ITEA

Information Technology for European Advancement

ITEA DESS
Public Full Project Proposal

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Software Development Process for Real-Time Embedded Software Systems (DESS)

ITEA COMPETENCES involved:

1) Complex Systems Engineering
2) Communications
3) Distributed Information and services

February 2001

1. Elaborate Project description

General goals

The goal of DESS is to define an innovative object-oriented component based software development *methodology* for embedded real-time systems, to create supporting environments by integrating state of the art *tools* and to prove the appropriateness of the methodology by implementing several *validation test cases*. The DESS methodology will allow European industry to leapfrog in the domain of embedded real-time systems. It will provide European industry a competitive edge.

Unfortunately, diversity is the common denominator in the embedded real-time world. The number of programming languages and development methodologies in use today is as high as the number of companies developing embedded units. The reason for this diversity is the lack of broad standardized development approaches suiting all needs. As a result, general incompatibility between the different strategies prevents reuse and co-operation.

It is therefore of uttermost importance to the future of embedded software development to focus on making the DESS methodology a common standardized asset. This however requires a broad view on the subject, a view that can only be achieved by merging the expertise from various partners working in diverse domains. This makes co-operation essential.

In addition, a broad methodology increases its formal or de-facto standardization capabilities. Tool vendors will be forced to implement such a widely used methodology into their products. Standardization and tool support creates a gateway to general acceptance of DESS outside the consortium.

Tasks

To manage the DESS project in the best possible way we use the following work breakdown structure:

WP1: Study and define the methodology

The goal of the DESS methodology is to provide an instrument that brings the benefits of modern Object-Oriented (OO) development strategies to the embedded world with its unique constraints of limited time and memory resources.

The methodology will lead the developer to innovative architectures that are *extendible*, *evolution capable* and *reusable,* as building families of products is an important aspect of modern projects. In the embedded context these goals can only be achieved when the timing and memory requirements are handled as early in the development cycle as possible. The way to meet these goals is through component-oriented development techniques focusing on both the development of components as well as on component architectures. Besides these primary goals, other requirements are to be met as well.

The methodology will be built on top of existing modelling languages and methodologies and extend their semantics where necessary. Code generators will be available to support fast design-to-code mappings.

WP2: Tailoring supporting development tools

The second cornerstone of DESS is the creation of development tools. No matter how fundamental a methodology is, good software development tools are essential to its successful adoption. This perception gets more important as the complexity of software grows.

As with the methodology, the idea is to take several existing tools used by the consortium partners or otherwise available on the market and extend their functionality where necessary. Integration of the methodology into several tools is important for acceptance of DESS in the

highly diverse embedded development market. How far this tool integration can go will depend on the extension capabilities of the existing tools. It is not the general goal of DESS to develop one 'big' tool that would be commercially exploited.

WP3: Validation test cases

The third DESS cornerstone is to prove that the methodology is well suited for its purpose through the development of validation test cases. The test cases will come from diverse domains making sure all aspects of real-time embedded systems are covered and handled adequately by the DESS process. Defining a too domain specific methodology would jeopardise its broad acceptance. In addition, though the test cases will be small enough to enable the full development to be performed in the foreseen time frame, the complexity of the test cases will be high enough to yield good judgement over the methodology and the tools.

WP4: Standardization and dissemination of results

It is the firm will of all the partners in the DESS project to disseminate the information about the approach proposed by and the results attained by this project, in order to reach the highest number of possible users and interested companies in the field. We reckon the outcome of the DESS project could reach the status at least of a de-facto standard, given the conspicuous and distinguished participation to the project by European industries and research institutions. Nonetheless, the management board of the DESS project will act proactively toward official Standard bodies whenever applicable and will participate in official calls of OMG to achieve the goal to make the DESS methodology a standard. As a second track, we will establish a 'Methods and Tools' board and invite tool vendors to participate in that board. The idea is to inform them as early as possible about our findings and conclusions and to motivate them to include DESS elements in their products.

