Network of Excellence

IST-004527 ARTIST2:
Embedded Systems Design

Periodic Activity Report for Year 2

Executive Summary

Joseph Sifakis – Artist2 Scientific Coordinator

Bruno Bouyssounouse – Artist2 Technical Coordinator

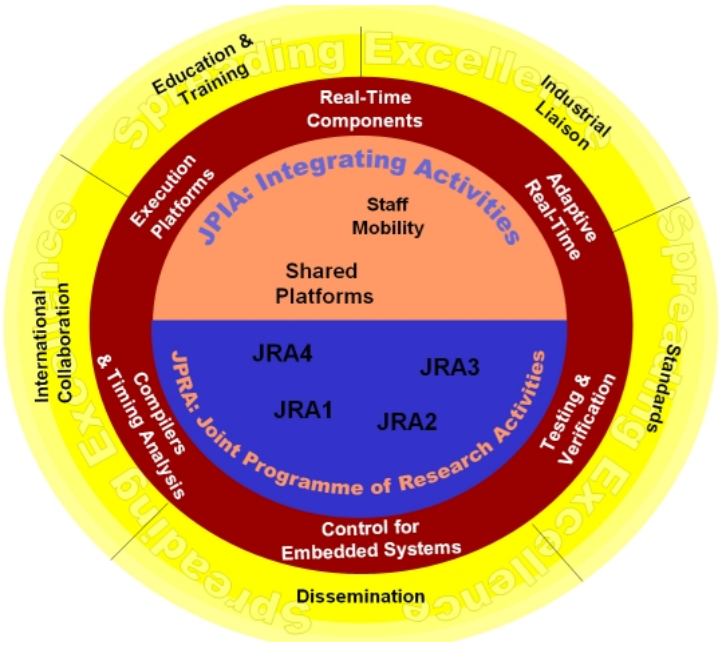
Artist2 Consortium

1. Project Objectives

The strategic objective of the ARTIST2 Network of Excellence is to strengthen European research in Embedded Systems Design, and promote the emergence of this new multi-disciplinary area. We gather together the best European teams from the composing disciplines, and will work to forge a scientific community. Integration will be achieved around a Joint Programme of Activities, aiming to create critical mass from the selected European teams.

The ARTIST2 Network of Excellence on Embedded Systems Design implements an international and interdisciplinary fusion of effort to create a unique European virtual centre of excellence on Embedded Systems Design. This interdisciplinary effort in research is mandatory to establish Embedded Systems Design as a discipline, combining competencies from electrical engineering, computer science, applied mathematics, and control theory. The ambition is to compete on the same level as equivalent centres in the USA (Berkeley, Stanford, MIT, Carnegie Mellon), for both the production and transfer of knowledge and competencies, and for the impact on industrial innovation.

ARTIST2 has a double core, consisting of leading-edge research in embedded systems design issues (described later in this document) in the Joint Programme of Research Activities (JPRA), and complementary activities around shared platforms and staff mobility in the Joint Programme of Integration Activities (JPIA).



Building the embedded systems design scientific community is an ambitious programme. To succeed, ARTIST2 builds on the achievements and experience from the ARTIST1 FP5 Accompanying Measure on Advanced Real-Time Systems. ARTIST1 provided the opportunity to test the concept of a two-level integration (within and between clusters) – four clusters in ARTIST2 originated as “actions” in ARTIST1. Building the ARTIST2 consortium and associated structure is the culmination of discussions and ambitions elaborated within ARTIST1.

ARTIST2 addresses the full range of challenges related to Embedded Systems Design, covering all aspects, ranging from theory through to applications.

2. Joint Programme of Activities

The Joint Programme of Activities is composed of 4 main branches:

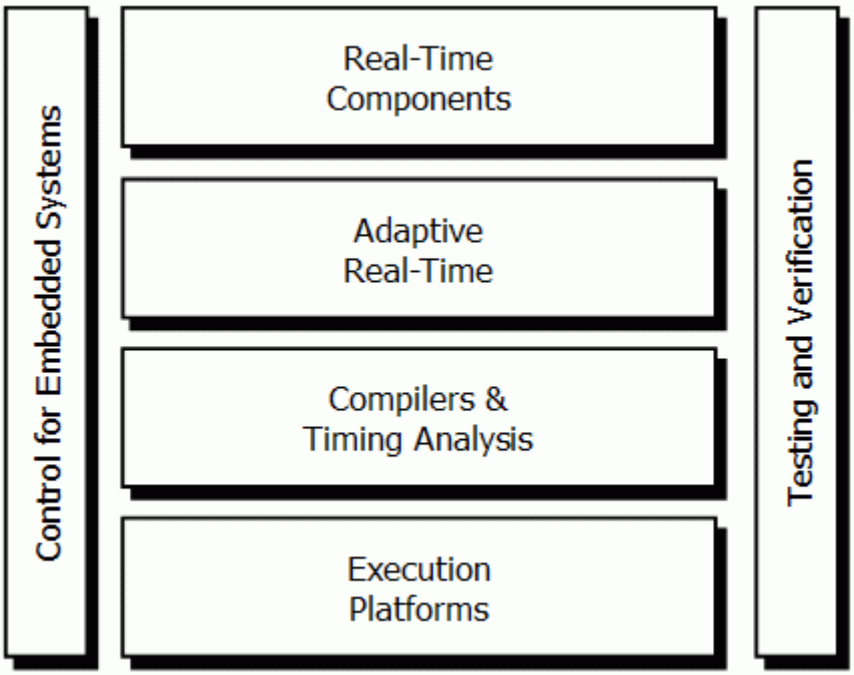
2.1 Joint Programme of Research Activities (JPRA)

The JPRA is composed of intra and inter-cluster research activities on cutting-edge topics in embedded systems design. While the main bulk of financing for these activities is taken up by outside programmes (Integrated Projects, National Programmes, Industrial Contracts, etc), the Artist2 NoE finances the extra burden due derived from integrating these into a single coherent research programme.

Thus, the essential ingredient within Artist2 is the JPRA, which motivates the participating research teams far more than the actual financing, which is tiny in comparison with the overall research aims. It is completed by the Joint Programme of Integrating Activities (JPIA), and the Joint Programme of Activities for Spreading Excellence (JPASE), and overseen by the Joint Programme of Management Activities (JPMA).

The structure of the research activities reflects the following decomposition of the embedded systems design flow.

This design flow is composed of the following cooperating activities, starting with component-based modelling and leading to implementation. These activities must be well coordinated, and supported by tools and methods to ensure satisfactory levels of productivity and quality. Accordingly, we have structured the area of embedded systems design into the following topics.



