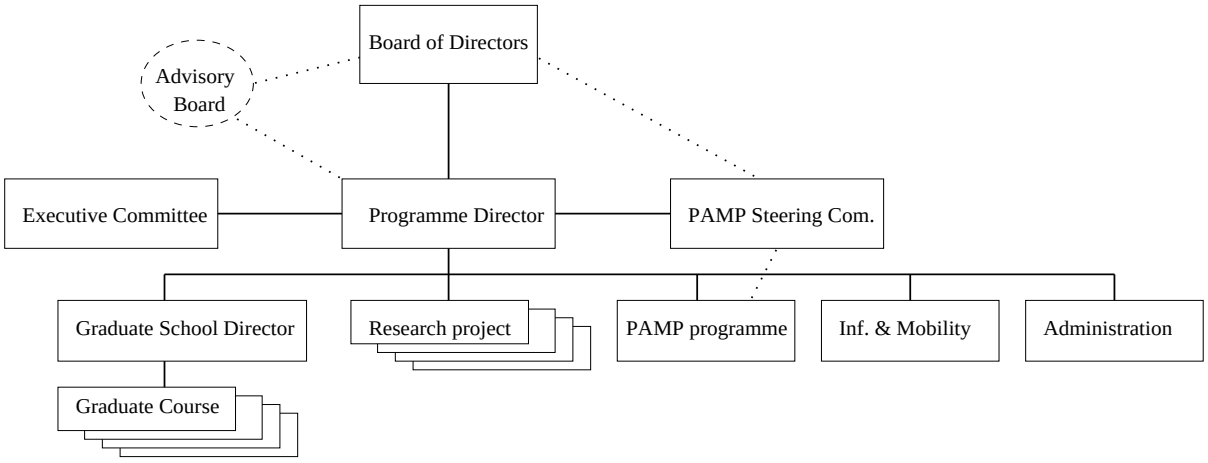
9 Organisation

ARTES has a formal organisation with a programme board etc., but more importantly an informal network of academic and industrial nodes which jointly are engaged in ARTES-projects and other ARTES-activities, as well as other forms of cooperation. The mission of the formal ARTES organisation is to support and encourage the informal network to focus their efforts on real-time systems, thereby reaching the goals of ARTES and striving towards the ARTES-vision.

The following sections present the formal ARTES organisation as well as the informal network.

9.1 The formal ARTES organisation

The ARTES programme is organised in affiliation with Uppsala University as the formal receiver of the SSF funds. A board has the overall authority and responsibility of the programme, while day-to-day operation is delegated to an executive programme director.



Board of directors

The Vice-Chancellor at Uppsala University has in December 1997, after consultation with SSF, appointed the following *board of directors* with responsibility for, and decisive power over, the ARTES programme:

- Bengt Asker, Chairman of the board
- Bertil Emmertz, ABB Industrial Systems

- Kerstin Paulsson, Kockums
- Anders Romare, Volvo
- Jan Torin, Chalmers University of Technology
- Karl Johan Åström, Lund Institute of Technology
- Lars Österberg, ENEA OSE Systems

The task of the board is to

- decide on policies, research programme and activities of ARTES,
- propose *programme director*, appoint *advisory board* and *graduate school director*,
- report annually to SSF about the progress of the programme,
- approve the annual budget of the programme, and
- review the activities and organisation of the programme and take necessary actions.

Programme Director

The task of the *Programme Director* is to

- be responsible for building and maintaining the ARTES network,
- be responsible for marketing the ARTES network, externally as well as internally,
- be responsible for the administration of the programme,
- propose policies and activities to be supported to the board, i.e. it is the responsibility of the director to propose projects, programmes and activities to the board of directors, that will be responsible for making the final decision.
- coordinate and supervise the programme activities,
- review the quality of on-going work and submit material for review.

In February 1998 Hans Hansson (Uppsala University and Mälardalens högskola) was appointed programme director by Uppsala University (in consultation with SSF and by recommendation from the board of directors). However, Hansson has been acting programme director since July 1997. The current engagement (July'97–December'98) is on a 50% activity level.

