



Esprit

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Information Technology**

**The Project Synopses
Software Technology
Volume 3 of a series of 7**

April 1988

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The Project Synopses
Software Technology
Volume 3 of a series of 7

April 1988

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LEGEND

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I Italy
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SOFTWARE TECHNOLOGY

Introduction

This directory contains information on forty seven projects supported within the Software Technology area of the ESPRIT programme. The entry against each provides a summary of its objectives together with information on the progress made and results obtained. Further information can be obtained from the person indicated on the project sheet.

From its outset in 1984, the objective of this part of the ESPRIT programme has been to encourage the development of a scientific basis for software engineering from which a range of industrial practices can be designed and implemented.

The approach has been primarily one of viewing the software development process in the wider context of complex system development. This has ensured that the collaborative, pre-competitive research and development actions of the ESPRIT programme have addressed the real problems faced by to-day's software industry in Europe, particularly the production of high-quality software products and improving the productivity of the software development process.

To achieve these dual goals, the Software Technology programme has concentrated on four key sub-areas:

(i) Theories, Methods and Tools

The definition and development of rigorous design methods and the development of the appropriate support tools. The work covers formal methods (formal in the mathematical sense) and informal techniques, and the appropriate use of the knowledge engineering techniques.

(ii) Management and Industrial Aspects

The development of techniques for project management and production management. The complexity of many software development projects is such that they require the coordination of large development teams, the production and revision of large amounts of documentation and code, the use of distributed computing facilities, etc. Appropriate techniques are therefore needed for resource management, documentation control, configuration management and version control.

(iii) Common Environment

Clearly, the information which is generated during each phase of the development process needs to be stored in a relevant form not only for easy access by the design team and the project managers, but also for the appropriate relationships to be maintained between the various design descriptions produced as the design proceeds. To provide the mechanism for

this "object management", a common utility is necessary which provides the relational database mechanism and the relevant common interfaces for design tools, project management tools, user access etc. This common environment provides the framework within which many of the results of the Software Technology programme can be integrated to form industrial systems. Within the sub-area the first generation environment, based on the entity relationship model has already produced common interface definitions which have entered the international standardisation process, and industrial systems are available. Next generation systems eg. incorporating knowledge engineering techniques, are under development.

(iv) Evaluation and Demonstration

Proper evaluation of the environments, methods and tools within industrial contexts is crucial for the industrial take-up of the results of the programme. Therefore a number of projects have been launched to provide cost/benefit data on the use of these systems in industry.

A BASIS FOR A PORTABLE COMMON TOOL ENVIRONMENT (PCTE)

Project Number : 32

The project develops a layer of basic functionalities for a portable common tool environment. This environment will be upwards compatible with UNIX Sys. V.

The PCTE "kernel" consists of:

- Basic mechanisms for process control and interprocess communication, as well as an Object Management System (OMS) based on an Entity-Relationship model, and supporting the subschema concept.
- User interface mechanisms providing the concepts of User Agent (supporting windows, menus and other bitmap facilities, and a command language) and of Application Agent (providing a syntax-directed editor and the interface to UNIX tools).
- Distributed facilities (LAN interface and higher layer protocols).

The kernel has been evaluated by developing a few significant tools, which include a Configuration Management System (CMS) and a Knowledge-Based Programmer's Assistant (KBPA).

The specification of the tool and user interfaces are available and in the public domain. These specifications are now controlled by an independent management board launched in October 1986. Various prototypes of the PCTE functionalities have been demonstrated. Commercial implementations are already available on the market (Emeraude on Bull SPS7 and Sun 3). An Ada version of the PCTE interfaces is available in order to ensure that the PCTE can provide the basis for an efficient Ada Project Support Environment.

PCTE offers the potential for establishing a European standard for support environment interfaces enabling the growth of a software tools market and the efficient, coherent development of large systems across multicompany development teams. Links are presently being established with various European national programmes and European development agencies, and industry prospects appear good for achieving a high level of coordination.

The PCTE Interfaces Management Board (PIMB) is controlling the interfaces and will be in charge of their evolution. The designers and developers of many tools have adopted these interfaces which have also become well known in US where the Ada version is expected to have a considerable impact.

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Start Date: 01-OCT-83

Duration: 54 months

**PERSONAL WORKSTATION FOR INCREMENTAL GRAPHICAL SPECIFICATION AND
FORMAL IMPLEMENTATION OF
NON-SEQUENTIAL SYSTEMS (GRASPIN)**

Project Number : 125

The project aims at a personal software development workstation for incremental graphical specification and stepwise formal implementation of nonsequential systems. The methodological framework is characterized by an integration of formal and informal techniques in the development process:

- Structured analysis diagrams and entity relationship diagrams are used for requirement analysis.
- An extension of the "initial semantics" approach to algebraic specification and high-level Petri-nets is used in a well engineered merge for specification of large distributed systems. Rapid prototyping is provided by the analysis of abstract implementations.
- Modula and Ada-like languages are considered for the programming activity.

Semi-formal transformations of system descriptions at different levels are supported by validation and documentation activities. A set of tools supporting the GRASPIN methodology is designed on top of PCTE common tools, which makes a significant use of graphics and of concepts such as focusing techniques, multiple windowing concepts, and simultaneous handling of different contexts.

A prototype system has been implemented and successfully demonstrated.

The final architecture of the system has been defined. Facilities include support for structured analysis techniques and for the SEGRAS specification language. The workstation provides both language dependent and independent tools. Among the former are the tools for validation and verification (analyzer, simulator, testbench) as well as the tools providing the user interface. The latter (language independent tools) include plain and structure editors, a parser and unparser, and an abstract machine. This abstract machine includes the language definition system and the manipulator which interfaces with the database management system.

The two-year enhancement plan to develop a final version of the system includes transfer activities dedicated to:

- Demonstrate the use of the GRASPIN methodology.
- Prepare and disseminate basic information for users.
- The introduction of the GRASPIN workstation into scientific and industrial organisations.

- Provide a forum for regular exchange of experience.

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Start Date: 01-SEP-83

Duration: 60 months

SOFTWARE DEVELOPMENT USING CONCURRENTLY EXECUTABLE MODULES (PEACOCK)

Project Number : 266

The objective of the project is the design and implementation of a unified family of languages covering the whole software life-cycle. All languages will use the concept of "Concurrently Executable Module" (CEM), and have a common signature (abstract syntax).

The family includes a semi-formal language for requirements capture, algebraic languages for formal specification, and procedural languages for implementation.

The PEACOCK Paradigm or Pi-language will give the developer the required freedoms, (formality, completeness, abstraction) :

- Allowing all sections of a specification to be expressed in a range of degrees of formality from unstructured text through to the most formal, such as algebraic equations or path expressions.
- Allowing sections to be in various stages of completion, from empty through to complete.
- Providing explicit sections which allow the developer to capture aspects of the specification at different levels of abstraction (e.g. the type view, the concurrency view, the algorithmic view).

The project will also provide education and training material, as well as evaluation reports on field trials.

The project is due to end in March 1988. The results of the project to date can be summarized as follows :

- Definition of concepts of the Pi-language has been completed (the Pi-language is a unified set of design and implementation method/languages covering the whole of the design process).
- A single way of modelling complex systems at all levels of abstraction.
- A single "language" ranging from requirement capture to implementation.
- A uniform method of system development.
- A division of the Pi-language into sub-languages corresponding to four different views : type view, object view, concurrency view, environment/distribution view.

The type view captures the properties of the underlying type exported by the CEM, together with the properties of other types used in the construction of the CEM. The object view defines the procedural interface for the CEM, each CEM being an object manager. The concurrency view defines the concurrency

offered by the CEM in terms of how its procedures may be called. The environment/distribution view is the only one that captures the properties of a whole system of CEMs, describing how the CEMs are distributed onto processors and connected to physical devices.

Several trials have been performed with various existing methods and languages :

- A lift system.
- Airport scheduling.
- A unix environment specification.
- A can filling system.

These trials have helped to make decisions about the Pi-languages and provided a basis for the refinement of the design.

A "PRIMER" has been produced. This document covers the users guide and the specification of the Pi-language.

Finally, some industrial applications of the PEACOCK concepts are about to start (this is outside of the ESPRIT programme).

Implementation of the PEACOCK environment will take time after the end of this project, but the expected results have a large potential impact on the software industry by providing a new software development paradigm for the development of concurrent systems.