Real-Time Components: The development of a general framework for component-based engineering of complex heterogeneous embedded systems is a grand challenge which spans many research problems. A key characteristic of component-based embedded systems is heterogeneity of component models. This heterogeneity concerns different execution models (synchronous, asynchronous, vs. timed), communication models (synchronous vs. asynchronous), as well as different scheduling paradigms. Technology must be provided to allow designing heterogeneous embedded systems from diverse types of components, and allow predicting and optimizing functional and non-functional properties of the designed systems.

Adaptive Real-time: This is a more recent approach to embedded systems design, where temporal constraints can be relaxed, which allows optimized use of resources. This includes applications – where managing the Quality of Service (QoS) is essential, such as telecommunication systems, multi-media, and wide-area networked applications. In this relatively new area, there is a recognized lack of design theory and tools.

Compilers and Timing Analysis: Once the application software has been developed, using the above, the system must be implemented on a given target platform. Compilation tools and their associated technologies play a fundamental role for automating this process. For the implementation of embedded systems, we need tools capable of combining platform independent software and a description of the target platform, to generate an executable code having the desired properties related to use of such resources as memory, power, energy, network bandwidth, and computation time). Resource-aware compilation requires the use of Timing Analysis tools to estimate the execution times of embedded software on a given platform.

Execution Platforms: This topic is strongly linked to the compilation and implementation of embedded systems. For a given application, it is important to have the technology, methods and tools to make rational choices about the platform and the design used, before proceeding to final implementation. Research in Execution Platforms targets the development of the theoretical and practical tools for modelling the dynamic behaviour of application software for a given platform. This is a new area of research, which will allow greater flexibility in designing optimal embedded systems.

Testing and Verification: This is transversal topic, which interacts with all the other topics in embedded systems design. It aims to ensure that the different design steps meet given properties, as well as the overall correctness of the implementation. This is a very active research topic, with results at different levels of the design process. The current challenge is in achieving on overall approach for testing and verification, focussing on two important aspects.

First is the Verification and Testing of real-time properties, to ensure that hard real-time constraints or quality of service constraints are met. Second is for Verification of Security Properties, where identification of gaps in security is desired.

Control for Embedded Systems: Embedded systems are deployed in the real world, and are often reactive to it. This interaction with the environment is intrinsic to the service provided. A large proportion of embedded systems can be considered to be controllers. On the other hand, most automated control applications will be implemented as embedded components. Thus, it is essential that work on joining control theory and embedded systems be included in the ARTIST2 NoE.

An overview of each intra-cluster (“Cluster Integration”) and inter-cluster (“NoE Integration”) research activity is provided in this document, and each platform has provided a deliverable that provides the detailed information.

2.2 Joint Programme of Integration Activities (JPIA)

The Joint Programme of Integrating Activities contains the technical but non-research activities that participate in the overall effort. As with the JPRA, the main financing for these technical activities is derived from other sources, and is small in comparison with the overall objectives.

The JPIA is composed of Platform Activities (roughly one for each cluster), and Mobility actions between partners – both core and affiliated partners.

Integration between research teams work to achieve critical mass in 2 important dimensions:

- Strong integration within selected topics by assembling the best European teams, to advance the state of the art in the topic.
- Integration between topics to achieve the multi-disciplinary excellence and skills required for the development of future embedded technologies.

The ARTIST2 platforms integrate the results of long-term efforts, and are meant to be durable, evolving with the state of the art. The partners are committed to durability, and have invested significant resources into their development. The construction of ARTIST2 has provided the opportunity to assemble existing pieces into a rationally-structured set of platforms, covering the area of embedded systems design.

Some of the ARTIST2 platforms have international visibility, and the ambition is for these to serve as world-wide references in their respective topics.

Both types of integration are achieved through Joint Programme of Integration Activities (JPIA) activities involving:

- Sharing Research Platforms, Tools, and Facilities
  State of the art research platforms, composed of competencies, resources, and tools targeting specific technical and scientific objectives around a chosen topic. These are made available to the R&D community for experimentation, demonstration, evaluation, and teaching.
- Staff Mobility and Exchanges
  Staff mobility actions continue to play an important part of integration between Artist2 partner teams. (see the “Spreading Excellence” deliverable).
  This is an essential activity for integration within the NoE, including mobility of students and/or researchers, between core teams, or between core teams and affiliated teams.
- Exchange of students and personnel within the consortium.
- Support for relocating staff and teams (according to needs).

An overview of each platform is provided in this document, and each platform has provided a deliverable that provides the detailed information.

2.3 Joint Programme of Activities for Spreading Excellence (JPASE)

The achievements and results from the Joint Programme of Activities for Spreading Excellence (JPASE) is contained in a separate deliverable, entitled: “Spreading Excellence”.

3. Contact Details and Contractors Involved

3.1 Core Partners

For a complete description including web links, see:
http://www.artist-embedded.org/artist/-Core-Partners-.html

Scientific Coordinator:	Technical Coordinator:
Joseph Sifakis	Bruno Bouyssounouse
Tel: +33 4 56 52 03 51	Tel: +33 4 56 52 03 68
Joseph.Sifakis@imag.fr	Bruno.Bouyssounouse@imag.fr
Mailing address: Verimag Laboratory - Centre Equation - 2, ave de Vignate - 38610 Gières - France	

Partic N°	Participant name	Country
1	Caisse des Dépots et Consignations	France
2	UJF / Verimag	France
3	RWTH Aachen	Germany
4	BRICS – Aalborg University	Denmark
5	AbsInt GmbH	Germany
6	University of Aveiro	Portugal
7	Universidad de Cantabria	Spain
8	Commissariat à l'Énergie Atomique – Laboratoire LIST	France
9	CFV, Université de Liège	Belgium
10	Czech Technical University	Czech Rep.
11	Dortmund University	Germany
12	Technical University of Denmark	Denmark
13	Swiss Federal Institute of Technology – Zurich	Switzerland
14	France Telecom R&D	France
15	Institut National de Recherche en Informatique et Automatique	France
16	Royal Institute of Technology	Sweden
17	Linköping University	Sweden
18	CNRS / Laboratoire LSV	France
19	Lund University (Sweden)	Sweden

Partic N°	Participant name	Country
20	University of Mälardalen	Sweden
21	Kuratorium OFFIS e. V.	Germany
23	University of Pavia	Italy
24	Universidad Politecnica de Madrid	Spain
25	Saarland University	Germany
26	ST Microelectronics – Central R&D	France
27	TU of Eindhoven	Netherlands
28	TU of Vienna	Austria
29	TU Braunschweig	Germany
30	University of Twente	Netherlands
31	University of Bologna	Italy
32	Uppsala University	Sweden
33	Universidad Polytecnica de Valencia	Spain
34	University of York	UK
35	Polytechnic Institute of Porto	Portugal
36	EPFL	Switzerland
37	Scuola Sant'Anna – Pisa	Italy
38	Tidorum	Finland
39	TU Kaiserslautern	Germany

Partner 23 – University of Pavia (Italy) – has withdrawn from the NoE.