To assist the programme director in running the programme, the board has appointed an executive committee and a graduate school director. In addition, to handle the associated PAMP programme a steering committee has been appointed.

Executive Committee

The main task of the executive committee is to assist the programme director in planning, preparing proposals and evaluating activities. Members of the ARTES *executive committee* are:

- Bengt Asker, Chairman of the board
- Hans Hansson, Programme Director

- Jan Torin, Chalmers University of Technology
- Anders Törne, Linköping University, Graduate School Director
- Jan Wikander, KTH

Graduate School Director

The board has appointed Anders Törne, Linköping University, as *Graduate School Director*. As such he is responsible for the ARTES graduate school. This includes to

- propose curricula,
- propose and evaluate ARTES courses,
- monitor and evaluate the progress in terms of course work of RT graduate students,
- plan and prepare the Summer school together with the Programme director.

PAMP management

To assist the programme director and board in the management of the associated PAMP programme a steering committee has been appointed. Member of that committee are:

- Bertil Emmertz, chair, representative of the ARTES board.
- Hans Hansson, ARTES programme director.
- Håkan Millroth, PAMP industrial coordinator, Ericsson Telecom.
- Per Stenström, PAMP coordinator, Chalmers.

PAMP will be handled as a relatively independent set of projects managed by the PAMP coordinator. The graduate courses, mobility and infrastructure will however be handled in conjunction with the corresponding ARTES activities.

The main tasks of the PAMP steering committee are

- to be responsible for liaison between PAMP and ARTES,
- to review plans and progress of PAMP projects and activities, and
- to help in disseminating the results from the projects and give scientific advice to the project participants.

To carry out these task, the individual responsibilities of the steering committee are as follows:

The representative of the ARTES board is responsible for reviewing that the projects in PAMP fulfill the general goals of PAMP and ARTES as detailed in this programme plan (including the PAMP programme plan in Appendix D. In particular, an annual progress review will take place to see that project progress coincides with the initial project intentions according to the milestones set out in the project plans. The industrial coordinator is responsible for monitoring the projects so that the industrial goals of the project are fulfilled as specified by the individual research plans. Finally, the coordinator is responsible for monitoring that the scientific goals are fulfilled in terms of quality of the work, Ph.D. student progress etc.

Advisory Board

The initial ARTES application proposed an *Advisory Board* consisting of internationally reputable scientist and experienced (national or international) representatives from industry. The main tasks of this advisory board should be to

- review the scientific quality and industrial relevance of the research and graduate education supported by ARTES, and
- in general be instrumental in the development of ARTES, e.g. by recommending activities to be supported (or cancelled).

A permanent advisory board has not been formed. Instead ARTES has (and will) engage internationally reputable scientist temporarily when need arise (e.g. for evaluation of project proposals, projects and the programme). This far ARTES has used the expertise of Prof. Alan Burns (Univ. of York) and Prof. John Stankovic (Univ. of Virginia). It should also be noted that the members of the board of directors have substantial scientific and industrial experiences.

Administration

It has been decided to have a minimal administration. Initially (during 1997-98), the programme director has a 50% engagement, with a 5% support, mainly to handle payments and bookkeeping. The balance between administrative support and programme director may change in the future, but this will not affect the total cost for the administration.

9.2 The informal ARTES network

The informal ARTES network consists of industrial and academic groups with documented interest in the real-time area. For each such group (or *node* in ARTES terminology) a contact person is identified. The contact persons receives information from ARTES, and are expected to marketing the network into their organisations, as well as being active partners in the development of the network, i.e., by providing input to the planning of ARTES and proposing activities to be supported. ARTES is flexible and open for new nodes to enter the network, thus providing a dynamic structure that can evolve and adapt to meet the demands of its environment.

A presentation of the current academic ARTES nodes are provided in Appendix B. The below table presents the current and estimated number of graduate students in the real-time systems area (including ARTES and PAMP) based on the presentations in Appendix B.

	1998		1999		2000		2001		2002	
	A	P	A	P	A	P	A	P	A	P
Stud. in area	75		90		110		130		150	
Stud. in pgm.	7	6	17	10	27	9	31	8	26	6
Lic. in area	20		30		40		50		60	
Lic. in pgm.	0	0	0	1	7	4	8	5	8	0
PhD in area	10		15		20		25		30	
PhD in pgm.	0	0	0	0	1	0	3	1	5	1

The following are the current industrial ARTES nodes.