For dissemination purposes, the DESS results will be published as a complete and integrated approach in embedded system design and development. Internal and external promotion of the project results will be organised through a web site with public and privileged access rights, through paper submissions to relevant conferences and through participation in exhibitions etc. External promotion might, as well, include presentations to specific users and tool developers both in Europe and in the US.

WP5: Software development process

Clearly, defining a method with all its powerful notations and providing supporting design and implementation tools in not enough to transform an idea into a working product. One also needs to adopt a suitable development process, defined in conformance with the underlying methodology, relying on available tools, and customizable according to the application domain.

The software process management work package will model the development activities, specifying the working details, to what phase they relate (i.e., when they have to be carried out), what are the conditions for initiating and finishing the activities, what resources (both human and tools) they need, etc. This process model will provide a set of guidelines for the users of the DESS methodology, and will be the base for possibly automating the most trivial parts of the process.

The development process includes management activities as well as technical development. Therefore, the DESS process models will cover both, providing guidance to both technicians and managers.

Technical and strategic relevance for European software technology, including a listing of the ITEA competence's addressed, and how these will benefit from this project

For the realisation of the DESS goals the following underlying technologies are needed.

- Object Oriented Analysis, Design and Programming (OOA, OOD & OOP).
- Standardised design notation (i.e. UML with RT extensions).
- State of the art CASE-tools.
- Executable visual modelling languages.
- Requirement tracing and management tools (at least for timing and memory footprint impact calculations).
- Component architecture concepts.
- Automatic code generation.
- Automated testing and regression testing
- Process modelling and enactment.

The strategic relevance of this ITEA project is significant for the European industry and will be even greater in the future. Over five billion processors (mostly embedded processors) are sold every year [1] [2]. Thus, many millions of products, with ever increasing functionality and complexity are coming into the market while their functionality will be more and more software based. More reliable and faster software design methods are therefore mandatory to be on time with your products. Moreover the major current methodologies and tools are non-European. This makes European companies dependent from Non-European (US) technologies. This dependency is very threatening as it is generally expected that the embedded real-time market will concentrate around a few main players (for instance RT Java) [3] [4].

Simplicity and transparency are requirements to get the new methods from DESS accepted by software engineers and by industries developing supporting tools for them. An objective in DESS is to communicate the DESS methods to a broader group of users and interested parties and to get working standards for them.

The following technologies are ultimately aimed for.

- Fully automated tracing of the customer requirements up to the lines of code.
- Fully automated testing of all customer requirements and worst case scenarios.
- Easy implementation of change requests and subsequent testing.

The results of this project address the following ITEA competence's.

- **Complex System Engineering**. In the DESS project research will be conducted on all the three main aspects of this competence. The aspects and the related work packages and tasks are the following.

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[1] IEEE Spectrum, January 1999, Technology 1999, page 38.

[2] In 1997 the world market of electronics products had a volume of 2300 billion dollars, of which 17% in consumer electronics products. The growth in that year was 12% and will be at about the same level in the coming years (Embedded Systems, February 1999, page 13 (in Dutch)).

[3] The Object Management Group has published at 13-03-1999 a Request for Proposal called "UML ™ Profile for Scheduling, Performance, and Time". Submissions due: December 20, 1999.

[4] According to the European Information Technology Observatory's latest annual assessment, America boosted its information technology outlays from 4.08% of gross domestic product in 1996 to 4.53% in 1997. Meanwhile, Japan weighted in with just 2.61% of its GDP, and Western Europe with only 2.34% (Business Week / May 3, 1999, page 16).

  - Representations for system architectures and effective instantiation of these architectures to specific application systems in WP1 / tasks 3 / 8.
  - Building system engineering processes, methods and techniques in WP 1, 2 and 5.
  - Methods and tools for system simulation and formal validation and verification in WP1, 2, 3 and 5.
- **Communications** and **Distributed Information and Services**. The partners in DESS are working in the given application areas. They are, of course, familiar with the characteristics of these areas and their specific challenges. By co-operating in DESS each partner has the opportunity to maximise the results of DESS with respect to their specific challenges. The consequences of these results are improved architectures of new designs at lower costs. So, indirectly, both ITEA competence's are truly supported.