3.2 Affiliated Partners

Affiliated partners play a very strong role in the Spreading Excellence from the core partners to the research and industrial communities at large.

Affiliated partners generally play an active role in the research activities, either participating directly in research, or transferring the results directly to industry.

Each of the JPRA and JPIA activities' deliverables provides the list of the corresponding affiliated partners and roles.

Affiliated Industrial Partners

The complete set of Affiliated Industrial partners, including web links, is available online, here: http://www.artist-embedded.org/artist/-Affiliated-Industrial-Partners-.html

Christer Norström Göran Arinder	ABB	Sven Holme Sørensen	SIEMENS
Thomas Thurner Matthias Grochtmann	DaimlerChrysler	Roberto Zafalon	ST
Alain Ourghanlian	EDF Electricité de France	Dr. Kai Richter	SYMTA VISION
Johan Eker	ERICSSON	Dominique Potier	THALES
Philippe Baufreton	Hispano-Suiza Groupe SAFRAN	Fabian Wolf	VW
Vladimir Havlena	Honeywell	Magnus Hellring	VOLVO

Dr. Michael Winokur

Magnus Hellring

Peter Mårtensson

Jakob Axelsson

Peter Mårtensson

Affiliated SME Partners

Alan Moore

Paolo Gai

Dr. Monica Donno

Carl von Platen

Joachim Stroop

António Garrido

Jan Lindblad

Fernando Santos

Bernard Dion

Affiliated Academic Partners

Prof. Andrea Bondavalli
University of Florence
Tel: +39 055 4237457

Prof. Ahmed Bouajjani
LIAFA - Université Paris 7 & CNRS
Tel: +33 (0) 1 4427 7819

Masaryk University Brno
Prof. Lubos Brim
Tel: +420 549 493 647

TU München
Prof. Dr. Dr. h.c. Manfred Broy
Tel: +49 89 289-17304

Università degli Studi di Cagliari
Ass. Prof. Salvatore Carta
Tel: +39 070-675-8780

IMEC
Dr. Francky Catthoor
Tel: +32 16 281202

Universitat Politècnica de Catalunya
Dr. Pau Martí Colom
Tel: +34 93 401 1679

Prof. GGeert Deconinck
Katholieke Universiteit Leuven
Tel: +32 16 32.11.26

Prof. Ivo De Lotto
Università degli studi di Pavia
Team leader
Tel: +39 0382 98 53 57

Prof. Dr. Ed Deprettere
Leiden University
Tel: +31 (0)71 5275776

Prof. Dr. Marisol Garcia Valls
Universidad Carlos III de Madrid
Tel: +34 91-624-8783

Prof. Dr. Sabine Glesner
TU Berlin
Activity Leader - Compilers Platform (JPIA-Platform)
Tel: +49 30 314 - 73 258

Prof. Axel Jantsch
Royal Institute of Technology (KTH)
Tel: +46 8 790 4124; +46 70 713 7428

Prof. Christoph Kirsch
University of Salzburg
Tel: +43 (0) 662 8044-6328

Prof. Stefan Kowalewski
RWTH Aachen
Tel: +49 241 80 21150

Prof. Luciano Lavagno
Politecnico di Torino
Tel: +39-011-5644150

Prof. Lucia Lo Bello
University of Catania
Tel: +39 095 7382386

Prof. Dr. Miroslaw Malek
Humboldt University Berlin
Tel: +49 30 2093 3027

Dr. Fabio Martinelli
Istituto di Informatica e Telematica
National Research Council C.N.R.
Tel: +39.050.315.3425

Dr. Marius Minea
Timisoara - Institute e-Austria Timisoara
Tel: +40-256-403284

Laurent Pautet
ENST
Tel: +33 1-45-81-73-22

Julián Proenza
University of the Balearic Islands
Tel: (+34) 971 17 29 92

Dr. Isabelle Puaut
IRISA
Tel: +33 02 99 84 73 10

Prof. Donatella Sciuto
Politecnico di Milano
Tel: +39-02-2399 3662

Democritus University of Thrace
Ass. Prof. Dimitrios Soudris
Tel: +30 25410 79557

Prof. Neeraj Suri
TU Darmstadt
Tel: +49 6151 16 3513

Dr. ir. G.J. Tretmans
University of Nijmegen
Tel: +31 24 365 2069

Prof. Pierre Verbaeten
Katholieke Universiteit Leuven
Tel: +32 (0)16 32 75 66

Affiliated International Collaboration Partners

University of California at Berkeley
DARPA MoBIES, CHESS
Prof Ed Lee
Prof. Shankar Sastry

Prof. Kang Shin
University of Michigan

Chinese Academy of Sciences (CAS)
Prof. Zhou Chaochen

Monash University
Prof. Heinz Schmidt

University of Notre Dame
Prof. Sharon Hu

University of Illinois at Urbana–Champaign
Prof. Lui Sha

Stanford University
Prof. Giovanni De Micheli

Tata Research Development & Design Centre (TRDDC)
Mathai Joseph

National University of Singapore
Prof. P.S. Thiagarajan

UNU-IIST (United Nations University - Institute for Software Technology)
Zhiming Liu

Vanderbilt University
Prof. Janos Sztipanovits

University of Virginia
Prof. John Stankovic
Prof. Tarek Abdelzaher

Columbia University at New York City
Dept. of Computer Science
Stephen Edwards

4. Vision and Assessment of the Work Performed

Artist2 finances durable integration between teams and not the concrete elements of the JPA which most often belong to other projects. These specific technical objectives may or may not be attained (this is the essence of research as opposed to development), but we feel that the main product of Artist2 is the emergence of a lasting European research community, that has a significantly enhanced capacity for preparing Europe's future.

The research is completed by work on the JPIA Platforms, which aim to transform research results in tangible tools and components.

We believe that the topics chosen provide a good coverage of the area, for embedded software and systems.

The ARTIST2 NoE is a complex construction assembled from world-leading communities, teams, and individuals. This is certainly an asset, but also a source of complexity in management. Each team has two essential characteristics: world-class excellence and strong interaction with top industrial players. Artist2 partners play a leading role in the different communities in embedded systems design, and they advance the state of the art in each of these.

Over the course of Years 1&2, Artist2 has been extremely active in submitting new proposals

It is difficult to abstract out a global synthesis of the overall technical achievements. This is due to the diversity and the low granularity of the actions to be covered (meetings, publications, attendance at workshops, visits, platforms).