Industrial Node	City	Contact person
ABB Research	Västerås/Lund	Bo Johansson
ABB Industrial Systems	Västerås	Bertil Emmertz
Alfa Laval Automation	Malmö	Mikael Meyer
Arcticus Systems AB	Järfälla	Kurt-Lennart Lundbäck
Berifors AB	Bromma	Lena Sundsvik
Carlstedt Research & Technology	Göteborg	Jesper Vasell
Combitech Software	Stockholm etc.	Johan Hellqvist
DDA Consulting	Malmö	Ola Dahl
Diagnostics, Pharmacia AB	Uppsala	Kjell Rosengren
ENEA OSE Systems AB	Täby	Lars Österberg
Ericsson	Stockholm etc.	Anders Nyman
Exallon Systems	Malmö	Göran Lindh
IAR Systems	Uppsala	Olle Landström
Industrilogik	Stockholm	Göran Anger
Kockums Submarine Systems	Malmö	Kerstin Paulsson
Lawson Förlag & Konsult AB	Lidingö	Harold Lawson
Mecel AB	Göteborg	Mikael Strömberg
Saab Military Aircraft	Linköping	Dag Folkesson
Saab Dynamics	Linköping	Lars-Åke Classon
Volvo Construction Equip. Components	Eskilstuna	Nils Erik Bånkestad
Volvo TU	Göteborg	Peter Lidén

10 Financial Plan and Budget

The plan and budget assumes that SSF decides to increase the level of funding to MSEK 10 in 1999 and to MSEK 15 in 2000.

10.1 Costs

The costs in the budgets have been calculated as follows:

Projects Projects are supported in graduate student units, each unit intended to cover the costs for one full-time graduate student, 20% supervisor, travel, basic equipment and overheads. The current amount for one unit is kSEK 500/yr.

In addition to the direct support from ARTES, we assume industrial involvement and indirect support from universities. Industry is assumed to cover its own project costs and salary to senior academics on industrial sabbaticals, as well as some support to thesis projects. Our contacts with industry in the currently planned and decided ARTES and PAMP projects indicate that the value of the industrial support is at least 60% of the project costs in the below table, in many cases substantially more. To get an estimate of the indirect support provided by the universities we assume that the total annual cost for a graduate student (including all overheads, but excluding supervision) is kSEK 625, and for a supervisor kSEK 900. This gives a total annual cost for the above graduate student unit of kSEK 805, hence the indirect support can be estimated to kSEK 305/yr, i.e. 61% of the project costs.

In calculating project costs we assume that an average admitted students will be funded by the programme from April 1^{st} (however for 1998 we assume that all PAMP students are funded from July 1^{st}). Also, we assume that the average funding level is 80% (with

20% departemental duties), and that 20% of the Licentiates will start industrial careers (not continuing towards PhDs).

Graduate school The annual cost for the summer school is assumed to be kSEK 350 for ARTES. This covers costs for inviting international experts, accomodation and facilities for real-time students and senior researchers, etc. External and industrial participants are expected to cover their own costs.

The remaining graduate school costs are related to graduate courses. This far, support of kSEK 50 for nationally offering courses that otherwise would be given as local courses has been provided. In coming years, support will additionally be given to course development and to the invitation of internationally leading scientists to give courses.

Mobility We assume support in units of kSEK 25 to cover additional costs for mobility between nodes, and support in units of kSEK 100 for invitations of guest researchers. (E.g. for 2000 the budget assumes 4 guest researchers and 16 units of node-mobility support.)

Infrastructure We assume for ARTES that the initial annual cost of kSEK 120 for information and advertisements will increase to kSEK 200 in 2000. Support to workshops are in units of kSEK 50, and feasibility studies in units of kSEK 50. (E.g. for 2000 the budget assumes 6 workshops and 5 feasibility studies.)