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<i>D</i>	<i>P</i>

Start Date: 01-JAN-85

Duration: 51 months

**AUTOMATED SUPPORT FOR SOFTWARE ENGINEERING TECHNOLOGY (ASSET)
FEASIBILITY STUDY**

Project Number : 267

The objective of this feasibility study was to demonstrate the technical feasibility of a proposal to develop advanced interactive graphics support for a range of methods covering each phase of the software lifecycle. The aim was to take the existing EPOS toolset out of its original framework and import it into a new generation of technology.

The final report of this study is complete. It shows that the EPOS system could be a valuable basis for developing advanced interactive graphics support.

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Start Date: 01-OCT-84

Duration: 9 months

SOFTWARE PRODUCTION AND MAINTENANCE MANAGEMENT SUPPORT (SPMMS)

Project Number : 282

The project aims at designing and implementing a system supporting all management activities in the software life cycle. One of the most important requirements of the system is the adaptability to different management methods.

The project plans to reach this objective by building a basic generic SPMMS Kernel which should be easily customisable, possibly using a rule-based approach.

Progress so far consists of:

- Specification of the SPMMS system.
- First prototype of the semantic data model.
- Complete architectural design.

Progress is being made on mapping simplified work breakdown onto the semantic data model. A subset of an organisation structure has been successfully mapped and demonstrated. Ongoing work is aimed at further validation of the semantic data model and implementation of further applications aimed at proving the sufficiency of the semantic data model. A prototype is being constructed and evaluated in a CRL environment.

The industrial world is lacking in automated systems supporting production process control and project management. This is considered as a key issue with respect to quality and productivity control. Therefore, industrialization of the final prototype could potentially have a considerable impact on software production and maintenance management.

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<i>I</i>	<i>P</i>

Start Date: 01-OCT-84

Duration: 54 months

FORMALISMS, METHODS AND TOOLS (FOR-ME-TOO)

Project Number : 283

The goal of the project was to define, implement and experiment with a technology for the systematic development, verification and validation of software systems, based on the principle of reusability of software components. The software development process, when conceived as a process with special attention given to the reuse of pre-fabricated components and to the structuring of the system to be developed into usable components as building blocks, is characterised as a combination of the "top down" and "bottom up" approaches.

Reusability of descriptions and analysis of the sequential aspects of software systems was based on a specification language defined by using some of the primitives of ASL (a kernel specification language with "loose" semantics).

Reusability of descriptions and analysis of the concurrent aspects of software systems is based on various classes of Petri nets, from condition-event nets to high level nets and stochastic Petri nets.

An environment of support tools was prepared to assist the developer in following a discipline for stepwise derivation and development of software components, for retrieval of components and for composition of software components.

Work was undertaken in the following areas :

- Study of the LPG (Langage de Programmation Générique) specification and programming language.
- Taxonomy of reusable components and requirements for a library of reusable components.
- Investigation of Petri nets (w.r.t. concurrency) and algebraic techniques.

Through an extensive use of case studies, the For-Me-Too project should improve the general understanding of components reusability within a project development. From an industrial point of view, these large scale and real-life experiments will permit a broad technology transfer.

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Start Date: 01-FEB-85 *Duration: 55 months*

RELIABILITY AND QUALITY OF EUROPEAN SOFTWARE (REQUEST)

Project Number : 300

The project aims at progress in quantification of software quality and reliability, thus enabling their specification, prediction, measurement and assurance.

The areas of work include the following:

- Identification and validation of metrics for the "quality" concept, and construction of a quantitative model for its prediction; particular emphasis will be put on robust regression methods.
- Development of metrics and models for reliability prediction, both for software systems in general and for domains requiring ultra-high reliability (eg. fault-tolerant systems).
- Investigation of the impact of using formal methods on reliability prediction and demonstration.

To facilitate the development and validation of the metrics, the project has initiated a database for industrial data on software quality and reliability.

Much of current REQUEST work can now be considered as state-of-the-art with respect to software quality and reliability modelling and measurement. In the software quality area, REQUEST has worked to close the gap that has grown up between the work on quality in the US and work in Europe. REQUEST has been able to avoid some of the pitfalls encountered by the original researchers and has concentrated on:

- Quantifiable definitions of quality factors.
- The use of quantitative quality indicators rather than checklists.
- The selection of appropriate statistical techniques for the analysis of quality metrics.
- Methods of interpreting quality indicators.
- The concept of a multi-level quality model suitable for project planning, development monitoring and final product evaluation.
- The high-level attributes (called quality drivers) which influence product quality.

The results can be divided into three areas corresponding respectively to:

- The work on quality.
- The work on model reliability.

- The work on data collection.

The REQUEST quality work has benefitted from an association with the Alvey Test Specification & Quality Management project (TSQM). This has led to the concept of producing a prototype Quality Management System (QMS) to incorporate work from both projects.

The initial development of the prototype has been completed. The implementation of the first part of the quality requirements specification subsystem (QRSS) was the responsibility of TSQM and has been delivered formally to the Alvey Directorate. This subsystem utilises the REQUEST work on quantitative definitions of quality factors, the TSQM work on quality requirement specification and the evaluation of quality specifications.

Work on modelling the reliability of single systems has concentrated on two aspects:

- The integration of testing activities and reliability modelling in order to improve the control of testing activities.
- Provision of suitable human-machine interfaces (HMI) to allow software managers and engineers to utilise reliability modelling packages more effectively.

A prototype of this interface has been demonstrated. Work on modelling the reliability of fault-tolerant systems has produced some innovative work in the area of dependency. This shows promise both as a means of quantifying the effort of dependency in models which predict the reliability of systems with multiple versions of software, and as a means of comparing the cost-effectiveness of testing and fault-tolerance in achieving required reliability levels.

The commitment of the REQUEST project to work in metric and model validation has included the collection of software project data. Besides the provision of data and a databank, this has involved :

- The development of standards of software metrics definitions.
- The development of a data model to incorporate the data requirements of quality and reliability modellers.
- Provision of guidelines to enable companies to start data collection and analysis activities.

Current research in the US is generally progressing along similar lines to the REQUEST project in all the above areas of work.

The availability of a (public) data bank dealing with software quality and reliability is of major interest for those industrials which have only a

limited experience on those fields. The large number of countries involved in the project should facilitate the emergence of European standards for metrics.

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UK	P
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F	P
D	P
I	P
F	P

Start Date: 01-JUL-85

Duration: 60 months

**INVESTIGATION OF PERFORMANCE ACHIEVABLE WITH
HIGHLY CONCURRENT INTERPRETATIONS OF FUNCTIONAL PROGRAMS**

Project Number : 302

The project investigated the functional programming approach for achieving an efficient exploitation of highly concurrent hardware architectures. This involved measurement of the complexity and parallelism of functional programs written in the FP, Lisp and Me-Too languages. The project aimed at:

- A tool for translating Lispkit and Me-Too to FP.
- Tools to provide a static measure of complexity and potential for parallelism of FP programs.
- An emulator for the parallel execution of functional programs.

The main success of the project has been in the static analysis of concurrency. A theory of complexity and parallelism for functional programs was developed based on the previous work of the partners. This was supported by the development of a complexity and parallelism analysis tool (CAT).

This analysis was based on the FP language and included the use of abstract types in the language.

Work on the parallel interpretation facility based on DACTYL was less successful. The output from this task is a study of machine architectures suitable for functional programs.

The CAT tool is an early version of a new generation of programming tools for concurrent systems. The parallel architectures now becoming generally available, require the development of such programming tools and methods to support applications programming.

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Start Date: 01-JAN-84

Duration: 42 months

RIGOROUS APPROACH TO INDUSTRIAL SOFTWARE ENGINEERING (RAISE)

Project Number : 315

The project aims at building a complete systems development environment based on an enhanced version of the VDM method.

The development process described by "project graphs" will be mathematically modelled in terms of logical systems (institutions) (eg. equational logic, temporal logic), their transformations, system descriptions in various logical systems and transformations of descriptions. Operational models of the project graphs will be related to the activities of project managers, software engineers, programmers and project librarians.

A wide spectrum language supporting specification design will be defined. Extensions of the model-based VDM method, particularly for the specification of concurrent systems, will be considered together with property-based methods and other model-based methods.

Tools supporting the RAISE methodology will be built (first in prototype form, then in production quality form), several industrial applications will be undertaken, and training and educational material will be produced.

Currently two major domains are progressing: the RAISE development method, and the RAISE specification language (RSL).

- The RAISE Development Method is taking shape; its formal basis is the Data Model that defines the elements of a specification. The notions of the RSL and one or more interaction or development languages have emerged. RSL expresses basic elements within a RAISE specification, which are termed structures. Also within RSL, basic relations that may be formed between structures can be expressed.
- The RSL syntax and semantics have been frozen until spring '88 and a preliminary tool set has been developed, to assist in the use of the RSL.

