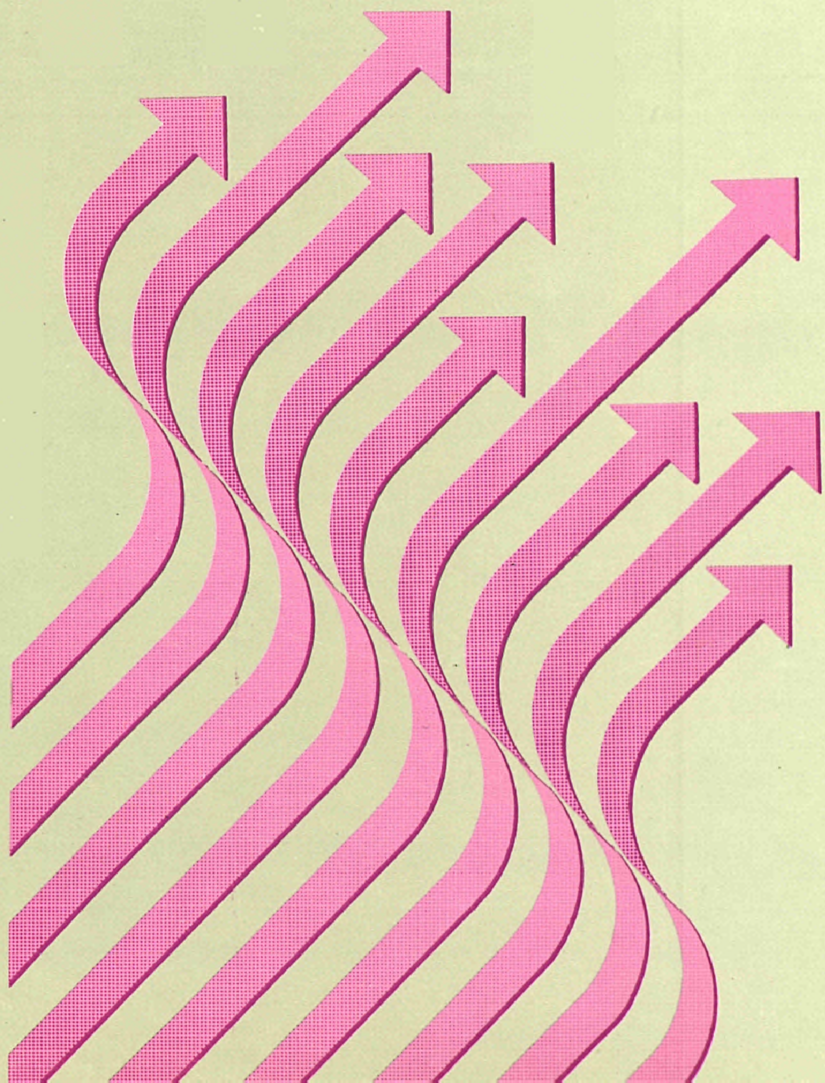
Esprit
The first phase: Progress and results



Commission of the
European Communities

1987

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The first phase: Progress and results

Commission of the European Communities
Directorate-General XIII

Telecommunications, Information Industries
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TABLE OF CONTENTS

Page

TABLES AND GRAPHS

0. PREAMBLE

In October 1985, the ESPRIT Review Board, an independent high-level body, presented its report to the Commission assessing the initial results of the Programme and the need for any changes affecting the future development of ESPRIT. The Board found that there was agreement among participants in all Member States that ESPRIT had been highly successful in promoting cooperation between large and small organisations and between industry, academia and research institutes.

In its Resolution of 8th April 1986, the Council noted the report, re-emphasized its commitment to the ESPRIT Programme, and welcomed the considerable progress already achieved in the area of transnational cooperation. The Commission announced to the Council that it intended to submit a supplementary report taking account of developments since the presentation of the Mid-term Review.

The Council requested the Commission, in particular, to cover the following topics:

- the potential economic impact and industrial application of projects;
- problems relating to the size and composition of consortia;
- cost/benefit as a function of differing levels of financial support;
- a comparison of the human resources involved in ESPRIT with the general resource situation in the Community;
- particular problems relating to the participation of small and medium-sized undertakings (SMEs).

This report, prepared for submission to Council, presents the results of the Programme, sector by sector, and sets out the issues of general relevance requested by the Council. It takes up the assessment of the Programme where the ESPRIT Review Board left off. The Commission, in drafting this document, believes that the theme of cooperation has been dealt with exhaustively in the previous report and that there is no need for repetition. Consequently, there is a focussing down on concrete technology results and an attempt to measure the impact and industrial application of individual projects, taking input from 200 reports by the technical evaluators (known as reviewers) who assist in monitoring the progress of each project every six months.

1. EXECUTIVE SUMMARY

ESPRIT:

the European Programme for Research and Development in Information Technology

ESPRIT, in its first three years of execution, is having a direct and long-lasting impact on improving the technological base of the Information Technology industry in the European Community.

The programme comprises precompetitive R&D projects, carried out by the collaborative effort of Community undertakings, on a shared cost basis. After a pilot phase that began in 1983 and since the beginning of the main programme, there have been two major calls for proposals, one each in 1984 and 1985. As a result, 201 projects are underway in the areas of Microelectronics, Information Processing Systems (Software Technology and Advanced Information Processing) and IT Applications (Computer Integrated Manufacture and Integrated Office Systems). Nearly 90% of these projects (179 out of 201) were on schedule in mid-1986. Of the rest, 14 projects were between 3 and 6 months behind schedule and only 8 more than 6 months late.

It is fair to say that there is now general agreement as to the initial success of ESPRIT with respect to the promotion of trans-European cooperation between IT organizations. Aside from universities and research institutes there are now 240 different industrial partners, 130 of which have less than 500 employees. The researchers assembled by ESPRIT had reached an estimated 2,900 by mid-1986.

As a collaborative effort between the Community and Industry, ESPRIT is providing added value above and beyond that which can be achieved by national programmes or isolated R&D actions undertaken by individual firms. This added value consists of:

- pooling scattered resources, both in manpower and financial terms;
- providing an increased choice of options;

- accelerating research and its exploitation, which is of particular relevance in a sector of fast technological development and short product life cycles;
- taking advantage of the EEC accompanying policies which aim at providing a coherent framework and a favourable environment in terms of market, common standards, and a common approach to trade policy which are prerequesite to the translation of R&D work into economic success.

There is an average of 3.5 industrial participants per project. According to all indications this trans-European cooperation initiated by ESPRIT has enabled more ambitious research projects of broader scope to be instituted and has accelerated their execution. Work sharing between partners has increased overall gains in spite of the overheads needed to set up cooperations.

This cooperation fostered by ESPRIT is now beginning to produce concrete, deliverable results. Projects nearing completion have realized all or almost all of their targets and most of those started later are meeting their envisaged milestones on schedule. Although only 3 years into a 10 year Programme, specific results with major industrial impact are already coming on stream.

In Microelectronics, in order to ensure a European chip capability, the first thrust is to achieve high density of circuitry on a chip. The dimensions of the basic circuit elements aimed at are in the submicron region (less than 1/1000 millimeter). The second thrust is high speed switching. For high speed circuits the goal is to obtain speeds expressed in picoseconds (1/1000000 microsecond). Such high speed circuitry is needed particularly for future telecommunications systems as well as for industrial automation.

An example of a tangible result is a demonstrator chip containing 10,000 (10K) basic elements in a chip and 200 picosecond access time. This so-called 10K array bipolar chip has characteristics which compare with the best in the world. As a spin-off from this R&D project a new line for the production of these arrays is being built by Siemens, at a cost of around 100 MECU. The development of prototypes is planned for next year, to be followed by full production.

In Information Processing Systems a shift is now discernable in the product development strategies of some key European companies attempting to ensure maximum benefit from the collaborative work being undertaken within ESPRIT. A most significant output so far has been the result of work on a Common Software Development System, PCTE, which brought together six of the major computer companies within Europe (Bull, GEC, ICL, Nixdorf, Olivetti, Siemens) with the goal of producing software faster, safer, and more efficiently than the current state of the art. The results obtained have already gone beyond meeting the original goals to spawning extensive complementary work both within ESPRIT and elsewhere, i.e. prototypes of the system were developed and evaluated, while a commercial implementation of a software product called EMERAUDE, was produced by GIE-Emeraude and released to the market in September 1986 - a prime example of timely exploitation of ESPRIT R&D results by industry.

This work is having wide industrial impact. The specifications of the developed system are being adopted by Member States R&D programs (e.g. the British Alvey Programme) and are the subject of discussions within the Ada (the European originated U.S. DoD language) framework. Through the work on PCTE an industrial group, known as the X-OPEN group[1], has been formed to support the adoption of a standard operating system interface for computers.

In the Advanced Information Processing work was carried out in Knowledge Engineering, External Interfaces and Computer Architectures. As an example of work in the first of these areas, advantage was taken of Europe's strong position in Logic programming languages by producing state-of-the art versions of such languages to be used in Knowlege based systems and this can be illustrated by the following examples which relate especially to the language Prolog.

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1) The X-OPEN group currently consists of six European companies (Bull, Philips, Olivetti, ICL, Nixdorf, Siemens) and DEC and Sperry from the U.S.

As a direct result of an ESPRIT project the Belgian Institute of Management has recently released BIM-Prolog, a computer based Prolog development system with a compiler producing code which executes faster than code produced by any other Prolog compiler in the world.

In another project, this time led by Professor Colmerauer (the originator of Prolog) Daimler Benz, Bosch, GIA, GIT and Prolog IA came together to further develop Prolog into an enhanced new language (Prolog III) with the intention of using it to build as Knowledge based system for the diagnosis of failures in automobile engines.

In the IT Applications area results were obtained in the Computer Integrated Manufacturing and Office Systems development. Of particular interest are the results on standards.

The work in the Multimedia Office Document Architecture based systems (ODA) was aimed at defining a multimedia document standard. It was an early ESPRIT project (Handling of mixed text/image/voice documents based on a standardized office document architecture -HERODE) which developed the European (ECMA) and worldwide (ISO) office document architecture standards. While further work is being done to expand the ODA standard a powerful on-line editor and tools were built to define manipulate, store retrieve and transmit documents in the ODA format. It was implemented on a commercially available workstation equipped with a specially designed picture scanner for the input as part of ODA documents and with a bit-map printer for output. This system has been demonstrated at technical exhibitions.

Although a small part of the overall C.I.M. effort, standardization work in this area has also been particularly promising. The Communication Network for Manufacturing Applications project has brought together major IT vendors and users with strong links to the U.S. National Bureau of Standards and the General Motors MAP teams to implement factory communications protocols. A draft implementation guide is already available.

The impact of ESPRIT on standardisation is being felt internationally. By finding a common voice, European industry is in a very good position to take a leading role in the definition of world standards in IT and to exploit the resulting market opportunities.

ESPRIT is paving the way for a European Technology Community. This means creating and promoting transnational opportunities for European companies, leading to technological renewal and economic competitiveness. As such the dynamic role of small and medium-sized enterprises is self evident. ESPRIT is laying the ground for technology transfer, and encouraging small and medium sized enterprises to participate. Over half of ESPRIT projects count the participation of at least one SME (defined as a company with under 500 employees). In the case of some small industrial organisations ESPRIT work often accounts for the greater part of their R&D activity. Without ESPRIT such organisations would not have the funds available for significant research activity nor would they be able to benefit from international collaboration.

2. STATUS OF THE PROGRAMME

On 28th February 1984, the Council adopted the first phase of the ESPRIT Programme (European Programme for Research and Development in Information Technologies). The Programme was conceived for a ten year period with three main objectives:

- to provide European IT industry with the basic technologies it needs to meet the competitive requirements of the nineties;
- to promote European industrial cooperation in IT;
- to contribute to the development of internationally accepted standards.

For the first five-year phase of the programme an overall effort of 1500 MECU was foreseen, 50% of which (750 MECU) was to be borne by the research budget of the Community. The programme is implemented by means of a public call for proposals, which is based upon an annual up-dated workprogramme adopted by the Council.

After a pilot phase, begun in 1983, and since the start of the main Programme, there have been two major calls for proposals, one each in 1984 and 1985. A total of 1016 proposals were presented in the first two years. At 30th June 1986, there were 201 projects underway in the five technical areas. Table 1 demonstrates that these 201 projects will consume 677.7 MECU, assuming they all run to completion.
A further limited call was issued in 1986. 127 submissions were received by 1st July 1986. They are currently being evaluated and the results of the call cannot be included in this report.

Table 2 translates the resources devoted to each area into actual work effort, which totals 11,700 man-years. The percentage of work executed per area at 30th June 1986 ranged from 33% in CIM down to 21% in Software Technology, with the other three subprogrammes in a narrow band of 27% to 30%.

The rate of execution of Phase I as a whole can be seen in Table 2. Given that projects are usually of 5 years duration, those started over 2 1/2 years ago, in 1983, are showing an overall consumption rate of more than 50%. Both the rate of commitment of projects and of the ensuing consumption of work effort are as scheduled.