Administration The administrative costs include a programme director with a 50% activity level, 5% administrative support, costs for boards, and a limited support to the graduate school director. (E.g. for 2000 the budget assumes kSEK 600 for programme director and administration, kSEK 300 for board and scientific advisors, kSEK 100 for PAMP management, and kSEK 80 for graduate school director.)

It should be noted that the reason for the relative high administrative cost for 1998 is that costs from the actual start of the programme in July 1997 are included.

(MSEK)	1998		1999		2000		2001		2002		Total	
Funding	A	P	A	P	A	P	A	P	A	P	A	P
SSF	5.0	2.0	10.0	4.0	15.0	5.0	15.0	5.0	15.0	5.0	60.0	21.0

Costs	A	P	A	P	A	P	A	P	A	P	A	P
Projects	2.1	1.2	5.8	3.6	9.8	3.7	11.6	3.4	10.4	2.6	39.7	14.5
Grad. Scool	0.8		1.1		1.4		1.9		1.9		7.1	
Mobility	0.4		0.7		0.8		0.8		0.8		3.5	
Infrastructure	0.4		0.6		0.7		0.8		0.8		3.3	
Adm.	1.5		1.1		1.1		1.1		1.1		5.9	
VAT (8%)	0.6		1.1		1.6		1.6		1.6		6.5	
Total	7.0		14.0		19.1		21.2		19.2		80.5	
Funding−Costs	0.0		0.0		0.9		-1.2		0.8		0.5	

11 Collaborations

The ARTES network includes almost all Swedish academic groups active in the real-time systems area. Hence, ARTES will in itself be the main organisation for national research cooperation. It will also be natural for ARTES to cooperate with related programmes and organisations, since many of the leading individuals in these efforts are also involved in ARTES. In particular , ARTES will have strong ties with the SSF programmes Autonomous Systems, VISIT, and HMI programmes, as well as with SICS and the NUTEK Real-Time/Complex Systems Programme.

Close contacts with industry will be ensured by the participating industrial nodes, the industrially dominated board, and the many existing industrial contacts at academic nodes.

The participating nodes are involved in many international projects, have extensive international contacts and collaborations. Through the ARTES mobility programme and infrastructure support these contacts will be further developed and made available to the entire network.

12 Other Plans and Policies

12.1 Continuation of successful programme

The ARTES network is creating an infrastructure for cooperation between academia and industry. The support from SSF is needed to establish the network and demonstrate its value. The graduate education and establishment of a strong national real-time systems research community will most likely lead to continued efforts in the area. Thus, if ARTES is successful, it should after the initial 5-10 years funding period be possible to finance many of its activities via fees and support from other funding agencies.

12.2 Future careers of young researchers

The ARTES graduate education is motivated by industrial needs (in particular a need of qualified personnel), and the majority of thesis projects will be performed in close industrial cooperation. Thus, the licentiates and PhDs will play important roles in advanced industrial research and development projects. The close industrial ties will be maintained, not only via industrially motivated projects, but also via periods of practical industrial training. Traditional academic careers will of course also be open for ARTES students. But the ambition is clear: at least 80% of the students should start an industrial career.

12.3 Recruitment of female students

This is an important but difficult issue, since the vast majority of undergraduate students in the area are males. Special efforts are needed to increase the number of female graduate students in the area.

ARTES will form a network of female graduate students, industrial engineers and researchers with the purpose of giving visibility to positive role models, facilitating recruitment, and providing support and encouragement to admitted female graduate students. Possible activities for this network include:

- A mentor-programme, where female engineers/scientists mentor female undergraduate students and try to get them interested in real-time systems and graduate education.
- Workshop and meetings to exchange views and ideas.

12.4 Intellectual property and exploitation of results

Due to the high ambitions and applied nature of many ARTES projects it is very likely that the research will result in commercially interesting methods and prototypes. Hence, it is important that the ARTES programme has clear rules for intellectual property rights. Furthermore, since ARTES projects typically are performed in conjunction with related projects funded from other

sources, it is important that these rules are compatible with corresponding rules for related programmes.

In general the intellectual property rights will follow those of the participating universities. For specific industrial collaboration a case by case agreement will be reached with the involved companies. It is in such cases important that these contracts do not violate any general rule at the participating universities.