Market relevance and timing

This project secures the competitive power in the following European industry sectors.

- Consumer applications like audio/video, telecommunications, automotive, computer.
- Professional applications like scientific, broadcast, military, medical, robotics and avionics.

This objective is reached in DESS by integrating the knowledge and experiences from a broad group of companies working in different industry sectors and by developing in the project a generic methodology for embedded systems. The resulting methodology is flexible and can be adapted for each specific situation. The broad group of companies working in this project is a solid base for its acceptance.

It is expected that the first practical results of the dissemination and standardisation activities (WP4) will be obtained in the very last phase of the project, where the base for these results is laid during the project. Products using the output of this project may therefore be expected in about three to four years.

As already noted the major current methodologies and tools are non-European. This makes European companies dependent from Non-European (US) technologies. A goal of DESS is to increase the influence of the European players in this market.

Finally the following items should also be noted.

- The results of DESS will increase the quality of products by re-using tested / certified components.
- Development costs will decrease while the recurring costs will reduce by using the DESS results.

Exploitation and Dissemination of Results

Given the relevance and the importance of this subject we have decided to implement these activities in a separate, targeted work package. This will guarantee that exploitation and dissemination of results will receive a prominent place in the project.
It should be stressed that the intention of this project is to make DESS as widely available as possible. As a result, the consortium partners agreed to make the methodology freely available to the public.
The objective is to publish DESS results as a complete and integrated approach in embedded system design and development. Internal and external promotion of the project results will be organised, establishing and maintaining external relations, and monitoring and influencing relevant standards if applicable. Furthermore a web page will be organised with pages with different access right both public and reserved to partners and to other ITEA consortia.
External promotion will cover efforts like paper submissions to relevant conferences, workshop participation, advertising material, attending official conferences, exhibitions and

fairs, once the project will have reached demonstrable results. External promotion might, as well, include presentations to specific users and tool developers both in Europe and in the US. The DESS project will act proactively toward official Standard bodies whenever applicable to achieve the goal to make the DESS methodology a standard. To improve the possibility of making DESS a standard, we will participate in official calls of OMG to enter input for real-time extensions of UML[5]. As a second track, we will establish a 'Methods and Tools' board and invite tool vendors to participate in that board. The idea is to inform them as early as possible about our findings and conclusions and to motivate them to include DESS elements in their products.

Influence on employment

The activities proposed in this ITEA project proposal help to improve the position of the European industry in the international competitive domain of embedded real-time systems engineering. An important goal of the DESS project is to increase the skills and the craftsmanship of its partners' software developers by the development of a new and validated software methodology and tools. This will lead to standardisation of languages and development expertise.

Through mutual co-operation, the major European embedded software companies together develop a method for making extendible and reusable architectures for real-time environments. This leads to evolution-capable software, which lowers the costs of software in modern products.
Therefore DESS project will provide the necessary technology and tools the European industry need to meet the reduced "time to market" constraints – a prerequisite for surviving in the growing embedded market. This is a fundamental condition to influence employment on a positive way. By presentations, symposia and other means the results of DESS will be communicated to other European companies and sub-suppliers to give them the opportunity to take advantage of these results.

Complementarity to other programmes

Within the 5th Framework Programme of the European Commission the action lines IV.2.2 (Real-time systems) and IV.3.1 (Component-based software engineering) of Key Action IV (Essential Technologies and Infrastructure) of the IST programme (Information Society Technologies) are complementary to DESS. The DESS project will seek to co-operate or endeavour cross fertilisation with relevant projects within the IST program.

Complementarity to ITEA Project AutoGo:
AutoGo complements to the ITEA-project DESS with respect to content and application areas. The main focus of AutoGo is to develop techniques for the analyses and test of embedded systems, which are developed in a state of the art manner. These techniques are methodologically integrated in an overall development process. The results of the project are dedicated to the application area of automotive systems.

DESS in contrast develops a method for component based architectures mostly developed with object-oriented technology. Besides the development of architectures, issues of quality assurance are addressed also. The methodology is demonstrated in various application domains, including robotics and telematics.