In addition to these fields of work, the first field trial of language, method and tools has started, while two other fields trial are being prepared to start in January 1988.

The system produced at the end will enhance the possibility of large scale use of VDM in industrial applications. This will be particularly the case for concurrent application domains. The industrial trials to be undertaken at the end of the project together with the educational material will improve the technology transfer process.

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Start Date: 01-JAN-85

Duration: 60 months

GENERATION OF INTERACTIVE PROGRAMMING ENVIRONMENTS (GIPE)

Project Number : 348

The main objective of the project is to investigate the possibilities of automatically generating interactive programming environments from language specifications.

Such an interactive environment will be generated from a complete syntactic and semantic characterization of the language to be used.

Such syntactical and semantical characterization will be formally expressed in a Language Definition Formalism (LDF): an inference rule-based approach and an algebraic approach are considered as the starting point for the design of the LDF.

A prototype system will be designed and implemented, consisting basically of an LDF compiler, a file system and a user interface.

Significant progress has been achieved by the GIPE project in several areas. One is the definition of TYPOL, a language for specifying static constraints declaratively; the formalism is compiled into Prolog for execution.

Another important set of results concerns the work performed on obtaining a method of enhancing 1st order algebraic data type specifications to support concrete syntax descriptions, using a sub-typing mechanism. Central to the future system to be built is the definition of the Virtual Tree Processor (VTP), which has been specified and implemented. The integration phase is now going on and a first version of the GIPE (Centaur) system has been demonstrated presenting major improvements with regard to the MENTOR system (developed at INRIA) which was a starting point for the project. One direction of work is now the improvement of the man-machine interface. Portability of those developments is assured by a software development environment common to all partners, connecting UNIX, LE-Lisp, C-Prolog, the VTP, and a virtual window manager. A port onto PCTE is envisaged.

This research-oriented project will result in a prototype system which should be easily transformed into an industrial project, very much on the lines of the Mentor system. The results should advance the understanding and implementation of semantic descriptions. The industrial applicability will also be demonstrated through well targeted experiments. It is also intended to use some of GIPE's results in the definition of a software factory (EUREKA project-ESF).

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Start Date: 01-NOV-84

Duration: 60 months

**PROGRAM DEVELOPMENT BY SPECIFICATION AND TRANSFORMATION
(PROSPECTRA)**

Project Number : 390

The objective of this project is to develop a strict methodology for program development by applying successive transformations to an initial requirement specification down to the final implementation. This of course will allow the user to prove that the implementation meets the specification, and that the program is correct. A wide spectrum language ranging from formal specifications to Ada programs will be defined with semantics covering concurrency aspects. As far as the transformation rules to be applied, these are proved to be correct once and for all. The use of Ada and Anna as a basis will ensure a high portability of the methodology. In order to support it, a collection of tools will be developed.

At each level of the methodology (from requirement specification to implementation) tools will be generated according to a uniform paradigm; this includes a syntax directed editor, a transformation and control language, a Method Bank (where rules and heuristics are stored) a Library Manager (where objects like developments and versions can be stored) and a Verifier.

PROSPECTRA is showing significant progress in a number of areas:

- At the methodology level where the abstraction and development mechanisms are now better understood.
- At the transformation level, where considerable experience has been gained by developing the OPTRAN System (a generator for batch made transformers on attributed trees).

The semantics of PAnndA-s (Prospectra Ada/Anna) - which is based on a two-valued logic - have also been stabilized, and scenarios have been designed to prospect the applicability of the PROSPECTRA methodology to practical systems.

The PROSPECTRA "basic system" is expected to be demonstrated in Spring 1988.

In addition to this general core, some work has also been carried out on Verification Techniques, one outcome being the so-called CEC (Conditional Equational Completion) System, originally based on Knuth-Bendix completion techniques.

Experiments are currently being carried out to check whether the PROSPECTRA Basic System Architecture could be based on the Cornell Synthesizer Generator, ensuring a high degree of homogeneity among the various tools being developed. PCTE is considered to be the ultimate basis for such a system.

It is expected that the PROSPECTRA project will make significant advances in

the field of the Transformational Approach (most of the partners formerly contributed to the famous CIP Project which was a leader in that direction) and bring it close to industrial exploitation. In that sense, a Demonstrator project is coupled with PROSPECTRA, and very tight links have been established between Academic and Industrial partners.

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Start Date: 01-MAR-85

Duration: 60 months

APPLICATION SOFTWARE PROTOTYPE IMPLEMENTATION SYSTEM (ASPIS)

Project Number : 401

The major aim of this project is the exploitation of state-of-the-art techniques in the fields of specification languages and artificial intelligence in order to construct tools and to support the partial automation of the first phases of the life cycle.

The main problems which will be tackled by the project are:

- Capturing the domain knowledge to be used by the assistants.
- Choosing an appropriate representation formalism for coding knowledge.
- Defining the basic architecture of assistants.
- Defining an appropriate language for interaction between assistants and users.

The final objective of the project is the creation of a set of advanced methods and tools which will permit a flexible approach to applications software production based on an interactive style including mainly:

- Rapid prototyping by interpretation of the components specifications.
- Reusability of components through knowledge based assistants.

Demonstrations of early prototype versions of the Analysis Assistant and of the Design Assistant were given in October 1987. These prototypes were based on a knowledge representation formalism called KRS (Knowledge Representation System) developed inside the project.

A migration from KRS to STRATA - a well engineered knowledge representation formalism developed outside the project by one of the partners - is planned in order to enable a concentration of efforts on the refinement of the prototypes. An early version of a rapid prototyping facility, to be included in the Analysis Assistant, was also demonstrated in October 1987. Its refinement and its strong integration with the Analysis Assistant are in progress.

A domain of application was chosen (Security Control Systems) to which all the demonstrations have been applied.

The implementation of prototype assistants for the first phases of the software life cycle and their application in an industrial domain will constitute the main impact of the project results on the European IT industry. The importance of this lies in the fact that, currently, a major source of errors in the software development process is the misinterpretation of the user requirements by the design team.

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Start Date: 01-MAR-85

Duration: 48 months

SOFTWARE ENVIRONMENT FOR THE DESIGN OF OPEN DISTRIBUTED SYSTEMS (SEDOS)

Project Number : 410

The objective of the project was the definition of formal description techniques and support tools for the development and implementation of OSI protocols and services and, more generally, of open distributed systems.

Two formal languages have been defined: ESTELLE (based on a state-machine model), and LOTOS which combines the algebraic specification language ACT-ONE and the CCS calculus.

The end results are Prototypes of :

- Syntax directed editors
- Compilers.
- Simulators.
- Debugging tools.
- Verification (proof) tools.

For both ESTELLE and LOTOS.

- Formal descriptions of a large number of OSI protocols and services.
- Ongoing work in ISO on standardization of the FDT (Formal Description Techniques) has resulted in both languages attaining draft international standard. This is expected to become an international standard in 1988/89.
- New theories for verification of protocol specifications.

A follow-up project (1265) will develop an ESTELLE workstation, and will use some real life projects in an industrial environment to demonstrate the benefit of the SEDOS approach towards protocol development.

There is a strong commitment to exploit the results of the LOTOS part of the project. Through the contribution of this project, formalisation of the development of protocols and communication software is becoming one of the most important approaches for industry to develop the increasingly complex distributed systems of tomorrow.

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Start Date: 01-NOV-84

Duration: 36 months

**AN INTEGRATED FORMAL APPROACH TO INDUSTRIAL SOFTWARE DEVELOPMENT
(METEOR)**

Project Number : 432

The objective is the application of formal methods to the process of developing industrial software. The development process will be studied and modelled by individualising building components for analysing existing methods and developing new methods of software development.

A language for requirement engineering will be defined with a semantics covering temporal aspects. Algebraic methods are adopted for specifying passive and active objects (process algebras and the algebraic specification language, ASL): denotational models of concurrent systems provide a basis for defining a calculus in which various properties of such systems can be proved.

In particular, the project aims at integrating the object-based language paradigm, the algebraic approach to software specification, the relational approach and so-called formal heuristics.

The impact on management and metrics of the application of formal methods in software development will be considered. Industrial take-up, especially in the area of constructing real-time distributed systems, is provided by the planned construction of prototype environments.