Furthermore, since the handling of property rights is both a difficult matter and very important for the motivation and possibility to start spin-off companies, ARTES encourages SSF to make a serious effort to develop general guidelines and/or rules for how to handle this matter. Especially since we see it as advantageous, even mandatory, that all programmes have the same IPR rules.

Finally, concerning exploitation of results, ARTES has the ambition to be instrumental in the establishment of new industries. For instance, based on the yearly review of ongoing research, ARTES will identify research results which are commercially promising, and then assist in establishing contacts between the researchers and the appropriate financiers, industrialists and entrepreneurs to facilitate the creation of new ventures in the real-time systems area.

12.5 Conditions for discontinuation of the programme

ARTES should be discontinued if it after an initial five year funding period has not had a fundamental impact on industry-academia cooperation and graduate education. It is the responsibility of the ARTES board of directors to monitor the development of the programme and to report to SSF, as well as recommend any necessary action.

If ARTES is discontinued, negotiations with participating organisations are needed to find solutions that make it possible for successful parts of the programme to continue, and such that the involved students can finish their studies.

A The project process

The typical way of applying for ARTES research funding is in response to a call for proposals launched annually by the ARTES board of directors. The major way of financing is in 2 or 2 +2 year periods according to the two year licentiate degree and the four year PhD degree. There will be first and second year checkpoints as outlined below. External experts will assist in (at least) the evaluation related to the 2nd year checkpoint.

A.1 1st year checkpoint

This checkpoint is to assure that the critical first year has given a good basis for a successful licentiate or doctoral project. The requirements of this checkpoint is that a state-of-the-art report (including industrial practice) and a specification of the rest (1 or 3 years) of the project are presented to the network and to the ARTES board. In response to these deliverables the ARTES board is, if required, supposed to give advice to improve the project.

A.2 2nd year checkpoint

In the case of a 2+2 year project a major evaluation of the project is carried out according to the evaluation criteria stated above. A report of the first 2 years, an updated specification for the second 2-year phase is required, while the licentiate thesis is optional. The ARTES board may at this stage decide not to support the second phase if the evaluation turns out not to be satisfactory.

In the case of a two year project, a final report is delivered together with a licentiate thesis. The project is evaluated and exploitation possibilities are investigated. The latter is the responsibility of the ARTES board.

The possible second two year phase ends similarly with a final report and a doctoral thesis. Exploitation possibilities are investigated.

A.3 Project timing

Milestone	**Deliverable/action**
1. Call	Call for proposals
2. Deadline	ARP application
3. ARTES board decision	Approval/rejection/reformulation letter.
4. Project start	Project starts when all resources are available.
5. First year checkpoint	a) State-of-the-art report b) Project specification Response from the ARTES board within six weeks.
6. Second year checkpoint	a) Final or intermediate (2+2 year project) report b) Licentiate thesis (optional in the 2+2 year project) c) Updated specification in case of 2+2 year project Response from the ARTES board within six weeks. Exploitation investigation (2 year project) by ARTES board.
7. Annual progress presentation	Progress presentation, e.g. at the ARTES summer school.
8. Project ending	a) Final report b) Licentiate/Doctoral thesis Exploitation investigation by ARTES board.

B ARTES - The Academic Network

The following academic groups/departments are currently (April 1998) actively involved in forming the ARTES network. The groups, as well as their current and envisaged funding situation year 2000, is presented below. The ARTES funding for year 2000 should be interpreted as an indication of interest and capability to supervise. (The order is appriximately geographically, from north to south.)

A presentation of the research orientation and focus of these (and some other) groups is provided in the Addendum of the original ARTES application.

An uppdated presentation of the ARTES network will continuously be made availably at the ARTES web-site (http://www.docs.uu.se/artes/).

B.1 The Department of Computer Systems (DoCS), Uppsala University

ARTES contact person: Wang Yi.

DoCS web-page: http://www.docs.uu.se/

The following groups at DoCS are actively interested in ARTES:

- The Hard Real-Time Systems research group (HRTS).
- The Design and Analysis of Real-Time Systems research group (DART).
- Formal Methods and Software Technology (FMST).