[5] The Object Management Group has published at 13-03-1999 a Request for Proposal called "UML ™ Profile for Scheduling, Performance, and Time". Submissions due: December 20, 1999.

Consortium overview

In this project a consortium works together consisting of the following partners:

Companies
BARCO NV (Belgium)
Bull (Italy)
DaimlerChrysler(Germany)
France Télécom (France)
Philips Semiconductors (Netherlands)
Siemens (Germany)
THOMSON csf (France)
THOMSON multimedia (France)

SMEs
Simulog (France)
TXT (Italy)
UNIS (Czech Republic)

Universities
CEFRIEL (Italy)
Eindhoven University of Technology (Netherlands)
GMD-FIRST (Germany)
INRIA Sophia (France)
INRIA Rennes (France)
K.U. Leuven (Belgium)
Magdeburg University
University of Paderborn (Germany)

The high number of companies in this consortium is a prerequisite for the success of the DESS methodology. As it is the goal to make DESS a cross-domain asset, partners from all domains need to participate *actively* in its development. Furthermore every company invited SME's and/or universities with whom they have successfully co-operated in the past. This results in partner clusters with high homogeneity and cohesion which in turn considerably reduces the danger of miscommunication in the consortium. This limited number of partner clusters combined with the clear separation of tasks and responsibilities – for example pure research will be conducted by the research institutions – will reduce the complexity of the consortium's management. Finally a good management strategy with detailed responsibilities being controlled by the project co-ordination committee will assert that the group stays on track and focused on its objectives.

Full description of work to be performed

Remark: most of the work packages described in this chapter are further split into tasks.

Work package 1: Study and define the methodology

Goals
To define the object-oriented and component-based software development methodology for real-time embedded systems DESS, based on the best practices of existing methodologies and innovation for missing concepts.

Methodology

Defining the DESS methodology will be a three-step process and will be organised as a set of 9 tasks. The first phase will consists of the following two tasks:

Inventory of characteristics of application domains (task 1.1)

From the different application domains both the common characteristics and the characteristics specific to individual domains will be extracted.

Inventory of existing methodologies and tools (task 1.2)

This task will study existing methodologies and tools and make an inventory of elements that could be used in the DESS methodology.

The result of these first two tasks will be a proposal of existing elements to include in DESS and aspects that need further innovation.

In the second phase, the missing concepts will be developed. The results of the first phase will not yield solutions for all real-time and embedded problems like time and memory constraints, concurrency, requirement traceability and complexity. It is also possible that incompatibilities between the current solutions exist. The second phase will tackle these problems by defining adapters and new concepts.

The second phase consists of the study of two core themes (tasks 1.3 and 1.4) that have impact on the whole software development process such as analysis, design, code generation and validation. The second phase is further augmented by four tasks (tasks 1.5, 1.6, 1.7 and 1.8) that study one specific aspect of the software development process and all its implications for embedded real-time systems. These four tasks are orthogonal to tasks 1.3 and 1.4.

Timing, memory and other resource constraints (task 1.3)

Several types of constraints will be studied with their impact on the whole development cycle. The type of constraints will be based on requirements identified in task 1.1. This will lead to a methodology for addressing these constraints.

Use of components (task 1.4)

Components are an important means of establishing reuse. A study will analyse existing approaches and verify their usefulness in the real-time and embedded context. This will lead to a methodology based on components.

Code generation (task 1.5)

This task will focus on ways to eliminate the overhead incurred by using high-level concepts and parameterization in the methodology. Both statically known information and dynamically known information will be taken into account.

Validation and testing (task 1.6)

This task will develop a set of techniques for the validation of components and systems, based on inspection and simulation, and for the testing of components and systems. Requirements for an appropriate testing tool environment will be developed.

Formal methods (task 1.7)

The goal of this task is to provide a formal background that guarantees that the DESS methodology is sound and reliable. Formalization will be exploited both in the analysis and in design and implementation phases.