After a first (pilot) phase devoted mainly to an extensive survey of existing methods, METEOR has built up advances in several fields: requirements engineering, by means of an extension to the Entity-Relationship Model (ERAE), definition of a language for formal design (COLD), extensions to the relational algebra (ALGRES), and prototyping (RAP System). Progress has also been made in the formal specification of concurrency (ACP: Algebra of Communicating Process, an extension of Hoare's and Milner's works). First attempts are made to define and specify a so-called "software engineering database" as a basis of the software manufacturing process. The different facets of this project (which addresses most of the fields in software technology) were presented in a three day workshop held in Passau (D), 9-11 June 1987. This supported the processes of integrating the various technologies into a single framework, and their dissemination throughout industry, - key problems in projects of this type.

The project is directly intended to set up adequate formal methods to be taken over by industry (eg. telecommunication); some preliminary results have already been applied by one of the partners to one of its customers.

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Start Date: 01-OCT-84

Duration: 60 months

**AN ADVANCED SUPPORT ENVIRONMENT FOR METHOD DRIVEN DEVELOPMENT AND
EVOLUTION OF PACKAGED SOFTWARE (TOOL-USE)**

Project Number : 510

This project will develop techniques for the formal definition of methods used in the development of software. The project focuses on one main idea, namely that the building of a support environment should be parameterized by methods expressed in a development language. It will seek to achieve understanding and formal modelling of :

- The software construction process.
- The application domains.
- The target systems.

It would continue with the definition, implementation and evolution of a prototype environment for software development based on formally defined methods.

Work is currently being done in what concerns experimentation with and formalization of the methods used in the development of software. Starting from the requirements defined in an early stage of the project, a development language, which is called DEVA, has been specified and a document containing its specification delivered.

A first prototype version of DEVA is currently available for internal use of the project and some tools to facilitate its use have been demonstrated. However, since experiments in using DEVA are the prime driving force behind its design, it is not a frozen language and intensive experimentation will be handled throughout the project life. The support tools for the prototype environment parameterized by methods have already been defined. Work is also being done on the specification of a requirement requisition tool and on method advisors.

The production of environments in an almost automatic way, parameterized by the methodology used will provide the evolutionary paths to the next generation of the Portable Common Tool Environment (PCTE).

This ensures the compatibility of European industrial investment in software development facilities and will be extremely useful for setting up case studies on the use of the Development Language for Office Systems and Computer Integrated Manufacturing. Therefore the impact of this project on the European IT industry community will be of great importance.

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Start Date: *10-OCT-84*

Duration: *60 months*

PROJECT INTEGRATED MANAGEMENT SYSTEM (PIMS)

Project Number : 1223(814)

The project aims at developing a rule-based project management system to be used as a consultant or as a training system. The prototype management consultant and management instructor will be evaluated through field trials.

This project is associated with P938 into P1223.

A theoretical approach has developed the concept of a "story board" as a suitable vehicle for representing the general activity of project management.

Important insights have been gained from a series of structured interview sessions with individual project managers from the three industrial partners of the Consortium.

A tools survey has identified and appraised many commercial packages aimed at project management. Work has started at the top-most level on system design. The architecture of the first prototype has been defined, and a hardware/software environment has been agreed by all partners.

This project will have immediate impact on project management in the software industry when the resulting prototype is industrialised and marketed (scheduled in 1989).

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Start Date: 01-DEC-85

Duration: 42 months

DEMONSTRATION OF PROSPECTRA METHODOLOGY AND SYSTEM (PROSPECTRA DEMO)

Project Number : 1227(835)

The PROSPECTRA project will provide a rigorous methodology for developing correct software based on transformations, together with a comprehensive support system. Both the method and the tools represent a significant departure from the current practice in the industry. The proposed project intends to show the feasibility of applying this methodology and its support tools to real-life industrial projects, as well as providing feedback to PROSPECTRA itself.

Formally this project is associated with P800, P1265 and P1271 into P1227.

Technology transfer actions (by means of courses taught by some academic members of the PROSPECTRA project) have been undertaken and it is intended to increase this transfer by having some members participating directly in PROSPECTRA itself.

Preliminary experiments have been conducted on specifying some examples with PANndA-S, data being collected about the way the PROSPECTRA methodology is understood by its users.

The next step of the project will be to import the PROSPECTRA Basic System and perform large examples with it. Key points to be checked are the effectiveness of the methodology and the efficiency of the system. It is the aim of the partners to gradually introduce this new technology in their industrial practice.

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Start Date: 01-JAN-86

Duration: 36 months

**FORMAL DESCRIPTION OF ARBITRARY SYSTEMS BY MEANS OF
FUNCTIONAL LANGUAGES (FORFUN)**

Project Number : 881

The project aims at developing a prototype of a general purpose system description environment based on the so-called "system semantics".

System semantics is an extension of the denotational semantics of programming languages in the sense that it is applicable to arbitrary systems: various properties of a system are described by corresponding meaning functions.

A prototype general purpose system description environment based on functional languages and extended with primitives of system semantics will be developed.

Another goal of the project is the design of a prototype system description language for the following two areas: analogue electronic circuits and digital systems (including VLSI).

Initial studies have demonstrated the feasibility of the approach, viz:

- In the domain of digital systems the studies have included the structural and synchronous behavioural semantics, the asynchronous behavioural model, the description of finite-state automata and the relation between structure and behaviour. Large examples have been worked out in detail to explore the potential of the approach.
- Syntactic constructs for the description of bi-directional systems have been partially defined.
- In the domain of analogue systems, a design method for broad-band amplifiers has been outlined. Current work is giving attention to transformational reasoning.
- An initial specification of a support environment has been produced.

The prototype system description language will be applied in two areas of high potential industrial interest:

- Analogue electronic circuits.
- Digital systems (including VLSI).

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DEVELOPMENT OF AN EFFICIENT FUNCTIONAL PROGRAMMING SYSTEM FOR THE SUPPORT OF PROTOTYPING

Project Number : 891

The aim of this project is to develop a functional programming system for the efficient support of prototyping.

Investigation and definition of capabilities and uses of a functional programming system will be examined in the following areas:

- Rapid prototyping.
- Efficient code generation for functional programs to be processed on conventional sequential hardware.
- Programming in the large - binding and modularity being the main issues.
- Persistent object management for long term storage.

A prototype system will be developed to demonstrate the approach.

A hospital dispensary study is in progress as a model application.

From the results obtained, further work on the programming environment is being done at ICL.

The steps preceding industrial application are:

- Development of functional programming in the large (for large projects).
- Development of a functional programming system as a prototyping environment, with various application areas such as industrial process and data base design.

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Start Date: 01-DEC-86

Duration: 36 months

**ADVANCED INTERACTIVE DEVELOPMENT
OF DATA-INTENSIVE APPLICATIONS (DAIDA)**

Project Number : 892

The project DAIDA aims at the definition and prototype implementation of languages, methods, software tools, and environments to support the interactive development, and maintenance of database-intensive information systems. Particular emphasis is placed on integrating all of the life-cycle stages of information systems development with each other and with system maintenance. To achieve this goal, a knowledge base management systems (KBMS) perspective is taken. The idea is to go beyond "expert systems" for software development in viewing the evolving results of analysis, design and implementation themselves as cooperating knowledge bases, rather than just accessing external existing expert systems.

Three layers of development have been identified :

- For modelling and requirements specification, a System Modelling Language (SML) and a design support environment will be developed, including an SADT-like interface and PROLOG-based prototyping and theorem-proving tools for validation and verification.
- For logical system design, the language TAXIS is being redesigned as a pure design language (TDL) with predictive specifications for transactions; the TDL environment will include editors, viewing and prototyping.
- For database structure and transaction design and implementation, an environment for the database programming language DBPL will be built which includes syntax-oriented components as well as database and transaction design tools.

Each level will be equipped with knowledge-based mapping assistants that support the realisation of requirements set by the level above. A global knowledge base manager observes the development process and records information about the use of the development environments; this information subsequently facilitates efficient and consistent maintenance of the multi-layered system representation. The basis of SML as well as of the global KBMS is the Conceptual Modelling Language (CML). The hardware/software environment is based on advanced workstations (Sun-3 and Micro Vax), making intensive use of BIM-PROLOG.

After a preparatory phase, work progressed in parallel in a number of key project areas, including language design (SML, TDL), functional analysis of the knowledge-based tools (mapping assistants, global KBMS) and design of the DAIDA development support environments (prototyping, user interface questions, architectural integration of tools).

The main achievements of the first year of the project can be summarised as follows:

- The extensions from CML to a Systems Modelling Language have been

identified ie. the addition of features of the specification Language Z.

- A first TDL design was completed that largely satisfies the diverse requirements of compatibility with SML (designing from functional specifications in the context of a world model), DBPL (designing for modular relationally oriented database programming), and PROLOG (design into full functional prototypes).