This steady progress can also be demonstrated on a project-by-project basis (Table 3). Nearly 90% of projects (179 out of 201) were on schedule at mid-1986. Of the rest, 14 projects were between 3 and 6 months behind schedule, and only 8 more than 6 months late. This is a generally very satisfactory performance, which programme management will attempt to maintain. However, the fact that the great majority of projects are currently on schedule does not imply that this will remain the case. Experience in R&D project management shows that, as projects move progressively towards their final objectives, milestones may become harder to meet. It is expected that all the projects will be scrutinised carefully in the coming months especially the 10% of projects seriously behind schedule; those which do not prove amenable to improvement will be terminated.

When the ESPRIT Programme was first conceived, the Commission and Community industry identified the foremost necessity of achieving substantial efforts at Community level. Table 4 shows the distribution of this work effort. The number of researchers working full time on ESPRIT projects climbed consistently to reach 2900 this year. As Phase I projects proceed, the total will decline from 1987 onwards, unless new projects are started in the course of 1987.

3. POTENTIAL ECONOMIC IMPACT AND INDUSTRIAL APPLICATION OF PROJECTS

3.1. Microelectronics

3.1.1. Microelectronics objectives

This subprogramme concentrates on the priority areas needed to ensure that the Community consolidates and maintains a competitive position for the timely supply of these essential elements with the required capability and at competitive prices to its IT manufacturing industry.

Two main themes are driving the work on the advanced microelectronics area:

(i) Computer Aided Design (CAD) to provide fast, easy to use tools to design Integrated Circuits (ICs) tailored to specific needs;

(ii) Processing technology to provide the technological capability of manufacturing ICs notably in the more promising sectors of digital signal processing, very high speed applications and optical transmission.

3.1.2. CAD: Objectives, Results and Impact

As improvements in fabrication techniques allow ever more complex circuits to be constructed, the bottle-neck in the exploitation of this capability lies increasingly in the domain of design and testing. Even with computer assistance, the skills needed to design integrated circuits are in short supply. The vast majority of systems designers are still unable to exploit the latest technology and obtain the benefits of cost and performance possible with high levels of integration.

At the same time, increased levels of complexity mean that a large percentage of such skills must be automated if circuits are to be designed efficiently in a short space of time with a high degree of reliability. Over the time span of the first phase of ESPRIT, the complexity is increasing from 100.000 to 1 Million transistors per chip (Table 5).

Even when these design problems have been overcome, testing the resulting chips for manufacturing faults becomes prohibitively expensive since the test time is an exponential function of their complexity. This means that radical solutions to the problems of design and testing have to be applied.

The size of the problem naturally motivates firms to collaborate. However, companies have slightly different market objectives from one another, which tend to be reflected in their detailed requirements on CAD systems. Furthermore, much research and development on CAD for VLSI has already been undertaken by the major companies.

Partly because of the existence of substantial amounts of collaborative work on CAD under the Microelectronics Regulation, the major call for work on CAD in ESPRIT was only scheduled for 1985. 10 projects have been launched involving a total of over 750 man-years of effort. The workplan is well covered by these projects and no further work on CAD was called for in 1986. A further 8 projects on CAD, involving an additional 700 man-years were previously funded under the Microelectronics Regulation, and many of these will come to an end in 1986. Several of the new ESPRIT projects represent further development of the results of this earlier work (e.g. CVS project making use of the results of CVT, Project 991 building on MR-09-DFT and Project 1058 on MR-03-KUL).

In order to harness this varied work while not penalising the participants in their legitimate commercial objectives, the establishment of standard interfaces is being strongly pursued which will allow both design data and design tools to be exchanged between different organisations with portable tools. This will be accomplished through a key project 887 known as "ECIP : European CAD Integration Project". This was started in January 1986 and involves 6 major European companies. All existing CAD projects have committed themselves to supplying ECIP with information on their research and to trying to implement emerging standards.

One project started over two years ago is taking on the challenge of VLSI design and is already achieving significant results with an industrial impact. This is project 97 "Advanced Algorithms, Architecture and Layout Techniques for VLSI Dedicated Digital Signal Processing (DSP) Chips". The work on bit-serial architectures has led to the creation of a fully operational silicon compiler from specification to layout for wave digital filters which is called CATHEDRAL-1. A second silicon compiler, CATHEDRAL-2, is on the way and will handle microcoded multiprocessor structures for DSP applications.

A digital filter synthesis programme called FALCON is available that can handle multirate filters of arbitrary amplitude/frequency characteristics. An international workshop has been organised to make potential customers familiar with this CAD tool. Using the results already obtained; a bit-serial VLSI transmultiplexer (184 orders of filtering with 92 coefficients) has been designed in 5u CMOS technology. The total design time (program execution and user interaction) to go through all the steps is 7 days. The resulting chip measures 76 sq mm and contains 30,000 transistors. The optimization tools described above directly reduce the transistor count by 30% compared to a straightforward translation of the filters networks into a layout. Traditionally, designing a chip with this programme and complexity would require some months. This is opening new possibilities for the telecom industries. Philips together with the Ruhr Universität of Bochum have already linked part of the software developed in the project to the new Philips digital signal processor that has successfully been programmed. Other industrial partners, e.g. SILVAR - LISCO, are introducing the tools developed in their design of new CAD systems.

One major project in CAD in terms of scale, ambition and industrial committment is project 888 "AIDA: Advanced Integrated Circuit Design Aids". Started in November 1985, this involves 3 major companies with some universities as subcontractors. It aims to apply advanced techniques such as modern programming techniques and knowledge-based engineering to attack the problems of rapid and reliable design of chips with 1 Million components. CAD tools, new methods and concepts will be defined, proved on experimental software and finally developed into industrial tools integrated into the existing CAD environments of the partners. AIDA should prove a rich source of ideas and an important test-bed for the proposed standards emerging from ECIP.

Finally, very noteable in CAD, are the CAVE Workshops, established 3 years ago, in which CAD researchers gather twice a year to discuss their work, trends and actions needed for the future. This serves the double purpose of disseminating the results of previous work and assisting in bringing about ideas and initiatives for future work. Its most important result, however, may well be that the researchers in this area in industry, academia and public institutions can now feel a sense of existing as a community with all its implications of solidarity and intellectual exchange.

3.1.3. Processing technologies: Objectives, Results and Impact

3.1.3.1 Silicon

The actual contracted work in hand is in line with the objectives of the workplan:

- By 1988, a 0.5 million components demonstration chip with a figure of merit of 50 femto-joules and 1 nsec delay time for the MOS process and a 10/20 Kgates, 100 psec gate delay demonstration chip for the bipolar process.

- By 1990, first samples of MOS circuits with more than one million transistors, with 0.7 um design rules and demonstration of 0.7 um bipolar process feasibility for 20/50 Kgates, 50 psec gate delay chips.

An overview of the envisaged evolution of these activities against time is presented as an example for CMOS in Table 5. This is a multiple entry diagramme showing the evolution of technological features from individual process steps to full industrial use versus time. For instance, following the lefthand margin and the diagonal lines, the definition of process steps for 0.7 u CMOS envisaged for end 86 at the level of an isolated advanced R&D action will have to be followed up by a further 2 years of work on defining and consolidating design rules and a further year before a pilot line can be implemented. Full industrial production would only take place after 5 years elapsed time from availability of process steps. The parallel developments and evolution necessary for CAD can be followed on the right hand column.

The four main projects which aim at the development of complete processing technologies are:

- Project 554 "Submicron CMOS Technology"
- Project 412 "A High Performance CMOS-Bipolar Process for VLSI Circuits"
- Project 243 "Submicron Bipolar Technology I"
- Project 281 "Submicron Bipolar Technology II"

Besides the two main silicon technologies - CMOS and bipolar - the present programme of work also includes a workprogramme which aims to develop a mixed VLSI technology, called BICMOS technology, to enable the fabrication of a single chip of very dense MOS logic circuitry together with high performance I/O bipolar devices.

The inter-relationship between these projects can be seen in Table 6, as well as their individual targets in terms of potential computing power (expressed as clock frequency x gate number).

To cite an example: 0.7 um CMOS is the objective of project 554. The table shows that the establishment of a pilot line featuring 0.7 u minimum geometries by 1989 will enable the expected state-of-the-art performance at that date (10^{13} gates x Hertz) to be achieved. This result is being pursued by putting the main thrust of the project in increased complexity and marginal gain in speed.

The main thrust on bipolar activities is on the other hand addressed at pushing the gain in speed to the limits allowed by power dissipation at constant gate count. Activities in GaAs sacrifice speed to the advantage of gate-count as the limiting factor in taking advantage of very high speed circuitry is the need to interconnect several low gate-count chips to implement a given complex function.

After their first eighteen months of life, these projects are on schedule and have notably achieved the following intermediate milestones:

- joint definition of process flow;
- issue of design rules;
- realisation of common test masks;
- work on individual process steps, simulation and comparison in the existing processes.

In order to integrate devices on a silicon wafer, more than 30 fabrication steps proceeding in a specific sequence and known as the process flow, have to be properly executed. Virtually all the steps of a process are strongly interrelated and no process step can be changed in isolation in an established process. In developing a new process, the identification of the interrelationships between the various steps is one of the most challenging tasks and this has been successfully accomplished by the consortia.

Each process is characterised by a complete set of design rules, i.e. the rules governing the dimensions of features that are permissible in designing and laying out an IC in a particular technology. Increased packing density means greater sensitivity to process variations so many divergent factors are considered when deriving a set of new manufacturable design rules. As an example of results achieved so far, the design rules (1.5 um emitter for bipolar devices) and the process flow chart of the BICMOS process (including 13 ion implantations and 16 mask steps) have been demonstrated on a simple design.

Where new processes are developed by means of collaborative work, a common set of test masks (including test patterns based on the expertise of each company) constitutes the common tool to implement the comparison of progress and results achieved in the numerous locations. The differences between the design tools, data formats, lithographic equipment, alignment marks and wafer sizes used by the partners have sharpened the difficulties of providing such a common set of masks, and delays have been encountered, which are now being gradually solved. In general, the diversity of equipment such as deposition or etching equipment enlarges the investigation capabilities within the projects; the realisation of a common mask, however, appears to be a delicate operation even when only 2 partners are involved.

Several new methods are being investigated in each project with a view to their integration in the final process flow. Work on these is progressing particularly well and the results achieved, notably the introduction of new isolation schemes, are ahead of the intermediate milestones. Furthermore, simulation data and electrical tests on structures realised with existing processes indicate that the developed methods are suitable for the targetted specifications at year 3.

One deliverable has already come out of Project 281. The design of the first demonstrator, a 10K-gate array, with 2 um, 200 ps delay, 3 layer metallization was completed in January 1986. A new line for the production of these arrays is being built by Siemens (D), at a cost of around 100 MECU. The development of prototypes is planned for next year, followed by full production.

In addition, techniques which represent a long term applicability across the whole sub-area are receiving special attention, notably in the case of silicon on insulator and 3D structures, and interconnection schemes for VLSI chips. In this latter field, Project 14 "Advanced interconnect for VLSI" has had an early industrial impact. The overall objective is to develop high density interconnect compatible with one micron MOS and Bipolar VLSI technologies. This interconnect technology will feature four levels of low resistivity metals with high electromigration resistance and stable, low resistance contacts to the underlying silicon device.

Immediate exploitation of this technique with 2 metal-levels is taking place for the realisation of a new 200,000 transistors CMOS circuit including four 16 x 16 multipliers and two 16 bit microprocessors. This circuit will have a 2 sq.cm size and samples are scheduled for September 1986 by Plessey (UK). These interim results give confidence that the final objectives will be achieved on schedule.

3.1.3.2 Compound Semiconductors

The quest for increased performance of computer and communications systems is supplying the impetus behind IC designers' efforts to constantly improve circuit specifications. The combination of superior speed and smaller power dissipation is one of the major driving forces behind the development of compound semi-conductor ICs.

In the last ten years, the level of integration of Gallium Arsenide (GaAs) ICs has increased very rapidly. However, Silicon is a very mature technology and quite complex processing methods are resulting in good yield. On the other hand, GaAs processes are just reaching the first steps on the maturity ladder and considerable progress in materials and process research is necessary.
At present, the GaAs technology encompasses ICs based on FETs (field effect transistors) as well as on more advanced devices such as HBTs (heterojunction transistors) or HEMTs (two dimension electron gas transistors).

Since higher processing speed is the major goal for computer designers, the GaAs technology will lend itself to improve performance of the major building blocks of computers and computer-based systems as for instance fast memories as well as the various logic functions to combine these.

During 1985 and 1986, GaAs ICs have grown in interest as evidenced by the number of new companies entering this business, especially in the United States and in Japan and by the announcement by Cray Research that their next generation supercomputer Cray III will be based on digital GaAs ICs. Given this fierce competition, the results of ESPRIT Programme seem to be in line with industrial world state-of-the-art.

The specific objective of this subarea is focussed on the demonstration by the end of 1989 of a building block of 10K to 20K gates complexity, gate delay of less than 50 ps with a figure of merit less than 100 femtojoules. This integrated circuit could be a 16K memory with an access time in the order of a few nanoseconds or a high speed data bus or a signal processing circuit for telecommunication applications.