Requirements management (task 1.8)

This task will develop a method that will guide software developers in the process of translating customer requirements into an analysis model. An additional goal is to define a proposal for tooling support for this model and method.

The next figure shows the overall picture of the tasks in work package 1

Phase one

task 1.1 inventory of characteristics of application domains	Task 1.2 inventory of existing tools and methodologies

Phase two: Core themes

	Timing, memory and other resource constraints	use of components
software development process (analysis, design, code gen., validation)	task 1.3	Task 1.4

Phase two: Specific focus

code generation issues	task 1.5
validation / testing	task 1.6
formal methods	task 1.7
software requirements	task 1.8

In a third and last phase, a document will be written describing the full DESS methodology. This task is called **Document generation (task 1.9)**.

Risks

- Due to the large number of partners the degree of co-operation could be too low to achieve the work package goals. Setting up a project co-ordination committee, which will meet regularly to discuss these matters and take corrective actions if necessary, will prevent such a dangerous track.
- From the technical point of view, merging the different existing assets and innovative concepts might be very difficult. Regular technical meetings where uniformity of the method will be one of the key issues will tackle this risk. The firm will of all partners to come to a standardised method (see WP 4) will prevent individual partners from jeopardising the development of a common base.
- Other efforts to come to a standardised method could interfere with our project. As stated in WP4, DESS will try to influence ongoing standardisation efforts and absorb good ideas from these efforts to strengthen our own method. The ultimate goal would be to make DESS the standard the industry is looking for.

Work package 2: Tailoring supporting development tools

Goals

The general idea of this work package is that the partners extend their current development tools where possible to adopt the DESS methodology - dedicated towards a proof and validation of concepts. Where extension of the current tool is not possible, an existing tool will be chosen enabling adaptation of the methodology. Every partner will implement the most useful methodology subset with respect to his or her specific domains, development targets and programming languages.
It should be pointed out that tools are not just Computer Aided Software Engineering (CASE) tools, but also assets like frameworks and libraries.

Methodology

Work package 2 will build as far as possible on off-the-shelf tools and existing prototypes. UML is anticipated to form the core of these environments.
The concrete development plans will follow a scenario-based approach. During the initial phase of the project, the necessary development steps are defined to adopt the methodology. Also during this phase, partners mutually agree on their development activities in order to avoid replication of work. This will lead to appropriate clusters in which partners complement their development activities. A cross-section activity will be initiated to globally co-ordinate the work. The clusters will be formed on the base of the partners' commonality w.r.t. application domains, tools, platforms, methods, or others.

Risks

Commercial tools might be difficult to extend without the assistance of the suppliers. The hypothesis, however, is that many tools are provided with APIs that might be exploited for the necessary extensions. Otherwise the intended extensions should still be documented and presented to the tool providers. Wherever appropriate the participants could encourage academic partners to provide their tool basis in order to perform some of the trials within work package 3.

Work package 3: Validation test cases

Goals
The goal of this work package is to prove that the methodology is well suited for its purpose and for all market domains through the development of several demonstrator test cases.

Methodology
Each partner will participate in a cluster to provide a working demonstrator in his market domain. Implementing test cases from varying domains is important to prevent the DESS methodology form being too domain specific and jeopardising general acceptance of the methodology.

The work package is therefore organised in different tasks mostly domain specific. Identified domains are the following:

- avionics
- automotive
- communications
- mobile robotics
- medical
- info-tainment
- telecommunications
- Audio/Video consumer electronics

Demonstrators will have enough complexity to allow:

- to examine partitioning strategies
- memory and speed constraints
- prototype and production code generation
- components behaviour and interactions between

Risks
As the partners in this consortium are experts in their domain, there is no risk that they would not be able to manage the complexity of the demonstrators. The remaining risk would be the non-applicability of the methodology. Feedback to the activities in WP1 and WP2 will tackle these risks.

Work package 4: Standardisation and dissemination of results

Goals

To disseminate the DESS results and to promote the standardisation of the DESS results.

Methodology

The goals as given above are described in more detail on page 4. To realise these goals the following actions are planned.