Substantial progress towards concepts for a uniform design of the SML, TDL, and DBPL environments and initial experiments with existing components to be included has been achieved.

The overall aim of the project is to contribute in the definition and implementation of tools for the production of quality software products in the domain of data-intensive applications. Behind the chosen approach is the conviction that the problem of software engineering is not solvable in general using current technology, the need for introducing knowledge-based environments for all steps in the software life cycle is thus identified.

The impact of this project is the increase in productivity and in quality of the software products that the European IT industry can achieve by using the techniques developed.

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Start Date: 01-MAR-86

Duration: 48 months

A RULE BASED APPROACH TO INFORMATION SYSTEMS DEVELOPMENT (RUBRIC)

Project Number : 928

The objective is to develop a system for creating information systems for business applications which match the requirements of users more accurately than is presently possible.

Individual end-user requirements are to be collected using a rule-based approach. This data will then be integrated into a single model and used to generate the applications software.

A prototype system will be developed consisting of :

- A rule-based fact gathering and presentation system with different views for presentation and with validation tools.
- A unified rule base (URB) to store, aggregate and validate individual requirements.
- An application generating system to realize applications from rule-based descriptions in the URB, either by transformation or by interpretation of the rules.

The conceptual design of the Unified Rule Base and the fact gathering and presentation system, are under development. As far as the conceptual design of the URB is concerned, research on the ability to use rules to describe the business and its activities is complete.

Work is now focused on the definition of the concepts for representing the user knowledge in the URB. Several representational formalisms are under experiment, and the semantics behind these concepts need to be settled. The development of a formalised framework, called the Design Discipline, to be presented to the application designer in the final version of the system, is also in progress.

The project seeks to establish and to apply, the principles for the use of AI technology in the development of business applications software.

Business software should become cheaper, due to reductions in the costs of application development.

Its quality and flexibility will also be improved due to the development methods used.

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Start Date: 01-FEB-86

Duration: 42 months

**DEBUGGING AND SPECIFICATION OF ADA REAL-TIME EMBEDDED SYSTEMS
(DESCARTES)**

Project Number : 937

The project intends to assist developers of real-time embedded systems in Ada by investigating formal methods and by designing software and hardware tools.

Formal semantics and proof systems for real-time languages, with emphasis on composability will be investigated. A specification language including real-time constraints and correctness preserving transformation will be designed.

Traceability of transformation decisions in the context of real-time constraints and analysis tools will be developed.

Work is in progress on the formalization of the semantics of an extension of Statelan with temporal logic, and on checking the consistency of combined specifications. Two directions have been taken : incorporation of Me-Too in the Statemate system and the methodology of refinement.

- Work has been started on translation of Me-Too and Statelan specifications in Ada.
- A system for tracing and analysing execution histories of Ada Programs without disturbing the target machine has been specified, and these tools have been implemented and demonstrated.

The industrial application of the results of DESCARTES can have immediate impact on the testability and therefore on the quality and reliability of real time embedded systems implemented in Ada.

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Start Date: 01-MAR-86

Duration: 36 months

INTEGRATED MANAGEMENT PROCESS WORKBENCH (IMPW)

Project Number : 1223(938)

The objective is the implementation of a prototype workbench with particular emphasis on planning, project control and decision support. The tools rely heavily on a common knowledge base. The system is intended to be UNIX V and PCTE portable.

This project is associated with P. 814 into P. 1223.

Current emphasis is on the definition of a workbench architecture, the design of the workbench software, and the design and implementation of a comprehensive set of use functions, covering all project management actions capable of being automated.

Other important results are :

- The development of an object oriented development method.
- The design of a Standard Manager Workbench Interface.

Following the survey of cost modelling theories and practices, significant progress has been made on a generic cost estimation tool, that can be instantiated for all existing models and combinations thereof.

The prototype system will be instrumented and used in industrial trials. An evaluation of the effectiveness of the system will be based on the results obtained.

When the prototype is industrialized after the end of the project the final result will have immediate impact on management of software development projects.

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Start Date: 01-FEB-86

Duration: 36 months

PCTE-ADDED COMMON TOOLS (PACT)

Project Number : 951

The objective is the development and documentation of a toolset for PCTE (Proj. 32). This implementation of a layer of functionalities above PCTE basic mechanisms will provide the tool developer with a higher level interface to PCTE. The project will be conducted in close collaboration with the PCTE project.

The prototype version will include :

- Tools for data definition and data query.
- Tools for environment administration.
- Document preparation tools.
- Communication facilities (user-user and gateways).
- Support for C, Pascal, Lisp and Prologue.
- Configuration management tools.

The initial tool set is now available on top of PCTE. It consists mainly of the following tools which have been adapted or ported : shell; basic object management system tools; data definition language interpreter; general text editor; Pascal and C compiler, linker, debugger; general text formatter; system administration tools; basic archiving and back up tools.

More basic work on the design and development of tools supporting advanced features is underway especially on the following critical areas:

- Object Management System : design of advanced data definition, query and manipulation tools.
- Dialogue management : definition of a model and an accompanying formalism to describe the interactions between any tool and a user.
- Common services : construction of a functional level offering well defined language interfaces exploitable by tools. This will form the basic layer for the integration of future tools.

The project complements PCTE and plans to provide a complete general purpose environment to industry in 1989. This environment will support tools developed by other projects. Based on the fact that a development environment should provide a high level of support to software developers, the project is expected to have a very important impact. The wide acceptance of PCTE depends on the level of achievement of projects such as this.

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Start Date: *01-FEB-86*

Duration: *36 months*

A KNOWLEDGE-BASE ENVIRONMENT FOR SOFTWARE SYSTEM CONFIGURATION REUSING COMPONENTS (KNOSOS)

Project Number : 1221 (974)

The objective of this project is an environment supporting a method for components reuse during software configuration.

The user requirements for such an environment will be captured through studies conducted by industries familiar with large applications development. A KNOSOS prototype will be constructed by integration and adaptation of a relational DBMS, a knowledge representation and manipulation tool, a software configurator, an automated configuration management system, and a common user interface with graphic capabilities. This prototype will be evaluated through field trials.

KNOSOS is embedded in the composite project 1221 (consisting of 974 and 1094).

The user requirements for the global system and a first implementation of an interface between the language LISP and a relational DBMS have been presented.

These tools constitute the basic building blocks of the KNOSOS system and contain different facilities for Knowledge representation. Case studies are currently being developed and the different building blocks are being tested separately.

The results of this project, which will be a general model of software components and a method to reuse them and configure large software systems, are to be available to facilitate the implementation of large industrial applications. The reason for this is that a considerable part of the cost of software development today is due to unintentional redevelopment or necessitated by modifications due to a change in the requirements, or to errors. This cost can be significantly reduced once reusable processes and associated tools are available.

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Start Date: 01-JUN-86

Duration: 36 months

FORMAL METHODS FOR ASYNCHRONOUS SYSTEM TECHNOLOGY (FORMAST)

Project Number : 1033

The project aims to provide a formal framework and a suitable toolset for the development of asynchronous embedded micro and distributed systems.

The formal framework is based on:

- Scott's domain - based state machine, for the mathematical model.
- Hoare's logic and temporal logic, for the correctness in analysis and design.

The toolset includes presentation language and tools such as design database, formal design provers based on theorem proving techniques, designer's assistants and simulators. The toolset will be linked to an asynchronous system development environment which is currently being implemented and will also be compatible with PCTE.

Progress has been made in developing a compositional method for asynchronous system design. Work has been advancing in proof methods. A case study based on an aero-space system.

Work is ongoing in the area of creating a formal methodology combining the compositional method, the proof method and an existing asynchronous design method.

The project will facilitate collaboration between universities in UK and Germany to harness expertise on asynchronous systems and formal methods and to advance these developments into an industrial context in the two countries. The project will be targetted for some early intermediate results which could lead to early exploitation as well as longer term industrial benefits.

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Start Date: 01-MAY-86

Duration: 24 months

A GENERAL ENVIRONMENT FOR FORMAL SYSTEMS DEVELOPMENT (GENESIS)

Project Number : 1222(1041)

The project aims at a meta-system generating syntax-directed editing, transformation and proof tools, from descriptions of the syntax and semantics of the formalisms used in software development. Meta-languages for the description of context conditions, transformation rules, proof rules and tactics will be defined.

This project is associated with P1158 in P1222.