The overall goal of Project 232 "Compound Semiconductor Materials and Integrated Circuits - I" was to establish gallium arsenide digital integrated circuit technologies using Metal Semiconductor Field Effect Transistor (MESFET), HEMT/Two Dimension Electron Gas Field Effect Transistor (TEGFET), HBT as active devices. Speed and power advantages of GaAs over silicon were to be suitably demonstrated. At the end of the project, all the milestones have been met.
These are:

- fully operational 1K SRAM in MESFET technology with 3-6 ns access time and a typical power consumption of 80 mW;
- 19 stage TEGFET circuits with gate delays of 20 ps;
- 19 stage heterojunction bipolar circuits with delays of 50 ps.

In addition, complementary programmes have been set up in the areas of lithography, dry processing, the selection of suitable dielectrics, material assessment techniques and specific process technologies. This has already had an industrial impact: an agreement has been announced between one of the partners and Cray Research to develop application specific ICs for the next generation of supercomputers.

For purposes of coherence and the optimal use of resources allocated to this part of the programme, work in the domain was divided between two main projects: one (843) on field effect devices (MESFET and HEMT) and another one (971) dealing with bipolar transistors (HBT), supported by a project (1128) on dislocation-free GaAs semi-insulating crystals.

Project 514 looking at the application of new developments of solid state physics in microelectronics had been especially successful, demonstrating for example room temperature oscillations in superlattices and two dimensional gases both for electrons and holes in GaInAs/InP structures.

3.1.3.3 Optoelectronics

In addition to providing faster logic switching times for ICs when compared to Silicon, III-V compounds can offer, depending on their actual composition, a special feature, "direct band gap", which opens up the whole new area of optoelectronic technology. The prospect of associating on the same substrate both electrical digital/analogue functions and optical emitter/receivers, allows a new generation of integrated optoelectronic devices with a large potential for short range or long haul communications. Integrated optoelectronics devices (OEICs) will provide the electrical/optical interface as well as the logic functions at a lower cost and with increased performance.

Two approaches to OEICs have been retained at this early stage, to increase as far as possible the transmission capability:

- to integrate electronic and optical components on the same chip towards integrated receiver and transmitter with bandwidth greater than 2.5 GHz;
- to use integrated optics to perform wavelength multiplexing (WDM).

These are the objectives of the two parts of project 263 "InP Based Optoelectronic Circuits".

Progress at the moment is limited to discrete devices. The latest material growth facilities have been installed and tested at two sites. The problems tackled and solved over this period have led to a significant improvement in the base technologies required for InP devices:

- quality in material growth is assessed using a variety of X-ray and infrared techniques;
- the achievement in design has meant a better understanding of photodetectors;
- low threshold (30mA) second order DFB lasers with a ridge structure have been realised and characterised showing:
  - . a good tuning range of the lasing wavelength within the gain peak of the active material;
  - . 2 GHz direct modulation capabilities with small chirp (0.2 nm).

  These two are key parameters for optical fiber communication : they indicate the capability to pack up information channels on a single fiber which can assess both the range of available wavelengths and the achievable bandwidth of one carrier frequency.

It was decided to integrate a simple combination of devices, comprising an InGaAs photodiode together with an InGaAs amplifying device (JFET) operating in the second infra-red transparency window (1300 nm). InGaAs is a member of the family of III-V compound semi-conductors, adapted for growth on an available substrate (InP) and optimized for light detection (and emission) in the 1300-1600 nm range. The integration of these two devices has been successfully demonstrated but this work has proved to be more difficult than expected, indicating that developing an integration technology is at least as demanding as developing each individual component, and consequently, some delays are occuring in this specific task.

In the field of non-linear optics, project 443 "Molecular Engineering for Optoelectronics" has achieved successful molecular engineering of a new organic compound transparent in the optical fibre windows. The project at completion will have investigated and produced new organic materials with enhanced nonlinear responses. These will have many applications especially for ultrafast optical signal processing.

MICROELECTRONICS
Referenced Projects

No	Title	Participating Organisations
14	Advanced Interconnect for VLSI	Plessey Research Ltd (UK), AEG Telefunken (D), GEC(UK) THOMSON CSF (F)
97	Advanced Algorithms, Architecture and Layout Techniques for VLSI Dedicated Digital Signal Processing Chips	IMEC v.z.m. (B), Bell Telephone NFG.Co.(B), Silvar-Lisco N.V.(B), Philips (NL) Siemens (D), Ruhr Univ. Bochum (D)
232	Compound Semiconductor Materials and Integrated Circuits - I	Allen Clark Res.Centre(UK), Lep-Philips (F), Siemens AG (D), Thomson CSF/DMH (F)
243	Submicron Bipolar Technology - I	Thomson CSF/DCI (F),Plessey Research Caswell (UK), Telefunken Electronic (D), Thomson CSF/LCR (F), Rhône-Poulenc Multitech.(F), Univ. of Berlin (D), Univ. de Toulouse (F)
263	INP Based Optoelectronic Circuits	CSELT (I), AEG Telefunken (D), CNET (F), GEC (UK), HHI (D), SEL (D), THOMSON CSF/LCR (F), CGE (F), STL (F)
281	Submicron Bipolar Technology - II	Siemens AG (D), RTC Compelec (F)
412	A High Performance CMOS Bipolar Process for VLSI Circuits	Nederlandse Philips Bedr. (NL), Siemens (D), Univ. of Stuttgart (D)
443	Molecular Engineering for Optoelectronics	CNET (F), ICI PLC (UK), THOMSON CSF (F), Univ. de Namur (B)
514	Quantum Semiconductor Devices	GEC (UK),THOMSON CSF/LCR (F)
554	Submicron CMOS Technology	CNET (F), British Telecom (UK), IMEC (B), Matra-Harris Semicond. (F), SGS Microelettronica (I), Univ. of Leuven (B)
843	Compound Semi-Conductor Integrated Circuits	STL (UK), GEC (UK), Philips-LEP (F), Siemens(D) Thomson-CSF/DMH (F), Plessey Research Caswell (UK), Farran Technology (Irl)

No	Title	Participating Organisations
887	European CAD Integration Project (ECIP)	Bull (F), Alcatel (F), ICL (UK), Philips (Nl), SGS Microelettronica (I), Siemens (D)
888	Advanced Integrated Circuit Design Aids (AIDA)	Siemens (D), ICL (UK), THOMSON-Semiconducteurs (F) Bull (F), IMAG/TIM3 (F), UMIST (UK)
971	Technology of GAAS-GAALAS Bipolar Integrated Circuits	CNET (F), Plessey Reseach Caswell (UK), GEC (UK), Farran Technology (IRL), Plasma Technology (UK)
991	Multiview VLSI - Design System ICD	Delft Univ.of Technology (Nl), British Telecom (UK) ICS Holding BV (Nl), PCS GmbH (D), Tech. Univ. Eindhoven (Nl), Univ. of Essex (UK)
1058	Knowledge Based Design Assistant for Modular VLSI Design	IMEC v.z.m.(B), Philips (Nl), SILVAR-LISCO N.V.(B)
1128	Large Diameter Semi-Insulating GAAS	LEP (F), Wacker Chemitronics (D), U.C.L. (B)

3.2. Software Technology

3.2.1. Software Technology Objectives

Software Technology is one of the major enabling technologies of the IT industry. The software part of the design process of systems accounts for an ever increasing proportion of total system effort. For many years now the costly difficulties caused by the software development, modification and correction processes have been recognized. Yet, very limited improvement has been achieved so far in reducing the high development costs of software products or in improving confidence in their quality.

Consequently, the rationale of the ESPRIT Software Technology subprogramme was based on the acceptance of the fact that future European competitiveness in the IT sector would be highly dependent upon European industry's ability to produce higher quality more reliable software at lower cost. Such an ability combined with the increasing availability of standard "off-the-shelf" hardware components enable the rapid introduction of new products and the reduction of total life-cycle costs.

The approach adopted by ESPRIT aims at reaching its objective of cost-efficient production of high quality reliable software through the achievement of a high degree of reusability.

The first goal is therefore to provide processes capable of supporting the development of reusable software. Considerably more than half of the cost of software development today is due to redevelopment necessitated by modifications due to a change of requirements, errors or is due to unintentional duplication. This cost can be significantly reduced once reusable processes and associated tools are available.

Process reusability facilitates the production of reusable modules. Software module reusability is analogous to component reusability in the automobile industry and of obvious further cost-cutting value. To that end appropriate Development Support Environments oriented towards resusability are needed.

The ESPRIT Workprogramme divided the work to be done in Software Technology in three areas:

- Theories, Methods and Tools
- Management and Industrial Aspects
- Common Environments.

In what follows the work underway and the result obtained so far are regrouped under two headings, according to the following structure:

- Development Support Environments: consisting of the work done under "Common Environments" and its extensions

- Advanced Development Methods and Tools: covering the work done under "Theories, Methods and Tools" and "Management and Industrial Aspects"

3.2.2. Development Support Environments: Objectives, Results and Impact

A Development Support Environment capable of meeting the required reusability objectives should have the following features:

- it must be available on a wide range of different computers. The different versions should conform to an agreed standard and methods of certification are needed for this purpose. The portability of such an environment, (i.e. the ability to run the software on computers from different manufacturers) is also particularly important with respect to the high development cost of such software.

- the ability to store in a common structure all information generated and manipulated during the development process. In addition to programs (in source or object form) many other objects (e.g. user requirements, design specification, documentation, test data, development history...) have to be stored for possible later reuse, for example during the maintenance phase or during a similar development activity.

- The provision of a wide and complete set of powerful, integrated and homogeneous facilities to support the development process. Until now tools and application developers have had to cope with the operating systems delivered by hardware manufacturers. A support environment should be considered as representative of a new generation of operating system offering high level functionalities adapted to the software development activity.

- The availability of an adequate user interface. A support environment must have interfaces that allow the data processing and professional to perform efficiently and must also have very friendly user interfaces for application end-users.

- The ability to take advantage of new techniques based on up-to-date technologies especially with respect to the recent advances in computer architectures and communications. For example, distribution of tasks over a Local Area Network (LAN) and high level Communication Protocols should be basic underlying concepts of a support environment.

The ESPRIT effort for such a Development Support Environment began after the first call of proposals in 1983 with the launching of a large project which brought together six of the major computer companies within Europe (Bull, GEC, ICL, Nixdorf, Olivetti and Siemens) with the goal of producing prototype Development Support Environments within a three year timeframe:

Project 32 : "A basis for a Portable Common Tool Environment" (PCTE)

The results obtained have gone beyond meeting the original goals to spawning extensive complementary work both within ESPRIT and elsewhere.

- Prototypes of the PCTE have been developed and evaluated.
- The specifications of development environment interfaces have been completed.

- A first version of the PCTE was demonstrated in December 1985.
- A full commercial implementation of PCTE, EMERAUDE, was produced by GIE-Emeraude and released to the market in September 1986 -a prime example of timely exploitation of ESPRIT R&D results by industry.

The PCTE work is having a wide industrial impact. The specifications of development environment interfaces are being adopted by other member States R&D programmes (e.g. Alvey) and are the subject of ongoing discussions within the ADA (the European originated U.S. DoD language) framework. Through the work on PCTE a major industrial group, know as the X-OPEN group[1] has been formed to support the adoption of a standard UNIX operating system interface for computers developed by European manufacturers.

To take advantage of hardware and related advances, a number of projects have been launched to assure the continuity of the PCTE work towards the development of the next generation of environments.

These include projects on Generation of Interactive Programming Environments (348, GIPE), Advanced Support Environment for Method Driven and Evolution of Packaged Software (SIO, TOOL-USE).

These projects broaden the partner involvement in this area far beyond the initial six companies (SEMA METRA (F), BSO (Nl), CWI (Nl), INRIA (F), Informatique Int. (F), U.C. Louvain (B), Generics ltd. (Irl), Univ. of Erlangen (D) et al.) and provide the evolutionary paths from the current PCTE environments to the next generation ones. This ensures the compatibility of European industrial investment in software development facilities.

Finally, at the recommendation of the ESPRIT Advisory Board, a review of the programme was conducted in 1985, and a special call for proposals was issued in the Autumn of 1985 which launched projects[2] specifically

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1) The X-OPEN group currently consists of six European companies (Bull, Philips, Olivetti, ICL, Nixdorf, Siemens) and DEC and Sperry from the US.

2) 951 PCTE - Added Common Tools (PACT)
1277 PCTE Portability (SAPPHIRE)
1282 PCET and VNS Environment (PAVE)
1283 VDM Interfaces for PCTE (VIP)
1262 Software Factory Integration and Experimentation (SFINX)

aimed at broadening the use and availability of PCTE by

- producing general tools to run on top of PCTE like syntax editors, desk-top managers, data manipulation languages, etc.
- porting PCTE on other operating systems
- Producing formal specifications of PCTE interfaces
- Providing demonstrators of the use of the PCTE within an industrial context and initiating the building of a European Software Factory.

3.2.3. Advanced Development Methods and Tools: Objectives, Results and Impact

Once the basic support environments are available the need arises for advanced methods and tools for software design, management and metrics. The integration of such methods and tools on top of support environments will provide exploitable software development environments for reusable software.