The following is a certainly non-exhaustive assessment of the work in the Joint Programme of Activities.

4.1 Integration of the European Research Area (JPIA)

Joint Programme of Integration Activities

Our assessment of Artist2 progress on integration over Year 2 is very positive.

4.1.1 Overview of Integration within Each Cluster

Real Time Components

This cluster results from the merge of two former clusters on Hard Real-Time (HRT) and Modelling and Components, to properly manage redundancies and improve synergies. The essential points of this objective have been reached. This area is now a focal point for the NoE. All teams work on Components in one form or another. Thus, it is strategic for the NoE to maintain and reinforce this cluster.

The size of this cluster is such that it is difficult to manage in a central manner as is done for the other clusters (e.g.: difficulty of organizing global cluster-level coordination meetings).

Adaptive Real Time

There is strong collaboration on all the research topics and around the common platform on "A Common Infrastructure for Adaptive Real-time Systems". The new activity on Real-Time Languages was started and a series of workshops and meetings were successfully organized.

The cluster has worked in cooperation for finding additional resources through joint European projects e.g.; the IST FRESCOR project that started in June 2006 and coordinated by University of Cantabria.

A new activity on Real-Time Networks is planned to start in Year 3, to address numerous research challenges in the framework of Wireless Sensor Networks (WSN), Mobile Ad-hoc Networks (MANETs) and Embedded Networked Systems. This is an excellent initiative, but nevertheless number of activities in this cluster is already large, with several on adaptive resource management

Compilers and Timing Analysis

This cluster brings together the two complementary areas Compilation and Timing Analysis. Compilers should also be aware of timing information. At the same time, Timing Analysis tools need flow analysis techniques available in Compilers. In Year2, we see that this complementarity leads to useful synergies between the teams.

Scientific discussion within the cluster is lively. There is a healthy competitive spirit, as witnessed by the WCET Competition being organized. Although only pairwise in some cases, cooperation is strong between several partners.

The integration of two new partners (Ace and Tidorum) at the start of Year 2 has been quite successful.

At the start of Year3, and new Affiliated Partner – TU Berlin (Sabine Glesner) – will coordinate the Compilers Platform activity.

Another affiliated partner, IMEC works on many aspects of System-on-Chip (SoC) design technology, including novel architectural templates, design methods and design tools.

The strong involvement of affiliated partners shows the interest and relevance of this clusters' research and integration activities.

We hope that these groups will participate in the WCET Tool Challenge with their academic prototypes.

Execution Platforms

There has been substantial progress in integrating different research directions and view points. Indicators that show this clearly are (a) the joint participation in summer schools, workshops and tutorials and (b) the number and quality of joint publications, and (c) the integration of tools.

This cluster is particularly well managed, and benefits from the strong leadership of its members, and its world-wide influence is considerable.

Control for Embedded Systems

The integration within the cluster has continued to progress nicely. Collaboration is increasing and there is a much higher number of joint publications in Year 2. This cluster is a bridge between the control community and the embedded systems community. Control-based techniques are important for the other clusters, e.g. for achieving adaptivity.

Testing and Verification

The activities of the cluster include work on "Quantitative Testing and Verification", the accompanying platform "Testing and Verification Platform for Embedded Systems", and "Verification of Security Properties". Integration on each of these topics is progressing well. Nonetheless, integration between the Security Properties activity and the rest of the cluster is static and not likely to move forward.

Given the importance of security aspects for current and future embedded systems, it seems essential to maintain and reinforce this topic within Artist2.

4.1.2 Overview of Intercluster Integration

Joint research involving the **Adaptive Real Time** cluster and the **Control for Embedded** Systems cluster, to integrate feedback control schemes into the Shark operating system (used as a shared platform) and to investigate the effects of different scheduling policies on delays and jitter in control loops The two clusters closely collaborated to investigate research issues that can have a significant impact on the embedded community. Furthermore, they have jointly organized the "First European Laboratory on Real-Time and Control for Embedded Systems", in Pisa, June 10-14 2006.

Collaboration on **Real-Time Components** has surpassed that which was initially planned. Beyond the current set of NoE Integration activities, there exists spontaneous interaction and collaboration between teams in the RTC cluster the other clusters, as documented in the RTC Cluster report (chapter II of this deliverable). This collaboration includes organization of workshops (e.g.: Leiden Workshop, forthcoming workshop on the Foundations and Applications of Component-based Design (http://www.artist-embedded.org/artist/-Foundations-and-Applications-of-.html) http://www.artist-embedded.org/artist/-Workshop-Distributed-Embedded-.html Workshop: Distributed Embedded Systems) as well as bilateral cooperation.

The University of Saarland (**Timing Analysis**) has started cooperation about Design for Predictability – new theme in the area - with partners in the **Execution Platforms** cluster, ETHZ, Bologna, and Dortmund.

Furthermore, the University of Bologna and teams outside Artist2 such as TU Karlsruhe, U Edinburgh, and TU Dresden have adopted the proposed **compiler platform**. Links to other communities (e.g. compiler researchers in the HiPEAC NoE) have been strengthened.

4.1.3 Progress on the Platforms – Highlights

The following are the main highlilghts from the different clusters over the course of Year 2. Naturally, the represent only a part of the total effort deployed.

Real Time Components

Good progress has been made on the "Component Modelling and Verification" platform, which capitalizes on the Integrated Project SPEEDS and French project OpenEmbeDD (http://openembedd.inria.fr), by integrating tools and contributions from CEA, France Telecom, INRIA, Thales, and VERIMAG, EPFL and, Uppsala. To allow communication between the various tools, model transformation techniques have been used or new ones are being developed. An important side-effect of this activity should be to find out which modelling constructs at user level are amenable to translation into a semantic level formalism for which effective analysis can be provided.

Adaptive Real Time

Significant progress has been made on the ART platform "Common Infrastructure for Adaptive Real-time Systems". A new release of the SHARK kernel 1.5.1 has been made available. Shark is now used for research at a number of sites, including the University of York, TU Kaiserslautern, Logobject AG – Switzerland, University of Illinois – Urbana Champaign.

Compilers and Timing Analysis

Within the Timing Analysis platform, the definition of a common intermediate program representation (AIR) will allow for an easier exchange of tool components and results.

An impressive amount of work has gone into improving the new functionalitities and features of the Compilers platform. The new funtionalitites and features include WCET-aware compilation and optimization, optimisation and conditional execution in CoSy, implementation of alias analysis techniques and infrastructure for high-level specification of C++ program analyses.