GENESIS is an ambitious project and there were (unavoidably) a number of loose ends and unclarified goals and solution strategies at the beginning. Since then, much progress has been made, in particular concerning the design and the first steps towards implementing the projection language KENSHO and the structure displayer's command language. The display group's plans are well thought out and ready for a trial implementation. Further work has been done on understanding the relations among the semantics framework for the metalanguage, the abstract definition of computation rules for a subset, ideas for implementing these in Prolog and some relatively concrete example theories for manipulating syntax and inference rules. The semantic framework is to be based on ideas from fairly classical first order logic, which fits well with the use of Prolog for prototype implementation. As a test, the specification of VDM (by means of GENESIS) has been carried out.

By the next review it is expected to see a demonstration of a prototype version of Kensho and the display command language, and more progress towards the definition of the semantic framework.

GENESIS will make it possible to generate tools for a wide range of methodologies based on different notations and logics from descriptions of the syntax and semantics of the notations used. In the long term, the development of GENESIS will lead to an order of magnitude reduction in the cost of providing support tools for formal methods.

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Start Date: 01-FEB-86

Duration: 60 months

**DEVELOPMENT AND INTEGRATION OF ACCURATE OPERATIONS
IN NUMERICAL DATA PROCESSING (DIAMOND)**

Project Number : 1072

The project aims at developing methods and tools allowing accurate floating point arithmetic on computers, based on a mathematical theory of computer arithmetic in which all operations are defined by so-called semimorphisms. Such systematic theory of computer arithmetic aims at performing the basic arithmetic operations to maximum accuracy and providing sufficient control over the rounding process so as to ensure reliable error bounds. This project will pursue different approaches: embedding of convenient arithmetic notations into ADA and Pascal; AI-techniques for formula transformation and symbolic manipulation; construction of a methodological framework and a knowledge base for numerical programming.

Current results to date are as follows:

- Implementation of numerical expression into Pascal SC (Scientific Pascal) and ADA using accurate operators.
- A prototype in Pascal SC has been realised. It shows with some critical examples how much more accurate and reliable the new operators are than the classical arithmetic operators.
- To improve performances of the Diamond tool an investigation of the symbolic applications has been completed.

The specification of a Pascal SC-ADA translator has been produced for assessment of an eventual future translation of all the Pascal-SC modules into ADA.

The project's results are expected to have a strong impact on accuracy, safety, reliability and economy of numerical programming, a field of interest for many scientific and industrial domains.

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Start Date: 01-JAN-86

Duration: 36 months

**SUPPORT SYSTEM FOR PRAGMATIC REUSE OF SOFTWARE CONCEPTS
(PRACTITIONER)**

Project Number : 1221(1094)

This project aims at methods to identify, isolate, document, store and retrieve program concepts at the design level, ie. design ideas, schema for software subsystems and components.

The potential of a linguistic approach as a basis for methods to analyse existing programs will be investigated. A prototype system supporting these methods will be evaluated by performing extensive experiments.

This project is associated with P974 and P1221.

In the first phase of the project program concepts and components were being collected on an empirical basis. Appropriate representations (in standard programming languages, SADT diagrams, Petri-nets, pseudo-code or natural language) were considered. Principles of the formulation of these concepts and components, without application-oriented details, were developed. A questionnaire for collection, storage and retrieval of program concepts has been derived. Some experimentation has been performed.

The approach adopted will result in the development of a support environment which will be immediately exploitable by the consortium. One partner will use the results to support existing large libraries of software while other partners will apply the results to future developments.

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Start Date: 01-DEC-86

Duration: 60 months

ADVANCED TECHNIQUES INTEGRATION INTO EFFICIENT SCIENTIFIC APPLICATION SOFTWARE (ATES)

Project Number : 1158

This project aims to integrate advanced techniques into an integrated Software development environment within the areas of scientific application programming, with particular emphasis on efficiency.

A programming language integrating three advanced techniques:

- Abstraction of data types and operators.
- Relational database programming for scientific data.
- Formal specification and proof will be defined by taking into account the specificity of scientific programming.

An efficient software development environment will include a proof subsystem which allows the user to validate an algorithm with respect to some specification, or to get error information if the algorithm is invalid. The adequacy of the whole system will be evaluated by developing application libraries.

This project is associated with P1041 into P1222.

- The programming system has been specified. The starting point was the 4x programming system (it involves a derivative of Fortran as an algorithmic programming language, some program manipulation tools and an execution environment). The code generation capabilities of the system have been improved and enhanced.
- The overview of program proof systems has been completed.
- The specification of the proof system:
 - A specification language has been designed. It allows the semantics of the user's operators including selectors and iterators to be define . The method uses models like VDM and the pre- and post-conditions of the operators. The conditions are expressed in the VDM models and use predicates of the first order logic. Axiom chapters give properties of the models.
 - A proof language allows the description of how one type implements another type giving a so-called "abstract function". Loop invariants can be also given to the system.
 - Generation of verification conditions has been defined using the Hoare's logic and the semantics of the programming language.

- The architecture of the whole system has been designed.
- The specification for the test application has been produced. The test application aims at the resolution of thermodynamic equations using the finite element method. The test has been specifically chosen to provide user feedback on the ATEs environment.

As they will have an industrial system available at the end of the project, it is expected that the delivered system will reach a pre-industrial state, with enough demonstrative value to act as an advanced reference for scientific software and CAD software designers.

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Start Date: 01-JAN-86

Duration: 48 months

**A MULTI-METHOD APPROACH FOR DEVELOPING UNIVERSAL
SPECIFICATIONS (AMADEUS)**

Project Number : 1229(1252)

The objective was to define a unified conceptual model semantically rich enough to describe specifications derived from any of the leading development methods. This would provide a basis for the integration of the wide range of existing and well understood tools and techniques currently used. This project aimed to provide for the harmonisation of system development environments by introducing an approach which permitted the use of multiple methods, but with a common and unified system specification as the outcome of its use. This was intended to be achieved by the availability of a unified representation scheme which could be accessed through appropriate interfaces, by tools and techniques relating to a method.

This project is associated with P1262, P1277, P1282 and P1283 into P1229.

The project team surveyed a number of different software development methods comparison studies and classified the development methods, mapping the model of development against the approach used. Methods include SSADM, SADT, JSD and NIAM.

A range of application and support system types such as office communications systems, control systems and robotic systems were examined to identify the real world objects dealt with.

These objects were grouped under headings such as objects manipulated, relationships, and activities.

A model was developed on the basis of the analyses performed. Whilst the model had some value in judging the completeness of the methods, much of the semantic information was lost in the transformation.

Reviewers recommended publication of the "Analysis of Methods" document. The results of the feasibility study were not sufficiently convincing to continue the work.

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Start Date: 01-APR-86

Duration: 12 months

**DYNAMIC SOFTWARE MIGRATION BETWEEN COOPERATING ENVIRONMENTS
(CHAMELEON)**

Project Number : 1228(1256)

The objective of the project is to build a Dynamic Software Migration system. The purpose of this system is to enable the migration and execution of active objects throughout a heterogeneous computer network. The elements of the system are an abstract common machine, an abstract common machine environment and the network.

This project is associated with HTDS 1228(1261).

The starting point for this project was the AMBER machine, an intermediate machine model. The abstract machine is a model reflecting the target machines in its domain with a common set of concepts to enable portability of programs. Two other intermediate machine models were proposed and examined by the partners, IACM and HARP. These designs differed in their ease of ability to support the languages "C" and SCHEME.

Both models will be developed within the project. HARP is a general purpose machine model and makes no assumptions about the supported languages. IACM is more closely modelled on the AMBER machine.

The productivity gains will allow users to undertake important projects which would be prohibitively time consuming with existing technology. For example, a software porting task which nowadays could take several months, could conceivably be accomplished in, at most, one morning. Therefore, this project is expected to greatly improve productivity and to drastically reduce the cost of moving software.

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Start Date: 01-SEP-86

Duration: 42 months

**SOFTWARE QUALITY AND RELIABILITY METRICS FOR SELECTED DOMAINS :
SAFETY MANAGEMENT & CLERICAL SYSTEMS (MUSE)**

Project Number : 1257

The project seeks to produce demonstrable Quality and Reliability metrics focused on three specific application domains : Safety, Management and Clerical Systems. These metrics will be applied on real software development projects to provide experimental trials data and user reactions for their analysis and evaluation. The research will combine specialists from the fields of software engineering, artificial intelligence, human factors and statistics. In addition, external fields such as Construction, Engineering and Manufacturing will be surveyed to see if they have quality and reliability paradigms which can be of relevance to software.

In addition to researching and testing domain-specific metrics as well as generic metrics for the selected areas, the project will seek to establish a basis for new generation metrics using Artificial Intelligence methods.