3.2.3.1 Software Design Methods and Tools

Analysis of many software development projects during the last decade both in Europe and the United States has shown that the emphasis in this area must be on the techniques for handling the high level design phase (e.g. user requirements, specifications, design). Reflecting this emphasis the work on Software Design Methods and Tools concentrates on

- Mathematically Formal Methods
- Application of Knowledge Based Techniques.

a) Mathematically Formal Methods

The need for design validation and verification as the design of a product proceeds has given rise to the development of formal design methods. Applying formal mathematics to system design could be the first step towards putting Software Engineering on a sound scientific basis and thus opening the way for ready and profitable use of the vast arsenal of Mathematics already available. More specifically, if software development methods and modules can be rigorously and unambiguously described in a Mathematical formalism their reuse in future software developments becomes a realistic goal (e.g. modifying formal specifications vs. modifying actual code and then deriving automatically the new code from the modified specifications).

The projects in this area aim at such mathematically formal descriptions of software modules and their development allowing for

- a level of automation of the transformation of these descriptions into software programmes (code)
- validation of these programmes with respect to their associated descriptions.

Work in this area is new but a number of early results are already available:

Project 315 "Rigorous Approach to Industrial Software Engineering (RAISE)"

One of the most widely adopted formal method in the European industry is the so called VDM[3] method. Concurrent systems are at the center of ongoing research on future generation systems. This project has provided extensions of the VDM method for the specification of concurrent systems which have been formally defined and validated. Prototype tools are under development.

Project 390 "Program Development by Specification and Transformation (PROSPECTRA)

This project developed a rigorous methodology for program development by transforming formal specification into ADA programs. Although many difficult problems remain, a significant part of the process has already been automated.

Project 432 "An Integrated Formal Approach to Industrial Software Development (METEOR)

The main aim of this project is to refine available formal methods so that they can be readily transferred to and used by as wide a range of industries as possible. To this end it has produced advanced models for requirement engineering and a specification formalism for the whole software life cycle.

[3] VDM = "Vienna Definition Method".

Project 410 "Software Environment for the Design of Open Distributed Systems (SEDOS)

Two languages (ESTELLE, LOTOS) have been defined for the formal description of OSI[4] protocols and services and compilers and syntax directed editors have been implemented for these languages (prototypes available). The languages defined are now under discussion by the corresponding ISO working groups for standardization purposes.

b) Application of Knowledge Based Techniques

The emergence during the last decade of new approaches and techniques in Artificial Intelligence, especially in the Knowledge Engineering domain, has created the possibility of exploiting these advances in software development.

Formal methods by themselves cannot adequately capture many of the aspects of software development and in particular many characteristics of the actual working environment (e.g. when tailoring software to the needs of a paticular company). Combining expertise captured by Knowledge Engineering with formal methods is a more practical approach which is the focus of state-of-the-art work in the area.

Naturally work in this subarea is highly dependent on the Knowledge Engineering part of the Advanced Information Processing (AIP) programme. Careful coordination in terms of technical and managerial issues has been put in place to ensure appropriate cross fertilization and feedback.

The main results of projects in this area (launched after the 1985 call) consist of developments of "rapid prototyping" techniques which provide the mechanism for communication of user requirements to the system designer.

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[4] OSI "Open System Interconnection".

Project 401 "Application Software Prototype Implementation System" (ASPIS)

A prototype requirements analysis subsystem is available and a complementary prototype "design assistant" is expected within one year. The approach allows user requirement specifications (i.e. the display of the functional behaviour of the system to be designed) to be checked with knowledge based techniques which assist in evaluating the application software before implementation. The significance of this lies in the fact that, currently, a major source of errors in the software development process is the misinterpretation of user requirements by the design team.

Other projects work on providing means of capturing, storing and manipulating expertise on all the other aspects of the software development process[5).

3.2.3.2. Software Management Methods and Tools

Managing software development is a complex and difficult task which offers substantial room for improvement. Work in this subarea aims at providing support for the control of these processes taking into account software life cycles, current industrial practices and human factors. There are three ongoing projects in this subarea.

Project 282 "Software production and Maintenance management Support (SPMMS)"

Following a pilot feasibility study, this project is producing an automated system supporting process control and project management. The architectural design is now completed and a prototype of the semantic data model is available to be used as the kernel of the system.
The two other projects (P 814 PIMS and P 938) have been launched more recently as a result of the 1985 call. They develop in common an approach oriented towards the use of intelligent knowledge engineering

5) 974 A Knowledge-Base Environment for software System Configuration Reusing Components (KNOSOS).
891 Development of an Efficient Functional Programming System for the Support of Prototyping.

techniques in order to provide a rule-based management system to be used as a consultant or as a training system.

3.2.3.3 Software Metrics Methods and Tools

Metrics methods are aimed at measuring products and methods characteristics with respect to parameters like performance, quality, reliability and safety. There is agreement that to improve development methods it is necessary to meaningfully measure such software parameters. Particularly pressing measurement demands come from the aerospace and nuclear industries. However, to reach consensus amongst scientific and industrial experts on exactly what to measure and how to measure it has proved difficult. To try and overcome this difficulty a large scale project was launched in 1984 to provide the basis for a common European position on this issue drawing together eight companies from five Member States[6)]:

Project 300 "Reliability and Quality of European Software (REQUEST)"

The work in this project focusses on two main topics:

- reliability of software products
- quality of software processes and products

A Consultation Quality Model has been defined after defining appropriate metrics and their measurement and analysis and is being evaluated. To avoid duplication of effort and to ensure cohesion within Europe, coordination with national programmes has been established.

Additional smaller projects have been launched[7)] in order to complement the work of REQUEST (e;g. on productivity measurement) and to apply metrication to well targeted domains (e.g. real time embedded systems or clerical systems).

6) STC (ICL) (UK), SIC IDEC (UK), Thomson CSF (F), Esacontrol (I), GRS (D), AEG Telefunken (D), CISI-IT (F), UKAEA (UK), Electronic Centr. (DK).

7) 1257 Software Quality and Reliability Metrics for Selected Domains: Safety, Management and Clerical Systems (MUSE).
1258 Testing and consequent reliability estimation for real-time embedded software.

SOFTWARE TECHNOLOGY
Referenced Projects

No	Title	Participating Organisations
32	A basis for a portable common tool environment (PCTE)	Bull (F), GEC Research Labs (UK), Nixdorf (D), Olivetti (I), Siemens (D), ICL (UK)
282	Software production and maintenance management support (SPMMS)	Siemens (D), CIT-Alcatel(F) Philips Int.B.V. & TRT (Nl) CERCI (F), Data Management (I), Standard Teleph. & Cables (UK)
300	Reliability and quality of European Software (REQUEST)	STC(ICL)(UK), SIC IDEC (UK) Thomson CSF (F), Esacontrol (I), GRS (D), AEG Telefunken (D), CISI-II (F), UKAEA (UK), Elektronic Centr.(Dk)
315	Rigorous Approach to Industrial Softw. Engineering (RAISE)	Dansk Datamatic Centre (Dk) Standard Telephone & Cables (UK), International Computers Ltd.(UK), BBC Nordisk Brown Boveri A/S (Dk)
348	Generation of Interactive Programming Environments (GIPE)	SEMA METRA (F), BSO (Nl), CWI Amsterdam (Nl), INRIA (F)
390	Program Development by Specification and Transformation (PROSPECTRA)	Univ.of Bremen (D), Systeam KG (D), Univ.of Dortmund(D) Syseca Logiciel(F), Univ.of Passau (D), Univ.of Strathclyde (UK), Univ.of Saarland (D)
401	Application Software Prototype Implementation System (ASPIS)	Olivetti (I), Tecsiel (I), GEC Research Labs.(UK), Cap Sogeti Innovation (F)
410	Software Environment for the Design of Open Distributed Systems (SEDOS)	LAAS/CNRS (F), Agence de l'Informatique (F), Bull S.A. (F), International Computers Ltd (UK), Tech. Univ. Twente (Nl)
432	An Integrated Formal Approach to Industrial Software Development (METEOR)	Philips N.V. & MBLE (B), CGE (F), AT.T & Philips (B) Stichting Math. Cent. (Nl), COPS Europe (Irl), Tech. Software Telem. (I), Univ. Passau (D), Philips Nat. Lab. (Nl)

No	Title	Participating Organisations
510	An Advanced Support Environment for Method Driven Development and Evolution of Packaged Software (TOOL-USE)	Informatique Internationale (F), Univ. Catholique de Louvain (B), GMD (D), Generics Ltd. (Irl), CERT (F)
891	Developmentof an Efficient Functional Programming System for the Support of Prototyping	STC (ICL) (UK), Tech. Univ. Twente (Nl), Univ. of St. Andrews (UK), Non Standard logics (F)
928	A Rule Based Approach to Information Systems Development	James Martin Ass. (Nl), Univ. of Manchester (UK), BIM (B), Micro Focus (UK)
951	PCTE-Added Common Tools (PACT)	Bull SA (F), GEC Co.(Software)(UK), ICL (UK), Olivetti (I), Syseca (F), Systems & Management (I), Eurosoft (F)
1221 (974)	A Knowledge-Base Environment for Software System Configuration Reusing Components (KNOSOS)	ESI (F), CNET (F), Dornier System GbmH (D), Matra (F) Yard (UK), CIT-Alcatel (F)
1223 (814)	Project Integrated Management Systems (PIMS)	CAP Sogeti Innov. (F), PACTEL (UK), The Turning Institute (UK), BSO (NL)
1223 (938)	Integrated Management Process Workbench	ICL Ltd. (UK), CETE Mediterranée (F), Verilog (F), NIHE (IRL), Imperial College (UK)
1229 (1262)	Software Factory Integration and Experimentation (SFINX)	SFGL (F), CRI A/S (Dk), CSATA-TECNOPOLIS (I), ERIA-Research & Dev. (E)
1229 (1277)	PCTE Portability (SAPPHIRE)	Cap Industry (UK), GIE Emeraude (F), Software Sciences Ltd. (UK), PCS GmbH (D)
1229 (1282)	PCTE and VNS Environment (PAVE)	GEC Software (UK), Syseca Logiciel (F)

N°	Title	Participating Organisations
1229 (1283)	VDM Interfaces for PCTE (VIP)	GEC Software (UK), Dr. Neher Labs (Nl), St. Mathematisch Centrum (Nl), Univ. of Leicester (UK)
1257	Software Quality and Reliability Metrics for Selected Domains: Safety, Management & Clerical Systems	Brameur (UK), CRIL (F), RWTUEV (D)
1258	Testingand consequent reliability estimation for real time embedded software	Univ.of Liverpool (UK), Liverpool Data Research Assoc. (UK), Software Eng. Services GmbH (D), City University (UK), John Bell Ltd. (UK)

3.3. <u>Advanced Information Processing (AIP)</u>

3.3.1. AIP Objectives

This area deals with future developments in the basic technologies of Information Processing and as such is concerned with means for improving the effectiveness of computing systems. In order to achieve substantial progress, the ESPRIT workprogramme addresses the following four key areas :

(i) Knowledge Engineering,
which represents the change from processing of numeric data to processing of information and knowledge. Particularly important is the development of knowledge acquisition, representation and manipulation techniques, which are also vital in improving human access to conventional databases.

(ii) External Interfaces,
through which the computing system communicates with its environment. This area deals with the recognition, understanding and synthesis of signals. These signals include those exchanged with humans.

(iii) Information and Knowledge Storage,
dealing with the developments in data and knowledge bases as well as with techniques of access to these bases and with new hardware devices.

(iv) Computer Architectures,
dealing with the organization of the processing elements used by the computing system. The development of novel computer architectures and their associated programming environments is a major part of the work in this area.

For the purpose of this report, to show the links between projects better, the work in the Information and Knowledge Storage area will be considered together with that in Knowledge Engineering.

A major emphasis of the workprogramme has been on the implementation of practical systems. It was expected that much of the work should build on existing technological bases. However, more theoretical aspects were also addressed, particularly in knowledge engineering, where substantial fundamental research is required.

Advanced information processing systems in general benefit from inputs from micro-electronics and software technology. The former supply faster hardware components, while the latter provide appropriate programming environments. Equally, AIP systems and techniques find substantial applications in Office Systems and Computer Integrated Manufacturing, as well as in other sectors.

3.3.2. Knowledge Engineering: Objectives, Results and Impact

Knowledge engineering is concerned with the construction and use of knowledge-based systems (KBS) and software tools to help this process.

A knowledge-based system is a software and hardware system that processes data, information and knowledge. A useful working definition of knowledge is that part of symbolically described information that is used by competent experts in a particular domain (medical, legal, etc.). For this reason a KBS is also referred to as an expert systems (ES).

For the purpose of this report, the knowledge engineering area is structured as follows:

the construction of expert systems comprises:
a) knowledge acquisition
b) knowledge representation
c) knowledge processing

Support tools are addressed by:
d) prolog
e) access to databases
f) dialogue.
These items are complemented by the demonstration of KBS's and their evaluation in industrial environments.