Execution Platforms

Work on the System Modelling Infrastructure Platform (Execution Platforms) has progressed significantly. Early integration of the simulation-based models, ARTS and MPARM, and of the formal-based models SymTA/S and Real-Time Calculus has been achieved. Initial linking between simulation- and formal-based models, MPARM and Real-Time Calculus has been investigated.

Control for Embedded Systems

Work on the Design Tools for Embedded Control platform involved tool integration, has focussed on further development of the individual tools by the cluster partners. Integration work has only just begun, and will cover continue over the course of Year3.

Testing and Verification

Work on the Testing and Verification Platform focused on implementing, improving and disseminating a large number of testing and verification tools allowing for the analysis of quantitative models including real-time aspects, resource models, hybrid and stochastic models.

These will be improved and evaluated more carefully through case studies. Work on distributed analysis tools will be strengthened. In particular, a common coordination layer integrating individual PC-clusters will be implemented in a European verification Grid.

4.2 Building European Excellence in Embedded Systems Design *(JPRA)*

Joint Programme of Research Activities

Advanced scheduling methodologies for increasing the predictability, for adaptive resource management and for reducing inter-task interference and provide temporal protection among the concurrent activities. Application in the design of OS such as Marte and Shark and in the definition of standards such as Real-time POSIX and the Ravenscar profile.

Design and analysis of network protocols for distributed embedded systems, with particular emphasis on supporting dynamic QoS management, mainly for multimedia systems, flexible scheduling, dynamic reconfiguration, graceful degradation and survivability for embedded control systems, particularly robots and vehicles.

We are leading the state of the art on Modelling Heterogeneous Systems, with many contributions having an international visibility and recognition:

- Work by INRIA, PARADES, and VERIMAG have developed a systematic method to formally model heterogeneous reactive systems [BCCC04] covering not only synchronous and asynchronous models, timed and untimed models, and their free combination, but also is able to model causality dependence relations, such as those induced by data- and control-flow dependencies. These find applications in automatic code generation from high level synchronous models on several platforms, notably asynchronous pre-emptive ones and correct deployment of synchronous designs over globally asynchronous, locally synchronous (GALS) architectures.
- Work by Verimag on the BIP framework, integrates results obtained over the past 5 years and has been implemented in a tool allowing the efficient execution of component-based specifications.
- Work by TU Vienna on a next-generation embedded architecture for Systems-on-a-Chip (SoCs) provides a predictable integrated execution environment for the component-based design of many different types of embedded applications (e.g., consumer, avionics, automotive, industrial).
- Work in Artist2 is still leading Timing Analysis worldwide. Only light competition exists in the US and in Singapore.
- Work in the Testing and Verification Cluster has international visibility, notably concerning use and wide dissemination of tools such as UPAAL, TIMES, IF, CMC, MoDeST, EMTCC, and FAST, as well as concerning results obtained in Testing and Verification. Excellent work in verification of security properties has been made for the semantic foundations and the verification of security protocols and web-services.

4.3 Impacts on the Area of Embedded Systems Design *(JPASE)*

Joint Programme of Activities for Spreading Excellence

Our actions for Spreading Excellence are at 2 levels:

1. *Targeted towards affiliated partners*
   Affiliated partners are not core members in the consortium, but receive support for travelling to Artist2 meetings, and actively contribute to the implementation of the Joint Programme of Activities (JPA). These affiliated partners include industrial, SME, academic, and international affiliates.

2. *Targeted towards the scientific and technical community in the large*
   This is achieved mainly bottom-up through the organisation of scientific events, publications, distribution of tools and components, industrial partnerships (not funded by Artist2), education; and through the Artist2 web pages.

Regarding Scientific events, we distinguish between conferences and workshops, schools, and high-level events mainly for International Collaboration.

- **High Level Events for International Collaboration**
  High-level Events are intended to gather together the very best world-leading experts from academia and industry, to discuss progress on the state of the art, relevant work directions.

  Three Artist2 members are on the steering board for the ARTEMIS European Technology Platform. In this capacity, they participate in working groups for defining the overall European long term strategy in the area.

- **Publications**
  The Artist2 community has been very active in publishing in scientific journals and conferences, as attested by the list of publications provided in this document. Clearly, this represents a huge amount of work. Publication of research is a bottom-up process, which may seem chaotic – but this is intrinsic to research.

- **Tools and Components**
  The Artist2 community plays a leading role in the distribution of software tools and components, on verification/validation tools. Some tools are distributed free of charge, such as UPAAL, IF. Others are commercialised, such as AbsInt, SymTA/S. For many other tools used in the platforms, and shared between the Artist partners, a common dissemination policy has not yet been defined.

- **Industrial Liaison**
  Artist2 has a wide array of affiliated industrial and SME partners (see the Periodic Activity Report). Most of these partners have participated in some way in the Artist2 technical meetings and the overall effort. There is strong, high-level industry participation through the various Spreading Excellence events organised by Artist2. Our active involvement in the European Technology Platform ARTEMIS also could have a significant and long-term impact.

  In addition, each Artist2 partner has an outstanding track record for interaction with industry. Globally, the Artist2 consortium has a very strong impact on European R&D in embedded systems, through participation in the three main Integrated Projects: DECOS, ASSERT, and RUNES. This impact is visible via the achievements in these Integrated Projects, related to time-triggered architectures and modelling and validation at the architectural level.

  We believe that the strong involvement of four main Artist2 partners in the SPEEDS Integrated Project has a very positive impact on progress in the state of the art, in component-based embedded systems engineering.

4.3.1 Spreading Excellence and Impacts on other European groups

Here is a non-exhaustive list of highlights of Artist2 impacts on other groups. All Artist2 teams have strong contacts and impacts on outside teams.

Contacts with oth NoE's in the area:

- Artist2 has initiated contacts with the HiPEAC and HyCon NoEs, in particular to discuss possible interaction and to provide some common input to the Artemis ETP definition.

In Year2, interaction with HiPEAC and HyCon also occurred at the cluster level.

- Interaction with HiPEAC took place through the Compilers and Timing Analysis cluster, around the respective compilation platforms (gcc for HiPEAC and ACE for Artist2.).
- Interaction with HyCon occurred mainly through the Control for Embedded Systems cluster. Furthermore, some collaboration started with the Adaptive Real Time cluster. Giorgio Buttazzo has been invited as a co-Program Chair to organize the International Conference on Hybrid Systems: Computation and Control (HSCC 2007).

ARTEMIS ETP

- Several Artist2 partners, including OFFIS, PARADES, VERIMAG; and TU Vienna, are actively involved in the ARTEMIS ETP, in particular leadership and active contribution to the Working Groups for the Strategic Research Agenda (SRA).
- Joseph Sifakis has been responsible of the ARTEMIS sub-group on Technology Frontiers, in which representatives from these other NoE's were represented.
- Artist2 teams (Saarland University and OFFIS) are strongly involved in the in the Transregional Collaborative Project AVACS, financed by the German Research Council (DFG).