Results to date are as follows:

- A survey and comparison on quality and reliability metrics in USA and Europe.
- The quality and reliability Q/R metrics and Q/R factors for use in the project have now been selected.

This project aims at paving the way for the European IT industry to improve systems of safety. The areas concerned (metrics in the field of safety management and clerical systems) are of immediate interest to the industry.

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Start Date: 01-JAN-87

Duration: 36 months

**TESTING AND CONSEQUENT RELIABILITY ESTIMATION FOR REAL-TIME
EMBEDDED SOFTWARE (TRUST)**

Project Number : 1258

The objective of the project is to investigate the characteristics of the major current design methods in order to assess their impact upon testability and reliability of software, and to attempt to generate software which is not only testable but by intrinsic structure more reliable.

Results to date are as follows :

- A survey of languages (high and low level) usable for Real-Time embedded systems has been completed. This survey includes the identification of the characteristic features of these languages varying between generations and levels which impact on the ability to adequately test real-time embedded systems. These characteristics include hardware and I/O support, concurrent task support and exception handling.
- Analysis of source host/target communication has been completed. This has also identified the key features such as speed and capacity to be affected by the host/target communication mechanisms.

The assessment of these features will help to assess the real-time and host/target aspects of software products during the test and development phases. This will provide data for management control.

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Start Date: 01-NOV-86

Duration: 36 months

HOST TARGET DEVELOPMENT SYSTEM (HTDS)

Project Number : 1228(1261)

The main objective of the HTDS project is to develop a prototype integrated tool system based on a PCTE environment to support automatic testing, high level debugging and remote maintenance.

The project aims to establish a framework for the test and debug process between the compiler output and executable target code.

The host target development area will be examined with a view to specification of a development system. Naked microprocessors, industry standard boards and industry standard computers, will be considered as targets. The advantages of distributing the tools between the host and target systems will be considered.

Prototype systems will be realised with tools in the areas of automatic testing, high level debugging and remote maintenance.

Standard solutions to the communications problems of developing host target systems, will be sought. It is anticipated that results from the Chameleon project P1256 will be of help in this task.

A preliminary test and debug specification has been written. This specification includes a full list and description of commands necessary to test and debug executable code in the proposed environments.

Two levels of interface are being defined in the process between the compiler output and the execution mapping. The upper level lends itself to the human interface and the lower level to the machine.

This project will engender a common approach to the test and debug phase of system development with the associated standardisation benefits.

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Start Date: 01-DEC-86

Duration: 46 months

SOFTWARE FACTORY INTEGRATION AND EXPERIMENTATION (SFINX)

Project Number : 1229 (1262)

This project has a dual purpose:

- To combine the results from a number of ESPRIT Software Technology projects into a preprototype of what can be described as a software factory or an integrated software engineering environment.
- To use the software factory as a vehicle for evaluating some of the tools and methods developed within the ESPRIT ST programme as a focal point for demonstrating to a wider forum the results obtained within the ST programme.

A number of specific objectives may be derived from the overall objective:

- Comparison with similar efforts evaluate and identify features of the work of other organisations in the same field (software factory), namely:
 - The STARS program of the US DoD.
 - The SIGMA program of Japan.
- Demonstration of prototypes in a common environment. Demonstrations of prototype tools will be undertaken and the following preparatory actions will be concluded:
 - Assistance in the exchange of information between the teams developing prototypes.
 - The preparation and distribution of descriptions and definitions of the software factory concepts and necessary underlying concepts, such as PCTE.
 - Training personnel working in the software technology programme in the software factory concepts.

The project is associated with P1252, P1277, P1282, P1283 into P1229.

The first year of the project was a definition phase.

A number of problems (quality, integration, documentation, training, etc.) have been investigated with a selected set of existing ESPRIT projects (eg. P410, P315, P125, P282). Some precise approach to the Software Factory concept is now emerging and will form the basis of the workplan for the main phase of the project.

This project will be an enforcement of the PCTE and PCTE compatible tools, in the sense that it aims at:

- Enforcing the PCTE concept as a possible European standard for tool development.
- Evaluating and testing PCTE as the backbone, and of PCTE compatible tools as components of a software factory.
- Distributing the knowledge of ST tools and methods in general and those based on PCTE in particular.

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Start Date: 01-SEP-86

Duration: 60 months

SEDOS ESTELLE DEMONSTRATOR (SEDOS DEMO)

Project Number : 1227(1265)

The objectives are :

- The demonstration of maturity (applicability, efficiency, etc.) of SEDOS technology (ESPRIT P410) by the development of an industrial prototype, the so called "ESTELLE Work Station".
- The demonstration of the applicability of ESTELLE for the formal description and development of protocols for the interconnection of systems by means of Application Oriented Evaluations. These are based on four important fields: Computer Networks, Industrial Networks, Telecommunications and Space.

In spring '88 the following tools will be in first prototype phase and will be integrated in the first prototype ESTELLE work station, for use during field trials at the site of the different subcontractors :

- Syntax oriented editor.
- Translator.
- Code Generator.
- Simulator motor.
- Implementation motor.

The project will provide a precompetitive demonstration (i.e. applicability, efficiency, etc.) of the SEDOS technology in different relevant fields.

This project is associated with P800, P835 and P1271 into P1227.

The ESTELLE work station architecture has been specified, as well as the functionalities of the tools. A syntax-oriented editor has been demonstrated.

The application oriented evaluation will produce a set of validated protocols which will be very important for European industry.

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MARBEN

F

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Start Date: 01-JUL-86

Duration: 36 months

SETL EXPERIMENTATION AND DEMONSTRATOR (SED)

Project Number : 1271

This project is a Design Method demonstrator. It is intended to provide an early feedback on the viability of using PCTE-OMS to support the kind of prototyping and design techniques which have been successfully used to develop a full Ada translator within 16 person years. The main vehicle for these prototyping and design techniques is the SETL language.

This project is associated with P800, P835, P1265 into P1227.

A prototype environment for SETL (Set Theoretical Language) has been implemented under MENTOR (an environment generator for programming languages developed at INRIA).

Some important results are:

- The definition of a flexible grammar for the full first order logic extended with abstraction terms.
- Definition of a MENTOR environment for low level rewrite rules, using this new grammar, and based on RAPTS.
- The translation of SETL in Ada
- Requirements for developments in cartography; this particular domain demonstrated shortcomings of SETL in regard to handling complex data structures and modularity.

The project will assess the adequacy of the PCTE-OMS to support software development by means of a wide spectrum of languages, and the adequacy of SETL as a specification and implementation language for industrial use.

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Start Date 01-JUL-86

Duration: 24 months

PCTE PORTABILITY (SAPPHIRE)

Project Number : 1229(1277)

The main objective of the project is to evaluate the adequacy, completeness, performance and portability of the PCTE.

Other objectives are:

- To link the Alvey Fortune and Eclipse projects with the Esprit PCTE initiative by porting them on top of the PCTE interface.
- To support the PCTE interface on a number of common machines.
- To port an ADA compiler to PCTE.

EMERAUDE version 8 has been ported to the SUN (July 1987). A first version of a Sun based PCTE was shown at the Stockholm ADA conference in May 1987. The SUN PCTE with the Eclipse IPSE and a tool to generate ADA code from MASCOT 3 diagrams, was demonstrated at the Esprit Conference (October 1987). ECLIPSE, the Alvey-developed integrated project support environment (IPSE), is being integrated on the SUN PCTE implementation, and was demonstrated at the ESPRIT 1987 Workshop.

There are some problems in porting the Emeraude PCTE to a PC/AT. These are mainly due to incompatibility in the word sizes.

PCTE implementations on the various hardware architectures will maximize the industrial application of PCTE and will provide a de facto standard PCTE for European software development projects.

The Sun version is available (Dec 87).

The IBM PC version is planned for early 88. The Vax workstation and HP9000 versions will be available in the third quarter of 1988.

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Start Date: 01-OCT-86

Duration: 36 months

PCTE AND VMS ENVIRONMENT (PAVE)

Project Number : 1229(1282)

The aim of the project is to encourage existing VAX/VMS users to use the PCTE, thereby increasing the acceptance of the PCTE, as a standard in Europe.

The main objective is to develop a number of software components, each completing a usable system, with the following functions:

- To give access to a PCTE workstation from industry standard DEC compatible terminals.
- To allow remote usage of VAX/VMS disk storage by PCTE OMS.
- To give efficient access from PCTE OMS objects stored on VAX/VMS disks.
- To provide direct access to PCTE tools for users of VAX/VMS based systems.
- To port the PCTE/PACT tools into a VAX/VMS environment.