3.3.2.1 Knowledge Acquisition

One of the salient characteristics of most KBS's is the separation of knowledge from its processing; ideally, a pool of knowledge would be brought to bear in appropriate ways depending on the specific problem to be solved in the domain of expertise of the KBS. It is therefore essential to provide mechanisms for the acquisition of relevant knowledge by the KBS. This knowledge is normally represented by a set of rules.

Two main approaches exist. The more traditional one is based on interviews with experts.

The second approach is based on the hypothesis that no amount of interviewing, even when aided by sophisticated tools, will generate a completely satisfactory knowledge base because experts cannot explain their reasoning in a way that is easily formalizable. This is more evident in the case of KB's derived from multiple experts or over a long period of time. It is necessary to use case studies (examples) instead of interviews to derive principles. It is possible that a mixed approach would be best.

ESPRIT projects cover both of these approaches. Following the first approach, a software tool and methodology called KADS (Knowledge Acquisition and Structuring)was developed in project 304 ("Design of Techniques and Tools to Aid in the Analysis and Design of Knowledge-based Systems") to help the KBS designer in structuring the interview process and using protocols of expert consultations to derive the knowledge that is necessary to build an expert system. KADS is a unique working tool. The KBS development toolkit to be produced by Project 1098 (A methodology for the Development of KBS) will include it in order to open the way for its commercial use; first demonstrations of the toolkit will be given in September 1987.

Learning knowledge from examples, the second approach, is the subject of project 1063 ("Integration of Symbolic and Numeric Learning Techniques"). This is a smaller and more speculative project than 1098. However, three state-of-the-art learning programs have been demonstrated and their integration is proceeding. Integration may contribute to overcome the excessive sensitivity to small errors in the examples exhibited by even the best logic-based learners developed in the USA and the inflexibility exhibited by the best entropy-based learners developed in Australia, the UK and the USA. Therefore, even a partial success of the integration goal of this project will constitute advancement of the state of the art.

3.3.2.2 Knowledge Representation

Many knowledge representation formalisms have been proposed; ESPRIT projects cover a good sample of them provided in the workplan. Two main ones are semantic networks and logic.

Several variants of semantic networks are also explored. P280 (Eurohelp), which deals with the issue of helping users of information systems (e.g. text editors) to use their systems correctly and learn about them has developed a type of semantic network called genetic graph to represent user and information system modules; such models evolve as the user becomes more competent and reflect the current use of the system. In November 1985, Eurohelp demonstrated a prototype system that provides guidance to users of electronic mail. Eurohelp is the only large industrial research project on intelligent help systems for information system users; the only other large project on this topic is the Unix Consultant at the University of California at Berkeley.
A kind of semantic network representation has been studied in P440 and partially implemented in Omega (see section 3.3.2.3). P256 has considered the issues related to the representation of qualitative or functional models of complex physical systems, such as power plants. It was completed successfully, and is now the basis for a more application-oriented project, P1220 "Design and Experimentation of a KBS Architecture and Tool Kit for Real-time Process Control Applications".

Logic is the oldest form of knowledge representation; the Prolog programming language, first developed in Europe in 1970, provides a computationally efficient mechanism to use an appropriate subset of logic. Several ESPRIT projects study Prolog-based representations and its interface with graphics; these projects also address the issue of interfacing Prolog and relational databases. These are very important practical issues for the success of knowledge-based computer-aided design tools.

3.3.2.3 Knowledge Processing

Knowledge processing is often identified with inference, the process of deriving conclusions from available facts therefore knowledge processors (software or, more rarely, firmware or hardware) are called inference engines.

Omega, already mentioned above, developed in the context of P440, includes an inference mechanism; it is a tool for building expert systems (an expert system shell).

This tool is comparable to what is available in the best US-built Expert systems shells based on semantic nets, such as KEE and LOOPS.

The goal of project P96 ("Expert System Builder")is to build an expert system shell (ESB). A rule-based system called SYPRUC, built by one of the partners in the consortium (CIMSA), has been one of the building blocks used to develop the first version of ESB, ESB0, to be demonstrated in October 1986.

An independent evaluation of SYPRUC has concluded that SYPRUC is a well-designed and documented expert system shell, more suitable for the commercial development of ES's than any other known rule-based European shell. Project 96 is continuing with the aim to improve ESB0 and develop a shell that includes the features offered by the best American shells, e.g. ART.

3.3.2.4 Prolog

Prolog is particularly useful for building tools for the construction of KBSs and, at least when suitably augmented, to build KBSs directly.

P1106 is developing an extension to Prolog called Prolog III, under the direction of Prof. Alain Colmerauer, the inventor of Prolog. Prolog III is fully specified and its implementation is proceeding on schedule. Its announcement has stirred considerable interest.

The Belgian Institute of Management (BIM) has recently released BIM-Prolog, developed in the context of project 107 (LOKI). BIM-Prolog is a Prolog development system including a compiler whose object code executes faster than the object code produced by any other Prolog compiler in the world on standard benchmarks.

Project 973 (ALPES, "Advanced Logical Programming Environments")is concerned with the development of an advanced logic programming environment. Three partners involved in this consortium, CRIL, Bull and Universidade Nova de Lisboa, had built three Prolog interpreters before forming it; and are very active in promoting the Prolog to be used in this environment as the basis for an international standard.

In order to provide Prolog with a graphics capability, an interface between Prolog and an implementation of the international graphics standard GKS has been developed in project 393 (ACORD). Although other such interfaces have been implemented elsewhere, this one uses a more complete version of GKS, was developed by members of the consortium with a deep understanding of the subject (having implemented C-Prolog earlier), and is accompanied by a major effort to define a methodology for the use of Prolog in graphics-intensive applications.

3.3.2.5 Access to Databases

Most existing knowledge-based systems deal with small knowledge bases and are not coupled to large databases.

Five projects addressing this issue have demonstrated partial results.

P311 (ADKMS, "Advanced Data and Knowledge Management systems",) has implemented and interface of a rule-based natural language parser with a system called BACK, similar to the American KL-ONE system. P316 (ESTEAM,"An Architecture for Interactive Problem Solving by Cooperating

Data and Knowledge Bases") has coupled Prolog to a relational database management system. P530 (EPSILON,"Advanced Knowledge Base Management System") has done the same, using techniques that translate rules into relational algebra expressions. P1117 (KIWI,"Knowledge-based User Friendly System for the Utilization of Information Bases") has developed a knowledge manipulation tool (knowledge handler) called OOPS suitable for access to external databases. BIM (107) is marketing a simple, efficient interface between its Prolog and the relational databases INGRES and UNIFY. This is probably the most efficient commercially available interface of its kind.

3.3.2.6 Dialogue

As data and knowledge bases grow, it becomes harder for their users (people or programs) to obtain quickly what they need. Easy to use interfaces are needed, which can provide dialogue facilities.

Project 311 (ADKMS) provides a sophisticated rule-based natural language (NL) interface to large DB's. Rules can be tailored, so that the interface can be more knowledgeable in a specific domain. This feature makes this interface superior to commercially available NL interfaces to DB's which use simple grammars or are based on keyword recognition.

Project 527 (CFID,"Communication Failure in Dialogue") studies the problems involved with failure in the dialogue of database users with the database. This project will demonstrate in November 1986 the first version of a system that detects changes in visual expression to support detection of failure in dialogue done via linguistic analysis. The integration of linguistic analysis and visual cues is a particularly advanced feature of this multidisciplinary project.

3.3.2.7 Demonstrators

Several projects (P107, P96, P1106, P857 ("Graphics and Knowledge-based Dialogue for Dynamic Systems"), P1220) include non-trivial applications to validate the tools they build. Sometimes, the developments of the application parallels the development of tools to provide useful feedback. Such an approach (exploratory programming or rapid prototyping) has been successfully used, out of necessity and thanks to the availability of powerful languages and development environments by the builders of AI systems.

For example, in P1106, the development of an expert system for the diagnosis of failures in an automobile engine component is proceeding in parallel with the implementation of the language Prolog III, so that it will be possible to test the hypothesis that this new language is an adequate tool for the implementation of expert systems in technical areas, thanks to the addition of powerful numerical capabilities to Prolog. This pionering work, led by the inventor of the Prolog language, Prof.A.Colmerauer, involves Daimler-Benz and Bosch.

3.3.3. External Interfaces: Objectives, Results and Impact

This area is concerned with how a computer communicates with its environment.

Data coming from the environment, sensed by sensors, transmitted as signals to the computer, are to be analysed and interpreted.

Conversely, in order to transmit information to the outside world, the computer has to synthesize appropriate signals.

Techniques for signal processing as filtering (= noise suppression) have been developed for a long time. However, in order to interpret the signals as for example to recognize an object in an image or to recognize a word in a speech signal, new computerized techniques have been proposed. Moreover, because of the ever increasing complexity of the tasks as for example determination of the depth and motion in a sequence of images, comprehension of continuous speech, new methodologies were to be studied together with their implementation on high performance architectures. This was the object of the calls for proposal in this area of ESPRIT. Work falls under three main headings :

- Image Processing
- Speech Processing
- Optical Processing

3.3.3.1 Image Processing

The field of digital image processing has grown considerably, finding a significant role in scientific, industrial, biomedical, space applications. It covers both image understanding and the synthesis of images from abstract descriptions.

Starting from an image considered merely as a rectangular organization of sampled data, the image understanding process constructs successive representations of the image first in terms of edges, texture, shapes (result of low level processing) up to an abstract representation of the complete scene (result of high level processing). However the interaction of all these processing levels is not well understood and only partial solutions tailored to a special application have been implemented.

According to the type of image and application, additional information must be extracted : the depth information is essential in applications such as robotics or medicine as well as the determination of motion for example to detect a moving object in a scene for surveillance purposes. In order to derive this information, a great deal of constraints on the scene (as for example illumination) or hypotheses on the type of motion must be imposed; in order to build systems working in industrial environment, most of the constraints must be relaxed.

Moreover, in order to obtain time efficient systems and/or low price systems, new architectures must be studied.
Results in image understanding are divided into three parts according to the type of image considered.

2-Dimensional Images
In P26 (SIP), a set of algorithms has been developed to process medical X-ray images (angiographic images). The originality of the system is the use of an explicit model of the scene (the knowledge of the organisation of the blood vessels) to control the different processing levels. Moreover, new techniques of reasoning derived from Knowledge Engineering have been successfully applied. A first prototype architecture based on

the "Transputer" (a processor that can be networked with other identical others) has been designed to implement efficiently the system. Thomson-CSF has been working on the project in consultation with CGR, a leading company in medical engineering.

3-Dimensional Image Processing

The purpose is to determine the depth information and the location of objects in a scene.

P419 (Image and Movement Understanding) concentrates on fundamental algorithms for 3D scene analysis. Methods to determine range information using stereovision have been studied. An original treatment of occlusions (hidden parts) in the scene has been developed using an expert system based on a-priori knowledge of the organisation of the expected environment and on empirical knowledge. So far, the project has defined modules to control the full treatment of a scene.

Architecture for stereovision is dealt with in P532 (Real Time Generation and Display of the 2.5 D Sketch for Moving Scenes). A prototype has been produced with off-the-shelf components that perform a depth map of an industrial scene in real time. The use of off-the-shelf components is expected to lead to a low-price system.

4-Dimensional Image Processing

This area deals with moving 3-D objects, ie. the goal is to determine the depth and motion from image <u>sequences</u> (The 4th dimension is the time).

P940 (Depth and Motion Analysis) has started in June 1986. Its goal is a very comprehensive study of algorithms for the analysis of depth and motion from image sequences, and their implementation in special hardware. The result is expected to have an important influence in the field of robotics.

3.3.3.2 Speech Processing

Because speech is normally produced in continuous form, it is not enough to recognise only isolated spoken commands. An important requirement for a system is to accept inputs from different speakers and to be insensitive to noise. The AIP research in this field covers the more fundamental aspects, while the parallel work in the Office Systems programme is part of the development of an integrated office workstation.

It is accepted that isolated word recognition for a single speaker and for small vocabularies (about 100 words) has been essentially solved. But there are still problems for isolated word recognition for single speaker and large vocabularies and for multiple speakers.

For continuous speech, difficulties are much larger. At the moment partial solutions exist only for some artificial language and for very constrained subset of natural language.

P26 - SIP has already obtained promising results for isolated word recognition with vocabularies from 1000 to 12000 words depending on the number of speakers. The final system should be able to recognize continuous speech using a vocabulary of the order of 1000 words with constrained syntax and with an adaptation to the speaker.

P1015 (PALABRE - Integration of Artificial Intelligence, Vocal Input-Outputs and Natural Language Dialog - Application to Directory Services) is concerned with the interface between speech processing and natural language processing. Once a sentence has been recognized, its meaning has to be understood and then represented in the computer in order to manage a real man-machine dialogue. A successful study has been carried out to demonstrate the feasibility of such system.

3.3.3.3 Optical Processing

Optical processing offers a potentially enormous bandwidth and processing at the speed of light. It is particularly suitable for global operations involved in pattern recognition, e.g., filtering, correlation, convolution. Work is required to develop a high performance interface between electrical and optical signals to develop real-time 2-D processing techniques.

Ongoing activities include work on an optical correlation technique which would perform recognition of objects in a scene in real time, and the a new acousto-optic device will be developed for real time wide band signal detection.