Interaction with other groups:

- The Execution Platforms cluster gathers together most of the relevant European research teams on the topic, and has strong links to all the other relevant teams outside Artist2, such as: TIMA/Ahmed Jerraya; IMEC's MPSoC research team; University of Dresden, Hermann Härtig; Universita degli Studi di Verona/Electronic Design Automation (EDA) group, Prof. Franco Fummi; University of Southampton,/Electronic Systems Design Group, Prof. Bashir Al Hashimi.

New project proposals:

- Artist2 teams are the driving for setting up a large Danish national research project aimed at coordinating the national activities within embedded system design in order to strengthen the industrial development and innovation, as well as research and PhD education.

Embedded Systems Institute in Eindhoven

- The Scientific Director of the Embedded Systems Institute (ESI) in Eindhoven, Ed Brinksma, is prominent member of the Artist2 NoE and sits on the Strategic Management Board. His appointment at the ESI ensures that the vast number of large industrial research projects on embedded systems carried out on routine basis by this center will be connected to the Artist2 NoE.

4.3.2 International Impacts outside the EU

Here is a non-exhaustive list of highlights of Artist2 impacts on groups outside the EU.

- The Real Time Components cluster maintains close ties with the CHESS project of NSF[1]. CHESS collects major US teams from key universities[2]. Also, close ties exist with teams working on the area of *Discrete Event Systems* originating from control, as well as the teams working on *Hybrid Systems*[3] and *Communication and Control*[4]. The work on standardization in OMG is done in strong collaboration with Carleton University Canada (Dorina Petriu and Murray Woodside).
- The Adaptive Real Time cluster had several interactions with the following research teams University of Illinois at Urbana Champagne, University of Virginia, University of California at Berkeley, Carnegie-Mellon University
- The Compilers and Timing Analysis cluster has strong ties to the Architecture and Compilers for Embedded Systems (ACES) group of Prof. Nikil Dutt at University of California, Irvine and the group of Prof. Rajeev Barua at University of Maryland at College Park focus on memory aware compilation and optimization issues.
- The Timing Analysis teams have links with Seoul National University (continuous exchange of PhD students and PostDocs), Florida State University, and Singapore National University.
- The Execution Platforms team has strong link with the main research groups in the area outside Europe, including: The University of North Carolina at Chapel Hill (Sanjoy Baruah and Jim Anderson); UC Berkeley (Jan Rabaey), MIT (Anantha Chandrakasan); University of Michigan (David Blaauw); Penn State University (Profs. Vijaykrishnan Narayanan, Mahmut Kandemir and Mary Jane Irwin); Carnegie Mellon University/System Level Design Group (Radu Marculescu),
- Teams from the Control for Embedded Systems cluster has strong ties and interaction with Carnegie Mellon Software Engineering Institute, US Army/AMCOM and Honeywell Labs.
- The Testing and Verification cluster has strong links to the work on software verification and testing taking place at Microsoft Research, Redmond, (Ball), NASA Ames and Kestrel Technologies (Holzman, Visser and Havelund) and Kansas (Hatcliff). Extraordinarily strong links exist to Parades (Sangiovanni Vincentelli), Rice University (Vardi, longstanding collaboration with Pierre Wolper on the highly appreciated and influential automata theoretic approach).

[1] http://chess.eecs.berkeley.edu/ : Center for Hybrid and Embedded Software Systems

[2] http://chess.eecs.berkeley.edu/people/project_personnel/

[3] http://hscc06.csl.sri.com/ is the conference of this domain

[4] See the control conference CDC'2005 http://www.esi2.us.es/~cdcecc05/ where a –plenary has been devoted to this topic.

4.3.3 Impacts on Industry

Here is a non-exhaustive list of highlights of Artist2 impacts on industry.

- The activities of the Real Time Components cluster are relevant for those industrial sectors where there is a need for mastering system integration of complex heterogeneous embedded systems. Two sectors are particularly active and have concrete, immediate needs: Aeronautics and Automotive. The teams in this cluster have tights links to leading industrial partners, e.g. through IST-Integrated Project "SPEEDS", and events such as the "Beyond Autosar" workshop held in Innsbruck this year. Specific effort has been dedicated to interacting with the automotive industry. This effort was made possible thanks to prior personal strong ties that some key participants (including: Werner Damm (OFFIS), Martin Törngren (KTH), Rolf Ernst (U. Braunschweig)) and affiliates (including: Stefan Kowalewski (RWTH Aachen)) of ARTIST2 had with the Autosar consortium.
- The Real Time Components cluster is, through CEA, Cantabria, and Thales, the driving force in the work of developing a profile of the Unified Modeling Language (UMLTM) for MARTE (Modelling and Analysing of Real-Time and Embedded systems).
- Work in the Compilers and Timing Analysis cluster is particularly relevant for industry. Work and tools on Compilation techniques are important for ST Microelectronics, in particular for generating code meeting given non-functional requirements for audio and video processing and data streaming applications in the TV, Set Top box, DVD player and recorder, mobile, base stations, printer and disk drive markets.
- Technology from AbsInt (Timing Analysis activity) is used by Airbus and the Critical Systems industry.
- Dortmund's cooperation with AbsInt (Timing Analysis, Execution Platforms activities) and the Universities of Bologna and Linköping exceeds expectations. Future opportunities include a commercialization of some of the results, for example through COWARE, ACE, AbsInt or ICD, a technology transfer centre located at Dortmund and headed by Peter Marwedel. The latter commercializes compilation techniques for network processors.
- The active participation of key industrial players such as STM and ACE (Compilers activity) is being intensified, and new upcoming research challenges are continuously taken up together by the participants in order to exploit synergy effects right from the start.
- ACE works closely with ST and with Philips having both a commercial relationship with them as well as being co-members of EU project consortia – in one case along with Verimag.
- Within the EmBounded Project (IST-510255) AbsInt is also involved in the development of the Hume compiler, a domain-specific high-level programming language for real-time embedded systems (Timing Analuysis activity).
- Furthermore, partners in the Compilers and Timing Analysis cluster are involved in the projects: MORE and SHAPES Integrated Project.
- Work done in the Execution Platforms cluster is relevant for the automotive industry, which is currently in a fast and spectacular evolution towards the intelligent, safe, environmental, interconnected, and economic car.
- Due to ARTIST2 activities involving Real Time Components and Execution Platforms, (e.g. the ARTIST workshop "Beyond AUTOSAR" in Innsbruck) several technical

meetings between TU Braunschweig and leading automotive suppliers in the AUTOSAR context held place. A main topic discussed was how compositional performance verification methods can be used in the automotive design process to facilitate the network integration problem. TU Braunschweig was invited to the SAE world congress 2007 in Detroit to present recent results in compositional performance verification.