1. The Project Co-ordination Committee of the DESS project will act proactively toward official Standard bodies.
2. We will participate in official calls of OMG to enter input for real-time extensions of UML[6].
3. We will establish a 'Methods and Tools' board and invite tool vendors to participate in that board.
4. A web page will be organised with pages with different access right both public and reserved to Partners and to other ITEA consortia.
5. External promotion will cover efforts like paper submissions to relevant conferences. workshop participation, advertising material, attending official conferences, exhibitions and fairs, once the project will have reached demonstrable results.
6. External promotion might, as well, include presentations to specific users and tool developers both in Europe and in US.

Risks

The success of the management of the risks in WP 1, 2 and 3 will be of utmost importance to have success with WP 4. We estimate that most of the success of WP 4 will depend furthermore on the perseverance of the DESS project members and the quality of their statements to bodies, vendors, conferences and other interested parties. Therefore this item and its progress will be followed very closely by the PCC.

Work package 5: Software Development process

Goals

The development of complex software like real-time and embedded applications requires an equally complex software process.

This work package aims at supporting the development process under several respects:

- Provide guidance to developers, indicating how the various development activities have to be carried out according to the methodology defined in WP1.
- Support coordination and communication among developers.
- Complement and integrate the functionality delivered by tools (like those developed in WP2).

Methodology

Work package 5 will address these goals by means of the following actions:

- Define suitable models describing the process development activities, specifying the working details, to what phase they relate (i.e., when they have to be carried out), what are the conditions for initiating and finishing the activities, what resources (both human and tools) they need, etc. The models will comply with the DESS methodology. On one hand they will be specifically tailored according to the applications' features, on the other hand it will be possible to customize them for the different developers' environments.
- Specify the functionality of a process infrastructure supporting the cooperation among the

[6] The Object Management Group has published at 13-03-1999 a Request for Proposal called "UML ™ Profile for Scheduling, Performance, and Time". Submissions due: December 20, 1999.

tools to be developed in WP2 and process-specific, human-oriented tools (such as developers' agendas, planning tools, e-mail, etc.). The DESS project will build on existing infrastructures (such as CORBA or Java RMI) as required by the methodology, the tools and the process models. The process infrastructure will support data exchange (according to a common format, possibly based on XML), and coordination information exchange (e.g., relevant event notifications).

The result of the work package will be a process support environment (equipped with a library of reference models) flexible enough to accommodate application- and user-dependent features, while specifically suited for real-time and embedded applications.

Risks

The experience of the participating partners and the exploitation of technologies already consolidated in the business processes and workflow management areas will guarantee low risk. The work package will coordinate with practically all the other WPs, since the development process is a transversal topic.

2. Project duration

Start: 01.10.1999
End: 30.09.2001

3. Rationale for funding.

In DESS quite a number of companies and institutions work together on development methods and tools for the software in its products. It can be expected that their working methods and tools are not all congruent today, but all participating companies believe that, together, they can *improve* their working methods considerably. European best-practices of all participating companies will be combined within the DESS methodology.

The great effectiveness of the DESS methodology, which improves amongst others the first phases of complex system development (analysis and design), should be stressed. For example, it has been observed that, when less than 5% of the life cycle costs (LCC) of a system has been spent in the design phase, the decisions relating 70% of the LCC have already been made. Considering that the most relevant components (more than 60%) of LCC are operation and maintenance costs[7], the huge potential advantages of the DESS methodology and tools, addressing the optimisation of analysis and design with respect to validity and therefore to operation and maintenance costs, is evident. From the above considerations, it can be inferred that the potential economic benefits of DESS greatly outweigh its research and development cost.

Furthermore by closely working together, a broad basis for standardisation of the DESS results is created. This standardisation will benefit the European software industry chain as a whole. In conclusion, Trans-European co-operation is a prerequisite for the successful completion of the DESS project.

Within software development, high investments are required to stay on track with new developments. In order to remain competitive and keep momentum by exploring these new working methods, funding under ITEA is indispensable.

[7] "Integrated Modular Avionics – part 5: How airlines will maintain next generation avionics" in Avionics November 1997

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