3.3.4. Computer architecture: Objectives, Results and Impact

The increasing demand for information technology systems of ever growing complexity requires the development of low-cost, high performance computers which provide the necessary processing power - both for conventional (but much faster) numerical processing tasks and for the increasing need to process symbols and knowledge (as opposed to numbers), and even to provide a capability to "reason", i.e. to draw conclusions from given data and knowledge.

Until recently the demand for an increase in computer performance has been met by the development of computers which run their instructions in a set of sequential steps (so called von-Neumann machines). An ever higher degree of component integration is providing very dramatic increases in the performance of the machines, whilst at the same time reducing their cost. It is now becoming evident, however, that in order to achieve the necessary performance for the emerging generation of applications, the expected advances in component integration will not be sufficient and computers will need to adopt a high-level of parallel processing. Therefore this part of the ESPRIT programme has concentrated on the development of machines and techniques for highly parallel processing with initial emphasis being given to the symbolic processing requirements.

Parallel Processing

Parallel processing is at the center of very active research in the U.S. (DARPA) and Japan (5th generation programme). As new computer architectures are emerging, there is still no consensus as to the best solutions for the future range of machines.

In ESPRIT, most work on parallel architectures is carried out in a large project (415 - Parallel Architectures and Languages for AIP - a VLSI directed approach) which includes 5 major European IT companies (PHILIPS, AEG, BULL, CSELT, NIXDORF).

The project started in 1984 with a review of existing and emerging architectures. These architectures have been evaluated against these difficult programming styles (logic, functional and object-oriented).

To date, two basic tools have been realized:

- a PROLOG compiler that can be installed in a variety of parallel computer architectures;
- a compiler for an "object oriented" language, i.e. a programming language where communication between abstract objects (data types, programme modules, etc.) is specified. This compiler is now being used by a partner of the consortium (AEG) to develop a simulator for VLSI chips with parallel hardware architecture.

In 1985, this project was complemented by project P1219, where a major emphasis is given to time critical applications, such as real-time speech and image understanding, which need high performance computer systems.

Although symbolic processing has been given the highest priority, high-performance numeric processing architectures will remain a major tool for a number of applications (e.g. complex simulations for aerodynamic, petroleum research). Project P1085, launched at the end of 1985, aims at a high performance numerical processing computer based on the "Transputer", a processor module that can be networked with identical others. A major problem with this kind of parallel computers is how to keep each processor busy most of the time, rather than waiting for data processed by other processors.
The results so far, are:

- The specification of a dynamically reconfigurable interconnection network to maximize the computer throughput.
- The specification of a floating-point Transputer to minimize component costs.

3.3.5. Conclusion for the AIP area

Even with most of the projects in this area being only 18 to 24 months on the way, some important results have already become visible.

The workplan in this area is very ambitious, and the AIP area started mostly with academic work with a relative lack of commercial interest.

The situation, however, has changed to the better. Commercial partners have developed a much better appreciation of the potential results from work in this area, and cooperation between academic and industrial partners has improved remarkably.

The projects have developed a more realistic perspective on the obtainable results. This also is partly due to the fact that ESPRIT increasingly encourages and supports projects which are geared to an implementation of prototype system.

One of the important results of ESPRIT is that Europe continues its leadership in the development of PROLOG, and that the gap in Expert System Shells could be narrowed. Europe was traditionally strong in the design of tools for the development of small expert systems; with ESPRIT, additional strength is being given to development tools for large systems.

ESPRIT has a decisive influence in emerging results in the topic of combining numeric and symbolic computing (e.g. extensions of PROLOG), but also on the architectural level. The latter is particularly visible in the area of signal processing.

Until two years ago, there was very little interest of US researchers in European activities in computer architecture. This has changed, and ESPRIT projects now play an important part in international discussions.

What still needs improvement and is currently receiving attention in this ESPRIT area is closer cooperation among projects and quick exploitation of results.

ADVANCED INFORMATION PROCESSING (AIP)
Referenced Projects

No	Title	Participating Organisations
304	Design of Techniques and Tools to Aid in the Analysis and Design of Knowledge Based Systems	Standard Telecommunication & Cables (UK), SCS(D), Univ. of Amsterdam (Nl); KBSC/Polytec.of the South Bank (UK)
26	Advanced Algorithms and Architectures for Speech and Image Processing	CSELT (I), AEG Telefunken (D), GEC (UK), Thomson-CSF (F), Univ. of Turin (I), Polytechnics of Turin (I), HITEC (Gr)
96	Expert System Builder	Plessey Electronic Syst(UK) CSELT (I), S.T. LYNGSO A/S (Dk), Trinity College Dublin (Irl), Plymouth Polytechnic (UK), RISO National Labs (Dk), LAI Marseille (F), TECSIEL (I) CIMSE (I)
107	A Logic-Oriented Approach to Knowledge and Data Bases Supporting Natural User Interaction	BIM (B), Fraunhofer Insti-tut IAO (D), Scicon (UK), Univ.of Creta (Gr), Cran-field Inst. of Technology (UK), SCS (D), INCA (D), Tech. Univ. Munich (D)
256	Time Dependency and System Modeling in KBS's Design for Industrial Process Applications	CISE (I), FRAMENTEC (F)
280	Intelligent Help for Information System Users	CRI A/S (Dk), Courseware Europe (Nl), Dansk Datama-tik Center (Dk), ICL (UK), Univ.of Leeds (UK), Univ. of Amsterdam (Nl)
311	Advanced Data and Knowledge Management Systems (ADKMS)	Nixdorf Computer AG (D), Bull S.A. (F), Olivetti (I) Univ.of Berlin (D), Univ. of Turin (I), Univ. of Bologna (I), Univ. of Dortmund (D)
316	An Architecture for Interactive Problem Solving by Cooperating Data and Knowledge Bases	CSELT (I), CAP Sogeti (F), CERT (F), Philips (B), Polytechnic of Milan (I)

No	Title	Participating Organisations
393	ACORD:Construction and Interrogation of Knowledge Bases Using Natural Language Text and Graphics	CGE-LDM (F), CII-HB (F), Triumph-Adler AG (D), Fraunhofer Instit. IAO (D), Univ.of Edinburgh (UK), Univ.of Stuttgart(D)
415	Parallel Architectures and Languages for AIP - A VLSI Directed Approach	AEG Telefunken (D), CII-HB (F), CSELT (It), CWI·Amsterdam (Nl), GEC (UK), Univ. of Munich (D), LIFIA (F), Nixdorf (D), Philips (Nl), Stollman & Co. (D), Univ. of Berlin (D)
419	Image and Movement Understanding	Univ. of Genova (I), CAPTEC (Irl), Trinity College Dublin (Irl), Univ. of Nijmegen (Nl), Video Display System SRL (I)
440	Message Passing Architectures and Description Systems	Delphi SpA (I), Bell Telephone (B), Vrije Univ. Brussel (B)
527	Communication Failure in Dialogue: Techniques for Detection and Repair	Education Research Centre (IRL), Linguistic Institute of IRL (IRL), Memory Computer PLC (IRL), Univ. of Leeds (UK), Univ. of Pisa (I), ITT Europe (UK)
530	Advanced Knowledge Base Management System	S & M (I), Bense KG (UK), Criss (F), Univ.of Pisa (I) Univ.of C.Bernard, Lyon(F), Univ.of Dortmund (D)
532	Real Time Generation and Display of the 2.5D Sketch for Moving Scenes	Univ.of Strathclyde (UK), Barr and Stroud Ltd (UK), Zeltron (I), Olivetti (I)
818	The Connection Machine: A Dependable Open Distributed System Architecture	CII-HB (F), IEI-CNR (I), Ferranti-Electronics (UK), Fraunhofer Inst. (D), GMD (D), LAAS (F)
857	Graphics and Knowledge Based Dialogue for Dynamic Systems	CRI A/S (DK), Univ. of Kassel (D), Univ. of Strathclyde (UK), Univ. of Leuven (B), Brown Boveri (D)

No	Title	Participating Organisations
874	Integrated Environment for Reliable Systems	MARI Advanced Microelectronics Jeumont Schneider (F), Univ.of Bolonia (I), Telettra (I)
940	Depth and Motion Analysis	Elsag (I), GEC (UK), MATRA (F), INRIA (F), ITMI (I), NOESIS (F), Univ. of Cambridge (UK), Univ. of Genoa (I)
957	High Densities Mass Storage Memories for Knowledge and Information Storage	Bull (F), BASF (D), Bogen Elektronik GmbH (D), Glaverbel (B), Leti (F), Simulog (F), Thomson-CSF (F)
973	Advanced Logical Programming Environments (ALPES)	CRIL (F), Bull(F), ENIDATA (I), LSI (F), IASI (I), Univ. Roma (I), Univ. Bologna (I), LRI (F), TUM (D), Univ. Orléans (F)
1015	Integration of Artificial Intelligence, Vocal Input-Output and Natural Language Dialogue - Application to Directory Services (PALABRE)	SESA (F), CNET (F), British Telecom (UK), ERLI (F), CNRS-LIMSI (F), Polytechnic of Turin (I), SARIN (I)
1063	Integration of Symbolic and Numeric Learning Techniques	Cognitech (F), Univ. de Paris Sud (F)
1085	Development and Application of a Low-Cost High Performance Multi-Processor Machines	RSRE (UK), APSIS (F),INMOS (UK), Telmat S.A.(F), Thorn EMI (UK), Univ.de Grenoble (F), Univ. of Southampton (UK)
1098	A Methodology for the Devlopment of KBS	Standard Telecommunications 1 Cables (UK), Polytechnic of the South Bank (UK), Scicon (UK), SCS (D), Univ.of Amsterdam (Nl)

N°	Title	Participating Organisations
1117	Knowledge Based User Friendly System for the Utilisation of Information Bases	CRAI (I), DDC (DK), Philips (NL), ENIDATA (I), Univ. of Antwerpen (B), Univ. of Rome (I)
1218	Next Generation Integrated Data Base and Knowledge Base Management System	Syseca Logiciel (F),Univ. of kaiserslautern (D), Absy (B), CRIL (F),
1219 (967)	Parallel Associative Development Machine as a Vehicle for Artificial Intelligence	CIMSA SINTRA (F), CSELT (I) GEC (UK), Non Standard Logics (F), Thomson CSF(F)
1219 (1106)	Further Development of Prolog and its Validation by KBS in Technical Areas	Prologia (F), GIA (F), GIT (D), Robert Bosch (D), Daimler Benz (D)
1220	Design and Experimentation of a KBS Architecture and Tool Kit for Real-time Process Control Applications	CISE (I), Framentec (F) Ansaldo (I), Aerospatiale (F), CAP Sogeti Innov. (F) NEA-Lindberg A/S (DK), Heriot-Watt University (UK)

3.4 Office Systems

3.4.1. Office Systems Objectives

The office environment requires the development of complete system solutions. Solutions that provide the user with adaptability, flexibility and inbuilt interworking capability will be the key to success on the market.

Research work in the field of Office Systems has to take account of the latest developments in micro-electronics, software technology, advanced information processing, and integrated system solutions need to be derived from current end expected user requirements.

The ESPRIT Office Systems Workplan is composed of five research areas :

1. Office system science and human factors
2. Advanced workstations and human-machine interfaces
3. Communication systems
4. Advanced multi-media storage and retrieval systems
5. Integrated office information systems

For the purpose of this report selected results of on-going work in Office Systems are grouped according to 4 major themes that are characteristic of the progress so far. These four main themes have a strong impact on industrial products :

i) OSI (Open System Interconnection) communication systems networks and interfaces, which provide the infrastructure for distributed applications.

ii) Workstations and advanced interfaces for which the market is expected to grow exponentially in the next years. Powerful processing capability, integration of human-machine interfaces, standard communication interfaces, local mass storage, a wealth of application tools and a drive towards lowering costs characterize these systems.

iii) ODA (Multi-media Office Document Architecture) based systems to provide tools for application development integrating data, sounds and picture according to a standardized formal structure that guarantees document interchange between different application systems.

iv) User-technology integration, to provide methods and tools for the dynamic interworking of information systems and the user organisations with their dominant human component.

3.4.2. OSI communication systems: Objectives, Results and Impact

The communications section of the Office Systems Subprogramme relates to the OSI concept by supporting R&D towards subsystems that comply with the reference model and the specific standards that have been developed and by encouraging development of new standards within the OSI-model.
10 projects involving 800 manyears have been launched in this domain in early 1985 and 4 early 1986. The projects concentrate on network architectures, on distributed operating systems, and on gateways and bridges.

Network architectures

The projects :

- "Broad site local wideband communication system - BWN" (73),
- "An integrated network architecture for office communications - INCA" (395),
- "Local integrated optical network - LION" (169), and
- "Ultra wideband coherent optical LAN - UCOL" (249)

apparently pursue different objectives on distances and performance, and have different time horizons. The data rates are between 20 Mbit/sec (INCA) and 10 Gbit/s (UCOL) whereas the radius of the networks is in the order of 25 km. Multimedia coverage, number of modes and cost level are further important parameters distinguishing the projects. Compared to networks reflecting the state-of-the-art (e.g. ETHERNET) the ESPRIT projects aim at up to 100 times transmission rate and 10 times the distance covered.