- Work done in the Execution Platforms cluster is also relevant for the SoC and NoC architectures, where several lower performance computation nodes are cooperating in order to globally achieve the expected performance. The University of Bologna has a strong, ongoing collaboration with ST Microelectronics and FreeScale on these topics. It is co-developing low-power system interconnects, as well as energy-efficient level-one memory architectures for on-chip processor tiles. It is also cooperating with FreeScale, to develop a complete software infrastructure for power management within the Linux operating system. Finally, it is involved in the CLEAN IST Integrated Project.
- Teams from the Control for Embedded Systems cluster have strong working links with Volvo, ABB, Ericsson, and are involved in the IST Projects RUNES, SOCRADES, and ATESST.
- An Open Repository for Test and Verification Case Studies (https://bugsy.grid.aau.dk/artist2) has been set up, and includes case studies from: Danfoss (Aalborg); Ericsson Telebit (Aalborg); Ericsson (Uppsala); Felix Ingrat at the LAAS Laboratory in Toulouse, France (Verimag); TK Systemtest (Aalborg); Skov A/S (Aalborg); ESI (Embedded Systems Institute, Eindhoven).

4.4 Managing the Network of Excellence (JPMA)

Joint Programme of Management Activities

We believe that the current two-tiered Management structure - dividing the management amongst cluster leaders and the Strategic Mangement Board composed of both cluster leaders and a limited number of other selected prominent core partners – is the right one for managing such a large research entity. It provides the right combination of flexibility and accountability, while leaving room for innovation and evolution.

Within the consortium, we have refined the reporting procedures, and strengthened the monitoring.

5. End Results

At the end of the NoE, we expect to achieve a more integrated community, in which the fragmentation by topics and communities will fade. This will be implemented through the disappearance of the currently existing clusters. This will take time, to create convergence of interests, and allow the emergence of recognized leaders. This will also require progressive changes to the consortium, by including new members and removing others.

We are currently promoting the emergence of Centres of Excellence in the area. For this, we are actively monitoring the evolution at national and European level, and positioning the NoE so as to be in line with this evolution.

A complete list of the detailed expected end results is provided in the Project Timetable / Milestones available in the overall Periodic Activity Report.

ARTIST 2

Network of Excellence

IST-004527 ARTIST2:
Embedded Systems Design

Periodic Activity Report for Year 2

Joseph Sifakis – Artist2 Scientific Coordinator

Bruno Bouyssounouse – Artist2 Technical Coordinator

Artist2 Consortium

Table of Contents

1. Overview

1.1 Project Objectives and Major Achievements

A detailed description of objectives, and particularly the main aims for integration, is provided for each cluster in the sections labelled « State of Integration in Europe ».

1.1.1 Historical Perspective

Before setting up the Artist2 NoE, a subset of the current consortium implemented an FP5 Accompanying Measure, whose objectives were to:

- Coordinate the R&D effort in the area of Advanced Real-time Systems
- Improve awareness of academics and industry in the area
- Define innovative and relevant work directions

This was achieved through work along 3 axes:

- Roadmaps for selected actions: (Hard Real Time, Component-based Design, Adaptive Real Time, Execution Platforms)
- International Collaboration
- Education

Information about these results is publicly available:

http://www.artist-embedded.org/Roadmaps/

1.1.2 Current Relation to the State of the Art

The NoE's current relation to the State of the Art is provided in the deliverables for this review:

- This document:
  sections "Description of the Area", for each Artist2 cluster.
- Each of the sections called "Brief Description of the State of the Art", provided within each of the 24 activity deliverables.

1.2 Workpackage progress of the period

Given the size of this NoE, and the structuring by clusters, this information is provided in detail in sections 3-10 of this document.

1.3 Deliverables for the Reporting Period

The due date for all the Year1 deliverables was August 31st, 2005.
The delivery dates are provided per deliverable below.

WP0 JPMA: Joint Programme of Management Activities

CDC	D1-Mgt-Y2 Year 2 Project Management Report		
UJF/VERIMAG	D2-Mgt-Y2 Year2 Project Activity Report		
	Executive Overview		
	chapter 1	Overview	
	chapter 2	Real Time Components	RTC
	chapter 3	Adaptive Real Time	ART
	chapter 4	Compilers&Timing Analysis	Compilers&TA
	chapter 5	ExecPlatforms	Execution Platforms
	chapter 6	Control for ES	Control
	chapter 7	Testing&Verification	Test&Verif

WP1 JPIA: Joint Programme of Integration Activities

UJF/ VERIMAG	D4-RTC-Y2	Component Modelling and Verification (Platform)	RTC
Scuola Sant'Ana	D11-ART-Y2	A common infrastructure for adaptive Real-time Systems (Platform)	ART
Saarland	D14-CTA-Y2	Timing - Analysis (Platform) + AIR Specification	Compilers&TA
Aachen	D15-CTA-Y2	Compilers (Platform)	Compilers&TA
DTU	D19-EP-Y2	System modelling infrastructure (Platform)	ExecPlatf
KTH	D23-Control-Y2	Design Tools for Embedded Control (Platform)	Control
Aalborg	D26-TV-Y2	Testing and Verification Platform for Embedded Systems (Platform)	Test&Verif

WP2 JPASE: Spreading Excellence

UJF/ VERIMAG	D3-Mgt-Y2	Report on Spreading Excellence	Global

WP3 JPRA : NoE Integration - Research Activities

Uppsala	D6-RTC-Y2	Forums with specific industrial sectors (NoE Integration)	RTC
INRIA	D7-RTC-Y2	Seeding New Work Directions (NoE Integration)	RTC
UP Madrid	D8-ART-Y2	QoS aware Components (NoE Integration)	RTC
Bologna	D16-EP-Y2	Resource-aware Design (NoE Integration)	ExecPlatf
Lund	D20-Control-Y2	Adaptive Real-time, HRT and Control (NoE Integration)	Control
Twente	D24-TV-Y2	Quantitative Testing and Verification (NoE Integration)	Test&Verif

Please note that workpackages WP5-WP10 concern only Cluster integration (not NoE Integration), and do not include the Platforms (which are in WP1).
Workpackage 4 (Modelling and Components) was halted at the end of Year 1

WP5 JPRA: Real-Time Components

CEA	D5-RTC-Y2	Development of UML for Real-time Embedded Systems (Cluster Integration)	RTC