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Hans Hansson, Professor, HRTS.
  2. Philippas Tsigas, PhD, Research Fellow, HRTS.
  3. Justin Pearson, PhD, Research Fellow, DART.
  4. Wang Yi, PhD, Docent, DART.
  5. Bengt Jonsson, Professor, FMST.
- Graduate students:
  1. Jakob Engblom, MSc, graduate student, HRTS.
  2. Andreas Ermedahl, MSc, graduate student, HRTS.
  3. Jan Gustafsson, Licentiate, graduate student, HRTS.
  4. Mikael Sjödin, Licentiate, graduate student, HRTS.
  5. Johan Bengtsson, MSc, graduate student, DART.
  6. Fredrik Larsson, MSc, graduate student, DART.
  7. Paul Pettersson, MSc, graduate student, DART.

B.2 The Systems and Control Group (SCon), Uppsala University

ARTES contact person: Kjell Nordström.

SCon web-page: http://www.syscon.uu.se/.

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Bengt Carlsson, PhD, Docent.
  2. Erlendur Karlsson, PhD.
  3. Kjell Nordström, PhD, Docent.
  4. Petre Stoica, Professor.
  5. Torsten Söderström, Professor.
- Graduate students:
  1. Magnus Mossberg, MSc.

B.3 The Mechatronics Group (DAMEK/KTH), Dept. of Machine Design, Royal Institute of Technology (KTH)

ARTES contact person: Jan Wikander.

DAMEK/KTH web-page: http://www.damek.kth.se/

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Martin Törngren, PhD.
  2. Jan Wikander, Professor.
- Graduate students:
  1. Ola Redell, MSc.
  2. Martin Sanfridsson MSc.
  3. De-Jiu Chen, MSc.

B.4 The Center for Real-Time Systems (CUS), Mälardalens Högskola

ARTES contact person: Lennart Lindh.

CUS web-page: http://www.idt.mdh.se/

Staff involved in Real-Time Systems research:

- Senior researchers:
  1. Christer Eriksson, PhD.
  2. Gerhard Fohler, PhD.
  3. Hans Hansson, Professor.
  4. Lennart Lindh, PhD.

5. Jacek Malec, PhD.

- Graduate students:

1. Joakim Adomat, graduate student.
2. Johan Furunäs, graduate student.
3. Ashraf Fawzi, graduate student.
4. Jan Gustafsson, Licentiate, graduate student.
5. Mårten Larsson, graduate student.
6. Markus Lindgren, graduate student.
7. Jukka Mäki-Turja, Licentiate, graduate student.
8. Anders Rosvall, graduate student.
9. Kristian Sandström, graduate student.
10. Mohammed El Shobaki, graduate student.
11. Stefan Sjöholm, graduate student.
12. Johan Stärner, graduate student.
13. Henrik Thane, Licentiate, graduate student.
14. Anders Wall, graduate student.

B.5 The Department of Computer and Information Science (IDA), Linköping University

ARTES contact person: Anders Törne

IDA web-page: http://www.ida.liu.se/.

The following groups are actively interested in ARTES:

- ESLAB.
- RTSLAB.

Staff involved in the Real-Time Systems research:

- Senior researchers:

1. Zebo Peng, Professor, ESLAB
2. Petru Eles, PhD, ESLAB
3. Simin Nadjm-Tehrani PhD, affiliated to ESLAB
4. Anders Törne, PhD, RTSLAB.

- Graduate students:

1. Lars Lindqvist, graduate student, ESLAB
2. Paul Pop, graduate student, ESLAB
3. Erik Stoy, graduate student, ESLAB
4. Peter Loborg, Licentiate, graduate student, RTSLAB.
5. Esa Falkenroth, Licentiate, graduate student, RTSLAB.
6. Stefan Kalmelid, graduate student, RTSLAB.
7. Tim Heyer, graduate student, RTSLAB.
8. Erik Herzog, graduate student, RTSLAB.
9. Paul Scerri, graduate student, RTSLAB.