Project BWN (ACEC, UNIV. LIEGE, BTMC, STOLLMAN, SG2, FRANCE CABLE) is making rapid progress : a 25 kilometer circumference backbone network, connecting multiple local area networks and featuring gateways to the public network and satellite channels, will be fully demonstrated in 1987. Transmission rate on the backbone is 140 Mbit/s, and average access rates for all bridges and gateways are above 2 Mbit/s full duplex. All components of the system have been specified and the major performance characteristics have been verified through computer simulations. The hardware and software developments are in full swing. The system will be suited particularly for installation on university campuses, science parks and environments with similar characteristics, particularly if several LANs and machines of different manufacture have to be connected by a high speed link.

The INCA project pursues different technology options for local networks: a CATV-local network is being developed and already being thoroughly tested in the laboratory. Other existing networks will be connected via available broadband channels. Using this infrastructure an advanced document handling application including a workstation will be demonstrated. A first demonstration is planned for 1987. An early spin-off of the project has been the development of a broadband modem that is likely to be marketed soon.

LION and UCOL projects will provide full terminal to terminal naming and addressing schemes, and are designed for mixed-mode operation. However, the UCOL bandwith aimed for is between one and two orders of magnitude higher than for LION, and delivery of UCOL prototypes will be 3-4 years later than the corresponding LION prototypes. In project LION the architectures, protocols, network controllers and ISDN-gateways are fully specified and implementation is under way for systems with transmission rates of 140 Mbit/s initially (LION I) and 565 Mbit/s later (LION II), and access rates of 2 Mbit/s, to be demonstrated in 1988 and 1989 respectively. Project UCOL has demonstrated the feasibility of utilizing mono-mode fiber technology allowing transmission rates up to 10 Gbit/sec, that will make it possible to multiplex several video channels. Mixed Time Division Multiplexing/Frequency Division Multiplexing (TDM/FDM) access protocols for UCOL have been fully specified, and the feasibility of using a modified Injection Locked Laser (ILL) for the emission of the bit stream has been demonstrated.

Distributed operating systems

Such network architectures as the ones described above are the infrastructure needed to support application-oriented distributed systems.

Applications development in a distributed environment require a uniform system interface and a comprehensive tool-set that allow programmes to be independent of the geographical, technical and functional particulars of the components of the networked system. In addition essential facilities have to be imbedded that allow fault-tolerant, secure and economical operation.

The construction of operating systems and tools for distributed systems is addressed in two projects :
"Communications systems architectures - CSA" (237), and
"Construction and management of distributed office systems - COMANDOS" (834),
the latter being launched as recently as early 1986. In the two projects taken together most of the major European IT manufacturers cooperate. The distinction between the projects is that CSA has adopted a theoretical or top-down approach to the very complex problem, whereas COMANDOS follows a more pragmatic route, aiming to utilize and integrate a number of partial solutions that have been developed already or at least have been described in the literature.

The CSA project has produced a comprehensive generic model of distributed system architectures, based upon the analysis of information flows and information handling requirements in the business environment. The particular value of this result is that it provides a theoretical foundation and a formalism with great descriptive power to be used to generate and justify industrial implementations of distributed architectures. The project is progressing systematically towards its goal, the development and demonstration of a prototype operating system and application programming support tools in a distributed environment.

Gateways and bridges

Within the OSI model several alternative implementations are possible for LAN-PBX access protocols. Special attention must therefore be given to the Terminal - LAN/PBX interface in order that, ideally, any terminal can be connected to any LAN/PBX. The project "Standardisation of integrated LAN services and service-access protocols - the E interface" (43) in which 9 IT companies cooperate has developed the formal specification of the so-called Serial Link E-Interface and works on two demonstrator implementations. The specification of the E-interface will be submitted to ECMA for standardisation early 1987.

3.4.3. Workstations and advanced interfaces: Objectives, Results and Impact

Workstations are distinguished by a powerful processing capacity and versatile external interfaces from the CRT-based terminals that dominated the market until recently. Workstations may also be characterized as personal computers that can be integrated in distributed information systems. In such systems they will increasingly take the load off mainframes and process servers.

Key technical factors for success are : an extremely open architecture that allows the introduction of features rapidly and economically; ergonomic and esthetic designs, and the availability of hardware and software features that allow the user to implement applications with a minimum of effort.

Substantial effort in the Office Systems are devoted to Workstations and the I/O interfaces. The great variety of options possibly makes it necessary to try different approaches in parallel.

Multi-media integrated workstations

3 related projects focus on architectural and integration aspects of workstations:

"Intelligent workstation-IWS" (82)

"Secure open multi-media integrated workstation - SOMIW" (367)

"Components for future computing systems - COCOS" (956).

The relationship and distinction between the 3 projects may be described as follows.

IWS (BULL TRANSAC, VRIJE UNIV. BRUSSEL, UNIV. NIJMEGEN, OCE) that was launched in 1984 addresses in particular user interface issues and develops a powerful office application tool-set. To be able to demonstrate this software, a machine was built called the Metaviseur. On this machine a number of languages were implemented, among them the object-oriented K-LISP, necessary to implement the Knowledge Representation System (KRS) developed by one of the partners (VUB). KRS provided a suitable environment for the development and demonstration of several office applications : an authoring system for Dutch, easily extendible to other languages; an office communication manager, an office appointment manager, and a graphics and picture editor.
The IWS already had an impact upon product development in at least one company.

The SOMIW project launched in 1985 has designed an architecture for a powerful and flexible workstation, using state-of-the-art components for the prototype being built. A UNIX-compatible operating system has been designed. Other software tools such as a screen manager and an ODA document manager have been designed as well. As soon as the basic SOMIW machine is operational (probably 1988), the software developed in IWS will be made operational on the SOMIW machine.

COCOS, launched in 1986, for which a 6-months feasibility study has been completed successfully, will develop an advanced machine architecture based upon the RISC Reduced Instruction Set Computer concept. As soon as this machine becomes operational, using a UNIX compatible operating system, the I/O modules and the software available from the SOMIW and IWS projects will be implemented.

Advanced interfaces

A number of projects address the various external interfaces, with a particular focus on those with the human user. The human user is capable of instructing a machine either in the manual mode or the speech mode. In the manual mode, data can be presented in graphical form, or

coded such as is done through keyboards. Graphical information is often entered via paper as an intermediate carrier.
Output to the user is in graphical form displayed on VDU's or paper, or as computer synthesised speech.
In reality, several I/O facilities are used in an integrated way. Obviously in an on-line dialogue at least 2 modes are utilised.
To convey meaning, the data must be structured in some way, be it in the form of graphical symbols or according to the grammar and symbols of a language, most often a natural language.

Paper graphics

"The Paper Interface" project (295) (AEG, PLESSEY, PHILIPS, OLIVETTI) addresses major issues related to paper as a carrier of graphical information. The project is progressing well.
A graphics coder has been developed that allows efficient compression of graphical information. A very versatile character recognizer is being developed, that is capable of handling a multiple set of character fonts and correcting misalignment. A handwriting recognizer is in the specification phase. Handwriting recognition is a promising application, that may provide new possibilities for data entry.

Picture coding

The visual mode is addressed in several projects, Emphasis is given to image coding. Intermediate results are already obtained by the project: "A high compression picture coding algorithm for photographic videotex" (563); (BT, IBA, KTAS, Dr. NEHER LABS PTT, CSELT, NIXDORF, CCETT) where an efficient coding algorithm is being developed. Several algorithms have been developed and demonstrated, and now the comparative evaluation process is under way. The optimal algorithm will be proposed for standardization to the appropriate bodies.

Speech

The work on speech recognition focuses on recognition of large vocabulary, continuous speech, speaker-independent recognition and high-quality speech synthesis.
The project :
"Investigation into the effective use of speech at the human machine interface" (449)

has been completed, and provides scenario's for partially speech driven CAD systems.
A similar assessment, for some typical office applications, has been done by the project
"Speech Interface at office workstations - SPIN" (64)
(CGE, CSELT, NIXDORF, AEG, TNO-UNIV.Amsterdam, CEA).
The conclusion is that there is a need for speaker independent command driven office applications. A 30-words vocabulary recognizer to be used in such applications has been built by the SPIN project and is operational. The demonstration is limited to French, but the algorithms do allow application to other languages.

Speaker independent recognition for large vocabularies and continuous speech is addressed by an introduction of project IKAROS that was launched early 1986.
Speech synthesis has been developed in SPIN for Italian ; the research continues to further improve the quality. The basic algorithm developed and its' VLSI implementation can be applied to other language synthesisers.

In the same project, a speech coder according to the multi-pulse method has been designed and applied to French. This very efficient coder will soon be turned into a product that may be applied to voice-mail services. Again, the principle can be applied to other languages without much modification.

Linguistics

Advanced recognition systems for linguistic expressions such as speech and handwriting, require a priori linguistic knowledge. Only with this knowledge acceptable positive recognition scores can be achieved.
The project
"Linguistic Analysis of the European Languages" (291)
does compile such linguistic data for 7 languages, with definitions and methods implemented largely independent of any particular language. Basic statistics on the character and word levels are now available for the 7 languages as well as statistics about grapheme-to-phoneme and phoneme-to-grapheme conversions. The latter data are also used for speech synthesis development.

3.4.4. ODA based systems: Objectives, Results and Impact

For the purpose of interchanging documents between systems of different vendors and between different devices in a system, it is necessary to define a standard way of describing the contents of the document.

Several alternatives for such formal description have been proposed. In ESPRIT, the Office Document Architecture (ODA) supported by a growing number of European companies has been selected and implemented in a number of projects.

In 1985, with the strong technical support of the partners of the project "Handling of mixed text/image/voice documents based on a standardised office document architecture - HERODE" (121), the ECMA 101 (ODA) standard was adopted, and in 1986 ISO adopted ODA as a draft standard (ISO nr. 8613).This project has had a direct impact on standardization, as shown in Fig. 10.

The HERODE project is now completed and succeeded by a new project, PODA (piloting ODA) (no. 1024) in which 5 major IT companies and 2 research institutions collaborate.

While further work is done to extend the ODA standard to additional data modes (voice,...) in project HERODE (SIEMENS, CGE-TITN, QUEEN MARY COLLEGE, CRIN/ADILOR) an on-line editor and tools were built to define, manipulate, store, retrieve and transmit ODA documents.
The implementation was done on a commercially available workstation, equipped with a specially designed scanner for the input of pictures as part of ODA documents and with a bit-map printer.

This system has been demonstrated at several technical exhibitions.

The projects
"A multi-media filing system - MULTOS" (28), and
"Design and operational evaluation of distributed office information servers - DOEOIS" (231)
adopted ODA for document structuring and have started implementation.

Thus ODA has been adopted by the majority of major European companies since ESPRIT was launched.

The MULTOS project is focused in particular on the development of large multi-media archive servers with storage capacity up to 200 Gigabyte for data and text, formal methods for extracting information automatically from documents to allow fast retrieval, and a user-friendly interface. The technologies used are optical non-erasible disks and magnetic disks, magnetic disks in particular for intermediate and index files. The project has produced the user interface, a "signature" method and is well on its way to provide a prototype server for data and text by 1987.

The DOEDOIS project focuses on distributed servers.
A general model for a distributed file service has been established, as well as the detailed specifications for several of the components for the system.
So far, the work has resulted in a preliminary but comprehensive functional specification and architecture for the distributed server system.

3.4.5. User-technology integration: Objectives, Results and Impact

In this section the results of those projects are described that will support the user and the manufacturer of IT systems in matching the technological possibilities and the user requirements. The projects that aim at improving the direct human-machine interface, as described in the section on workstations have a direct impact on this issue as well.
The projects reported here address particularly the problems that go beyond the specific human-machine interfaces, and have to do with the interworking of organisations and information systems.

Human factors

The main goal of the project :
"Human factor laboratories in information technologies - HUFIT" (385)
(FRAUNHOFER, HUSAT, ICL, SIEMENS, BULL, OLIVETTI, PHILIPS-IPO)
is to enhance the ability of the IT industry to improve user-friendliness of products to be developed.

A detailed analysis has been made of the development process in 2 of the participating companies, with a particular attention for the involvement of human factor expertise in that process. Recommendations for the enhancement of that process are now being investigated by the partners. A report has been issued on the assessment of the useability of IT products.
Specific user interface solutions that have been investigated include :

- ergonomics of speech technology
- assessment of direct manipulation dialogues
- specification of a software package to support development of software for human-machine interfaces.

Extracts of these and other reports have been produced and will be made available to interested parties.

Application system life cycle
Tools which support the user in the IT application in the office are gaining increasing attention. The availability of comprehensive solutions will be crucial to the success in the market. Until now two ESPRIT projects address this item.

Based on the concept of Petri-Nets the project
"Functional analysis of office requirements - FAOR" (56) (STC, GMD, BIFOA, EAC DATA)
has developed a tool-set for communication-, information-, function-, user needs-, and cost/benefit analysis. A data base that contains the data about the application environment and the user requirements, supports the tools. Field tests to validate the overall concept and the tools are under way in the UK.