(The workplan of which these objective are part, is being revised and will be updated in January 1988).

This project is associated with P1252, P1262, P1229(1283).

The team have studied how the VAX storage might be used in the PCTE environment. Two alternative proposals have resulted for the first implementation work.

The first proposes to dedicate a VAX virtual volume to a non-Vax PCTE workstation. The other proposes to implement the object server on top of VMS, and to implement the access by remote procedure calls from PCTE workstations.

A study of the full implementation of PCTE on VAX has been done which makes proposals on how each of the PCTE functions can be ported to VMS.

This project will pave the way to the PCTE for VAX/VMS users. This will enlarge the domain of application of PCTE in the IT community.

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Start Date: 01-NOV-86

Duration: 36 months

VDM INTERFACES FOR PCTE (VIP)

Project Number : 1229(1283)

The project aims to produce a formal specification of the interface to the Kernel of the PCTE and the User Interface. There are a number of objectives in producing such a specification:

- The formal specification will give a precise semantic description of the interfaces.
- In producing a formal specification, ambiguities in the natural language specification will be exposed, thus the natural language specification can be improved.
- The formal specification can be used to derive an improved natural language specification.
- PCTE implementations will have access to a precise specification. Moreover, the investigation of rapid prototyping could show a means of comparing implementations against the formal specification.
- The formal specification could be used to derive a PCTE environment.
- Tool writers will have access to the precise specification needed to support tools emerging from other ESPRIT projects.

This project is associated with P1252, P1262, P1277, P1282 and P1229.

Initial studies of the interfaces of the PCTE are under way.

Analysis of the natural language specification, particularly of the user interface, has already revealed ambiguities, omissions and errors which have been submitted to the PCTE Interface Management Board.

This project will demonstrate the value of formal interface specifications in industrial environments. The costs of evolutionary development can be reduced by the availability of a precise and probably correct interface specification.

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Start Date: 01-NOV-86	Duration:	36 months

**ADVANCED SOFTWARE ENGINEERING ENVIRONMENT LOGISTICS FRAMEWORK
(ACCUEIL DE LOGICIEL FUTUR, ALF)**

Project Number : 1520

The objective is to create an operating framework for third generation, integrated project support environments by developing the required software infrastructure.

ALF can be seen as a continuation of the PCTE and PACT, and is based on the PCTE-defined operating system for software engineering environments.

The project will integrate knowledge-based systems and information system techniques into software engineering environments. Thus, it will provide the basis for a rationalised approach to building initiative-taking, project-support environments.

The provision of an initiative engine by the incorporation of rule-based mechanisms into the underlying framework of the common integrated environments, demonstrates a novel approach to software engineering.

ALF will incorporate tools produced within other ESPRIT projects, and be executed under a tight schedule.

The technical annex of this project has been negotiated and the project started in October 1987.

The production of software systems will be facilitated by the adoption of the disciplined software and systems engineering approach of which ALF is part. It is expected that it will constitute the progression from the PCTE to the next generation of software engineering environments.

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Start Date: 01-OCT-87

Duration: 48 months

SOFTWARE PRODUCTIVITY EVALUATION MODEL (SPEM)

Project Number : 1527

The main purpose of the SPEM project is to build a constructive model for evaluation of software productivity, usable in an industrial context and for real world software projects.

The goals of the SPEM project can be summarized as follows :

- To contribute to the measurement, comparison and improvement of software development productivity, in an industrial context.
- To better formalize the choice and the measurement techniques of significant Estimation Models.
- A prototype of a new model of productivity will be developed, used and validated.
- This model will be an input for the SPMS environment (P282).

The project started very recently. An examination of the state-of-the-art, based on a bibliographical survey has been completed.

This model should allow :

- A comparison of software productivity of various projects in the same company or in different companies as a basis for improvement.
- Managers to improve productivity by identifying the factors which are the causes of an insufficient productivity and taking corrective action.

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Start Date: 01-MAY-87

Duration: 36 months

PCTE HOST-TARGET DISTRIBUTED TESTING ENVIRONMENT (APHRODITE)

Project Number : 1535

The objective is to provide an initial basis for a PCTE host target distributed testing environment.

The project will result in:

- A set of recommendations for programming and interfacing target systems, and for allowing their testing in a distributed host-target environment.
- A prototype of this PCTE host-target distributed testing environment, implemented on a network of PC/AT hosts and including one or more target systems.
- A preliminary evaluation of the prototype to assess the viability of the system as a production system.

Based on the results of the first review a study of the adaptations necessary to port Emeraude/PCTE to Chorus has been made. A model of the overall architecture has been defined but is not yet complete. Details of the actual actor model to be used are being discussed.

An effect of the project will be to increase the functional use of PCTE environments.

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Start Date: *01-JAN-87*

Duration: *24 months*

**DISTRIBUTION AND REUSABILITY OF ADA REAL-TIME APPLICATIONS
THROUGH GRACEFUL AND ON-LINE OPERATIONS (DRAGON)**

Project Number : 1651 (1550)

The project focuses on methods and tools for designing reusable software for distributed real-time applications of a long-lived nature (such as FMS and space application systems).

Criteria for structuring systems in terms of reusable, target-independent ADA components will be investigated along two directions : formal specifications of module interfaces and operations and support for distribution and target computer and plant configuration management. In fact changes in target architecture and plant dimension and parameters are a major cause of unanticipated software changes which make software hard to reuse : the issue is addressed in the project by structuring the program as suitable, distributable units which are completely insensitive to target characteristics. Provisions for reconfiguration, task migration and modification in non-stop mode require careful analysis of the ADA tasking system : the intended approach is to start from existing formalisations of ADA semantics and extend them. Reusability will be obtained by assembling components and specialising, that is instantiating, highly generic components. A database, or library, of existing components will be designed.

The initial task of the project provided a requirements specification, concentrating on : identification of application domains, identification of target computer architectures and characteristics of applications. In considering these requirements various items were addressed : reusability, reconfigurability, re-testing, specification and documentation, performance degradation. Subsequent activity will include the selection of a case study.

The project will contribute to the industrial use of Ada and will advance industrial understanding of the problems and opportunities of software re-use.

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Start Date: 01-APR-87

Duration: 36 months

**REPLAY AND EVALUATION OF SOFTWARE DEVELOPMENT PLANS
USING HIGHER-ORDER META SYSTEMS (REPLAY)**

Project Number : 1598

REPLAY aims at providing a significant proof of the feasibility of reusing development plans (and components as by-products) with an industrial software product process. It is an experimental research project, aiming at making some advances in the rather poorly understood domain of reusability.

Besides building on progressive generalisation of case studies, REPLAY is exploring both top-down replay of developments and bottom-up assembly of components. The possibilities of continually controlling these development plans is investigated by means of abstract interpretation and modelling of operational properties.

Current domains under analysis are replays of:

- Proofs.
- Transformation sequences.
- Development (process or programs).
- Configuration.

The examples used for observation and experimentation are derived from the compiler generation world (MIRA and ABSYNT tools), VDM and theorem proving (ABRIAL's B system/ML/LCF), configuration expert systems (Adèle/Pélagie) and specification (LPG/F1). A prototype expert system has also been built for HLA typing (a medical problem) in order to explore operational properties.

The latter phase of technical integration will allow experimental validation, together with some support tools, such as an expert system for description and generation of assembly plans. It must be noted that this project will make extensive use of the DEVA language defined in the TOOL-USE project (P510).

Although no direct industrial product should be expected, a better knowledge of the problem should result - in the long-term - in dramatic improvements of productivity.

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Start Date: 01-FEB-87

Duration: 36 months

SYSTEM MEASUREMENT AND ARCHITECTURES TECHNIQUES (SMART)

Project Number : 1609

One of the most critical problems that is faced by fault-tolerant system production, is how to monitor architecture design together with development process in order to meet performance criteria, ensuring cost effectiveness and management efficiency. The global objectives of the proposal are to provide techniques and tools for solving most of the complex quantification aspects by:

- Identifying all the relevant parameters to be measured or processed.
- Formalizing and modelling performance within the reference systems for single components and for structured fault-tolerant systems.
- Validating the models on existing projects.
- Building a set of tools to support system designers and developers for defining fault-tolerant information system at each phase of the life cycle.

The project started very recently.

The validation of the proposed approach will contribute to promote architecture techniques and associated performance recommendations for next generation of fault-tolerant systems.

The applicability of the proposed software throughout the European scientific software community should make possible increases in efficiency of the European fault-tolerant data processing industry and, in turn, that of other industry. This will be done by using the models and tools that the project will provide.

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Duration: 30 months

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