WP6 JPRA: Adaptive Real-time

Cantabria	D9-ART-Y2	Flexible Scheduling Technologies (Cluster Integration)	ART
Kaiserslautern	D10-ART-Y2	Adaptive Resource Management for Consumer Electronics (Cluster Integration)	ART
York	D12-ART-Y2	Real-Time Languages (Cluster Integration)	ART

WP7 JPRA: Compilers and Timing Analysis

Saarland D13-CTA-Y2 Architecture-aware compilation (Cluster Integration) Comp&TA

WP8 JPRA: Execution Platforms

TUBS D17-EP-Y2 Communication-centric systems (Cluster Integration) ExecPlatf

Bologna D18-EP-Y2 Design for low power (Cluster Integration) ExecPlatf

WP9 JPRA: Control for Embedded Systems

Lund	D21-Control-Y2	Control in real-time computing (Cluster Integration)	Control

UPVLC	D22-Control-Y2	Real-time techniques in control system implementations (Cluster Integration)	Control

WP10 JPRA: Testing and Verification

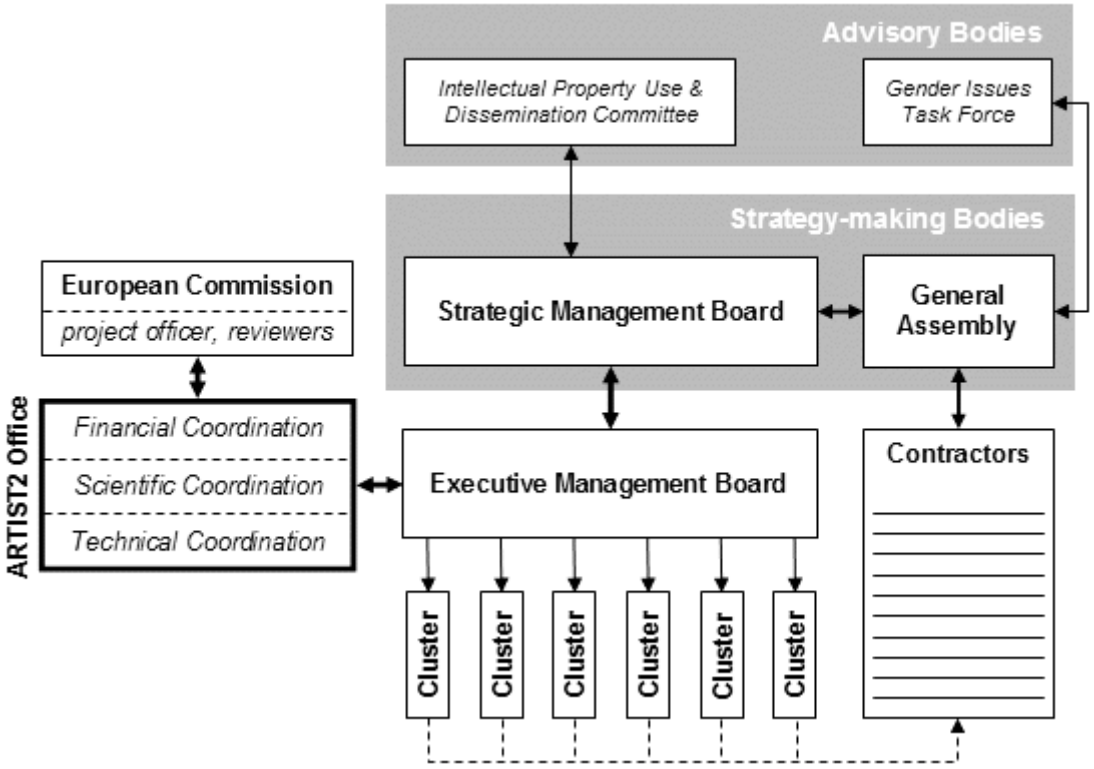
Twente	D25-TV-Y2	Verification of Security Properties (Cluster Integration)	Test& Verif

1.4 Consortium Management

1.4.1 Governance Structure

Scientific Coordinator:	Technical Coordinator:
Joseph Sifakis	Bruno Bouyssounouse
Tel: +33 4 56 52 03 51	Tel: +33 4 56 52 03 68
Joseph.Sifakis@imag.fr	Bruno.Bouyssounouse@imag.fr
Mailing address: Verimag Laboratory - Centre Equation - 2, ave de Vignate - 38610 Gières - France	

The methodology adopted for achieving the JPA objectives follows the same lines as for managing a laboratory. The activities, their objectives, their technical description, the partners involved, their roles, and the resources available have been clearly defined in the initial Description of Work, and updated in the deliverables. This will be monitored and guided by a tight and rigorous management, as defined in the diagram below:



The main governance bodies are:

The **General Assembly** is composed of one representative per core partner. It is convened at the beginning of the project and meets once per year. It is chaired by the Scientific Manager.

The **Strategic Management Board** is initially composed of the NoE cluster leaders, and a representative of the Coordinator – who attends, with no voting rights. It is chaired by the Scientific Manager, assisted by the Technical Manager. It meets at least once per year –

close to the General Assembly meeting. Its members are elected by the General Assembly every two years, according to modalities to be determined in the Consortium Agreement.

The **Cluster Leaders** (who compose the Executive Management Board) are responsible for the overall coordination of the activities led by their cluster. A cluster functions as a virtual team – with a degree of autonomy for defining its internal meetings and day to day management.

1.4.2 Partners Involved

This is provided in the publishable Executive Summary, in the first part of this document.

1.4.3 Contractors

There are no changes to the consortium at the end of Year 2.

1.4.4 Project Timetable

The JPA is organized into activities. The activities should not be considered as tasks of a workprogramme, with begin/end and synchronisation dependencies. Of course, the detailed description of an activity could be decomposed into sub-tasks and intermediate milestones, but this would imply a granularity that is too fine for research activities.

The inter-dependencies between activities are complex and rich, and will evolve dynamically. The work plan and major milestones for the activities are provided in cluster description, and repeated in the 18 month workplan.

1.4.5 Other Issues

None

1.4.6 Plan for using and disseminating the knowledge

The main instruments for using and disseminating knowledge are:

- Workshops and Schools organised.
  The list is quite impressive, and is provided in the deliverable on “Spreading Excellence”.
- Artist2 Web Portal.
  Here also, the quantity of information made available to the greater embedded systems community is quite impressive, and continusouly growing. This is possible through the efforts of the entire consortium, who now have direct access for updating the contents.
- Course Materials.
  There is a growing body of course materials made available via the Artist2 web portal.
- Publications.
  The Artist2 consortium is very prolific in publishing research articles, surveys, textbooks, roadmaps, and position papers.