B.6 The Department of Computer Engineering (CE), Chalmers University

ARTES contact person: Jan Torin

CE web-page: http://www.ce.chalmers.se/

The following groups are actively interested in ARTES and Real-Time Systems:

- Validation of Fault Tolerance, VFT
- Fault-Tolerant Distributed Systems, FTDS
- Software Fault Tolerance, SFT
- Massively Parallel Architectures and Neural Networks, MPANN
- High-Performance Computer Architecture, HPCA
- Predictability and Computer Architecture, PCA

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Arne Dahlberg, PhD, FTDS.
  2. Fredrik Dahlgren, PhD, HPCA.
  3. Håkan Edler, MSC, SFT.
  4. Lars Åke Johansson, PhD, FTDS.
  5. Jan Jonsson, PhD, HPCA.
  6. Johan Karlsson, PhD, VFT.
  7. Per Stenström, prof, HPCA.
  8. Jan Torin, prof, FTDS.
  9. Jonas Vasell, PhD, PCA.
- Graduate students:
  1. Kristina Ahlström, MSc, FTDS.
  2. Örjan Askerdal, MSc, FTDS.
  3. Susanne Bolin, MSc, SFT.
  4. Vilgot Claesson, MSc, FTDS.
  5. Robert Feldt, MSc, SFT.
  6. Peter Folkesson, Licentiate, VFT.
  7. Martin Hiller, MSc, SFT.
  8. Magnus Karlsson, MSc, HPCA.
  9. Guang Li, Licentiate, MPANN.
  10. Thomas Lundquist, MSc, HPCA.
  11. Henrik Lönn, Licentiate, FTDS.
  12. Jim Nilsson, MSc, HPCA.
  13. Rolf Snedsbol, Licentiate, FTDS.

B.7 Control Engineering Laboratory (CtrlC), Department of Signals and Systems, Chalmers University

ARTES contact person: Bengt Lennartsson

CtrlC web-page: http://www.control.chalmers.se/

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Bo Egarth, Professor.
  2. Martin Fabian, PhD.
  3. Bengt Lennartsson, Professor.
  4. Michael Tittus, PhD.
- Graduate students:
  1. Anders Hellgren, MSc.
  2. Torbjörn Liljenvall, MSc.
  3. Stefan Pettersson, MSc.
  4. Marcus Rubensson, MSc.
  5. Knut Åkesson, MSc.

B.8 The Center for Computer Architecture (CCA), Halmstad University

ARTES contact person: Per-Arne Wiberg

CCA web-page: http://www.hh.se/cca/

The following groups are actively interested in ARTES:

- The Embedded Super Computing research group (ESC).
- The Intelligent Mechatronics research group (IM).
- The Real-Time Mobile Communication research group (RTMC)

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Albert-Jan Baerveldt, PhD.
  2. Lars Bengtsson, PhD.
  3. Bertil Svensson, Professor.
  4. Per-Arne Wiberg, Licentiate.
- Graduate students:
  1. Magnus Jonsson, Licentiate.
  2. Maarja Kruusmaa, Licentiate.
  3. Elisabeth Ulemann, MSc.
  4. Anders Ålander, Licentiate.

5. Nicholas Wickström, MSc.
6. Wolfgang Svensson, MSc.
7. Pär Wåxnäs, MSc.
8. Dan Hellgren, MSc.

B.9 The Department of Automatic Control (CtrlL), Lund University

ARTES contact person: Karl-Erik Årzén

CtrlL web-page: http://www.control.lth.se/

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Bo Bernhardsson, PhD.
  2. Björn Wittenmark, Professor.
  3. Karl-Erik Årzén, PhD, Docent.
- Graduate students:
  1. Anton Cervin, graduate student.
  2. Johan Eker, graduate student.
  3. Magnus Gäfvert, graduate student.
  4. Charlotta Johnsson, graduate student.

B.10 Department of Computer Science (DNA), Lund University

ARTES contact person: Boris Magnusson

DNA web-page: http://www.dna.lth.se/

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Boris Magnusson, Professor.
  2. Görel Hedin, PhD.
  3. Klas Nilsson, PhD.
- Graduate students:
  1. Roger Henriksson, Licentiate.
  2. Anders Ivö, MSc.
  3. Patrik Persson, MSc.

B.11 The Department of Computer Science and Business Administration (IDE), Karlskrona/Ronneby Högskola

ARTES contact person: Lars Lundberg

IDE web-page: http://www.ide.hk-r.se/

Staff involved in the Real-Time Systems research:

- Senior researchers:
  1. Lars Lundberg, Associate Professor.
  2. Håkan Grahn, PhD.
- Graduate students:
  1. Magnus Broberg, graduate student.

B.12 Funding situation 1998 (KSEK)

Source	DoCS	SCon	KTH	CUS	IDA	CE	CtrlC	CCA	CtrlL	IDE	DNA	Total
University	1.350	400	-	6.000	1.400	3.500	900	3.000	1.500	1.500	1.650	21.200
Nutek	2.200	-	1.300	1.500	2.400	3.750	2.500	400	1.400	-	2.100	17.550
TFR	750	700	-	-	-	760	700	-	500	-	-	3.410
Industry	1.300	50	330	200	-	1.600	-	-	-	-	-	3.480
ARTES	-	-	150	400	400	500	-	-	400	-	500	2.350
other SSF	-	500	600	-	500	300	-	-	-	-	-	1.900
o. found.	-	-	-	800	-	3.100	-	3.700	-	-	-	7.600
EU	-	-	300	-	350	1.000	-	500	-	-	-	2.150
TOTAL	5.600	1.600	2.680	8.900	5.050	14.510	4.100	7.600	3.800	1.500	4.250	59.640
PhD exams	1.5	0	-	0.5	2	2	1	0	1	0	2	10
Lic exams	1	1	1	4	3	5	2	1	-	-	-	18

B.13 Expected situation 2000 (KSEK)

Source	DoCS	SCon	KTH	CUS	IDA	CE	CtrlC	CCA	CtrlL	IDE	DNA	Total
University	1.700	400	400	6.000	2.000	4.000	900	4.000	1.500	1.500	1.500	23.900
Nutek	1.800	-	600	2.000	3.000	4.350	2.500	1.000	1.200	-	3.100	19.550
TFR	800	300	-	300		1.150	700	-	800	-	-	4.050
Industry	1.200	500	300	2.000	300	1.600	-	-	-	-	1.000	6.900
ARTES	2.500	500	1.000	2.000	1.500	2.000	500	2.000	1.000	1.000	1.000	15.000
other SSF	-	500	1.200	-	800	300	-	1.500	-	-	-	4.300
o. found.	-	-	-	6.000	-	6.100	-	3.500	-	-	-	15.600
EU	-	-	600	-	350	1.000	-	800	-	-	-	2.750
TOTAL	8.100	1.900	4.100	18.300	7.950	20.500	4.600	12.800	4.500	2.500	6.600	92.050
Prof.	2	-	1	2	1	5	2	2	2	1	2	20
Dr.	6	-	2	6	4	9	2	6	1	1	5	42
Grad.stud.	14	-	7	35	12	26	6	15	6	4	10	135
ARTES G.S.	5	1	2	4	3	4	1	3	2	2	2	29
PhD exams	3	-	1	5	3	5	1	4	1	-	1	24
Lic exams	5	1	4	12	6	-	2	7	3	1	22	43

Legend:

- "University" denotes internal university funding.
- Nutek is the National board for Technical and Industrial Development.
- TFR is the Swedish Research Council for Engineering Sciences.

- "Industry" denote direct funding from industry or from industrial research foundations.
- "other SSF" denotes funding from SSF, other than ARTES.
- "o.found" denotes funding from other foundations, e.g., the KK-foundation.
- "EU" denotes funding from the European Union, e.g. within the Esprit-programme.
- "ARTES G.S" denotes ARTES graduate students.

Note also that the reason for the "half PhD-exams" in 1998 is that the student is shared between DoCS and CUS.

C Addresses

This appendix contains names and addresses of members of the ARTES board, executive committee, PAMP steering committee and project leaders.

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D PAMP - programme plan

[The PAMP programme plan is available in postscript and pdf format at
http://www.docs.uu.se/artes/pamp/plan.{ps,pdf}]