The project
"Office support systems analysis and design - OSSAD" (285) (IOT, IPACRI, CETMA)
developed a formal method and a language (OSSADIC) to be used for the analysis and design of the office system. Field tests to validate the method developed have been started in three banks in France, Sicily and in Germany.

OFFICE SYSTEMS

Referenced Projects

No	Title	Participating Organisations
28	A Multimedia Filing System (MULTOS)	Olivetti (I), Battelle Inst. (D), CNR-IEI (I), Cretan Research Inst. (Gr), Mnemonica (Gr), Philips(Nl) Triumph-Adler (D), ERIA(E)
43	Standardisation of Integrated LAN Services and Service Access Protocols (The E-Interface)	Philips (Nl), British Telecom (UK), OCE Nederland(Nl) RCE/SESA (F), CSELT (I), GEC MARCONI (UK), Nixdorf (D), Plessey Telecom (UK), TITN (F)
56	Functional Analysis of Office Requirements (FAOR)	STC (UK),BIFOA (D), EAC Data (Dk), GMD (D)
59	NewInformation Models for Office Filing and Retrieval (MINSTREL)	NSC (Irl), DDC (Dk), Univ. College Dublin (Irl), GN Netcom (Dk)
64	Speech Interface at Office Workstations (SPIN)	C.G.E. (F), AEG Telefunken (D), CEA (F), CSELT (I), Nixdorf (D), TNO (Nl), SNS Pisa (I), OROS (F), NT Univ. Athens (Gr)
73	Broad Site Local Wideband Communication System	ACEC S.A. (B), Univ. of Liège (B), Bell Telephone (B), SG 2 (F), Stollman(D) France-Cable (F)
82	Intelligent Workstation - IWS	Bull (F), Creatan Research Institute (GR), INRIA (F) Univ. Nijmegen (NL), Univ. Brussels (B), OCE (NL)
121	Handlingof Mixed Text/Image/Voice Documents Based on a Standardised Office Document Architecture (HERODE)	Siemens (D), TITN (F), CRIN (F), QMC-IRL (UK)
169	Local Integrated Optical Network (LION)	TITN (F), CSELT (I), Nordsk Kabel (Dk), BT (UK), Univ. Patras (Gr), Politecnic of Milan (I), University Paris VI (F), University of Toulouse (F)

No	Title	Participating Organisations
231	Design and Operational Evaluation of Distributed Office Information Servers (DOEOIS)	ICL (UK), CII-HB (F), Fraunhofer/IAO (D), Trinity College (Irl)
237	Communications Systems Architectures	Plessey (UK), MARI Software Services(UK), Philips (Nl), Société Générale de Service (F)
249	Ultra Wideband Coherent Optical LAN (UCOL)	FACE Research (I), GEC (UK) Polytechnic of Milan (I)
285	Office Support Systems Analysis and Design (OSSAD)	IOT (D), CETMA (F), IPACRI (I)
291	Linguistic Analysis of the European Languages	Olivetti (I), Acorn Computers (UK), CSATA (I), Univ. Nijmegen (NL), CNRS-LIMSI (F), Univ. of the Ruhr (D), UNED (E), Univ. of Patras (GR), Logica (UK)
295	The Paper Interface	AEG (D), Ing. C. Olivetti (I), Philips (D), Plessey Ltd. (UK)
367	Secure Open Multimedia Integrated Workstation (SOMIW)	Bull Transac (F), AEG Telefunken (D), CEN/SCK (B), CSELT (I), INRIA (F), Italtel (I), Sarin (I), Sobemap (B)
385	HumanFactor Laboratories in Information Technologies (HUFIT)	Fraunhofer/IAO (D), Bull Transac (F), HUSAT Research Centre (UK), ICL (UK), Olivetti (I), Philips (Nl), Siemens (D)
395	An Integrated Network Architecture for Office Communications (INCA)	GEC (UK), Olivetti (I), Nixdorf (D), ATM Computer (D), Univ. College London (UK)
449	Investigation into the Effective Use of Speech at the Human-Machine Interface	British Maritime Techn.(UK) ICL (UK), Voice Input Ltd. FINCANTIERI (I)

N°	Title	Participating Organisations
563	A High Compression Picture Coding Algorithm for Photographic Videotex	British Telecom Plc (UK), CCETT (F), Copenhagen Telephone Comp. (Dk), CSELT (I) Dr. Neher Labs (Nl), Independent Broadcast Auth.(UK) Nixdorf (D)
834	Construction and Management of Distributed Office Systems (COMANDOS)	Olivetti (I), ARG Applied Research Group (I), CII-HB (F), Trinity College Dublin (Irl), Fraunhofer Gesellschaft (D), ICL (UK), Nixdorf (D), CNR-IEI (I), Lab. Génie Informatique(F)
956	Components for Future Computing Systems (COCOS)	Bull Transac (F), ICL (UK), SGS Microelectronics (I), Nixdorf (D), Olivetti (I), INRIA (F)
1024	Piloting of the Office Document Architecture (PODA)	Siemens (D), Bull Transac (F), Olivetti (I), ICL (UK) TITN (F), QMC-IRL (UK)

3.5. Computer Integrated Manufacturing (CIM)

3.5.1. Objectives and rationale

CIM is an area of considerable strategic importance since it represents a major new market for European IT and automation equipment vendors. It is also key to the strengthening of the European manufacturing base. It provides a challenging testbed for innovative techniques and products emerging from other IT fields, eg microelectronics, software engineering, Advanced Information Processing, and communications technology, and is a focus for hi-tech developments such as new materials and fibre optics. Progress in these areas is monitored and exploited in many existing CIM projects.

CIM objectives are to strengthen the capability of community vendors and improve the competitiveness of manufacturing industry. The approach taken is to create an environment in which multi vendor systems can be progressively implemented at reasonable cost, and to advance particular CIM technologies in which Community IT suppliers can compete effectively. Measures of progress include reductions in the unit cost and lead time of products, and improvements in their quality; reductions in the cost, and improvements in the productivity, flexibility and reliability of manufacturing systems; reductions in inventory, work-in-progress and scrap rates. Vendors engaged directly in effecting such improvements are in an advantageous position to exploit their working relationships with leading edge users and thus extend market penetration.

The CIM workplan was originally divided into six subareas, but to aid understanding of the relationship between projects and their overall contribution to the objectives, descriptions of results are grouped under three main headings relating to the measures stated above.

i) Design rules, architectures, communications and interfaces, to provide a unified framework for CIM, conforming to the ISO model for Open Systems Interconnection. International Standards activities are continuously assessed, and areas identified in which European initiatives could advantageously be supported.

ii) Methods and tools for real-time manufacturing control of production, within a flexible and highly automated environment.

iii) Selected CIM technologies whose development or refinement is of particular value for European Community industry (users and vendors). This includes systems for flexible machining and assembly, advanced robot and machine tool control and multi-media data capture and interpretation.

3.5.2. Design Rules, Architectures, Communications and Interfaces

Contributing primarily to reductions in the cost of designing, installing and maintaining manufacturing systems.

The diversity of function within CIM presents interfacing and interworking problems that have yet to be solved in an economic manner. It has been conservatively estimated by leading edge users that currently 70% of the costs of installing and implementing a new CIM system are attributable to this overhead. This is a serious deterrent to progress, especially for small manufacturing companies.

CIM, by its nature, is a multi-vendor domain, so the problem can only be addressed by attempting to establish a unified framework, within which different manufacturing functions are defined, and their boundaries and methods of communication specified. ESPRIT work in this area is based on four major and inter-related projects - Open Systems Architectures (OSA), factory communication networks, CAD interfaces and robot integration.

Each of these projects has a carefully balanced consortium where the involvement of a broad spectrum of users and vendors ensures a pragmatic approach and widespread adoption of the results. Close links are maintained with standardisation activities, and three of the projects have already gained international recognition as major contributors to CIM standards.

The four major projects are:

Project 688 (AMICE - A European Computer Integrated Manufacturing Architecture started October 1985). This takes as a starting point the results of the ESPRIT pilot project 'Design Rules for CIM', the results of which were published by North Holland in September 1985. The project will develop a generic architecture, based on open systems concepts, and will provide guidance for the user in implementing these. Intermediate and final results will be available in the public domain, and are being used as inputs by European representatives of ISO TC 184. Feedback on user requirements is provided by other CIM projects which also act as testbeds for emerging elements of the architecture. A set of CIM scenarios has been derived from the project partners (19 major vendors and users), and a principal target of the project - to establish a coordinated view of the major IT vendors on the Open System Architecture - has already been achieved. The first project output 'CIM Open Systems Architecture (OSA) - Key Concepts' was issued early this year, and publication of the first specification of the generic architecture, CIM OSA Version 0, is scheduled for March 1987.

Project 955 (CNMA, Communication Network for Manufacturing Applications, started January 1986). The project addresses factory communications, a key component of the overall systems architecture. There is a close working relationship between this and project 688, with several partners in common. User pressure, especially that deriving from the General Motors MAP initiative, is forcing a fast pace in the development of factory communications networks. Early engagement in the area is essential if European vendors are to exploit the lucrative potential market for factory communications equipment, and if users are to have the guidance they need to lay sound foundations for their investments in CIM.

The project aims to implement communication protocols for manufacturing needs. It complements MAP and is expected to influence its future direction. Useful links have already been formed at technical level between CNMA and the General Motors team. The CNMA team, consisting of five major IT vendors and five users, has issued a draft implementation guide for internal use by the consortium. The refined implementation guide, which will detail the profile of specifications adopted and advise on how these should be used to achieve interworking in a vendor independent environment, will be available for public release in the first week of October 1986. In early December 1986 full interworking of the vendors' systems, up to and including level 7 of the ISO Open Systems Interconnection model, will be demonstrated.

Project 623 (Operational Control for Robot System Integration into CIM, started February 1985). Whilst project 688 addresses the overall architecture, and project 955 the communications needs of manufacturing, the aim of this project is to provide methods and tools for the functional integration of robot systems into CIM. The project also builds on the results of an ESPRIT pilot project, and based on these has produced a major text 'Design Rules for Robot Integration in CIM', scheduled for publication in late 1986. In draft form this is already in widespread use by other ESPRIT contractors (eg projects 278, 319, 338, 477). Several tangible deliverables have already been achieved. These include a subsystem for explicit robot programming, and subsystems for planning assembly operations and optimising production layouts. These subsystems are already being used by KUKA and Renault Automation in designing and implementing real production systems.

Project 322 (CAD Interfaces - CAD*I, started November 1984). Within the overall CIM architecture, this project is defining interfaces which will allow the data generated and held in different CAD systems to be exchanged. This enables the implementation of multi vendor CAD systems and facilitates the free flow of data without expensive conversion and restructuring. In addition, it will permit CAD data to be interfaced with Computer Aided Engineering systems, such as those used for the static and dynamic analysis of structures. Tests of existing interfaces have been completed and the results fed into the CAD*I definitions. These have now reached a sufficiently mature state to be published and the development of pre- and post-processors to start. BMW, a wide range user of CAD systems, provided the practical inputs for the tests and will act as a testbed for the implementation. The project results are providing important inputs to the development of International Standards via close interaction of the project team with ISO/TC184.

3.5.3. Methods and tools for real-time manufacturing control

Contributing primarily to reductions in lead times, inventory, and unit costs; improvements in plant flexibility and productivity to maximise return on investment

Present day manufacturing is characterised by sub-optimal productivity arising from long lead times in the design-to-product phase, heavy investment in inventories and work-in-progress, and lack of adaptability to changing market needs. These factors arise from the 'islands of automation' approach and consequent deficiencies in the information flow within the total manufacturing operation. A key target of the area is to improve the rapidity and ease of information flow throughout the manufacturing cycle. This is necessary in order to achieve the necessary degree of responsiveness, productivity, and quality to make the user's investment in CIM an attractive proposition. Four projects, which are working within the overall open systems framework described earlier, address these problems and have achieved significant interim results.

Major benefits would result from closing the control loop between production planning activities and manufacture of products. Project 477 (Control Systems for Integrated Manufacturing, started January 1985) addresses as its primary task Production Activity Control (PAC). Information gathered from the shop floor interacts with that held in planning systems to close the control loop by minimising the need for human intervention and reaction times of the manufacturing system. The project has defined an architecture and developed a novel method for modelling data flow through production systems. The latter represents an early spin-off from the project for which exploitation plans are being prepared. Different sets of PAC user requirements have been developed and are now being used to prepare the three implementation sites for developing and demonstrating the project outputs. These are for machine tool manufacture, electronics assembly and automated engine assembly, at COMAU, Digital and Renault sites, respectively.

Project 418 (Open CAM System) is complementary with project 477. Here a more vertically structured approach is adopted by establishing the information flow requirements in different functional manufacturing cells of varying complexity. Existing shop floor and planning systems have been methodically analysed. From this a reference model and a skeleton architecture for CAM have been derived which take into account that, with the growth of automation and flexibility, the complexity of planning increases as functions become increasingly time critical. These early results are being incorporated in the production planning activities of the prime contractor, FN (Fabrique Nationale, Belgium) where project outputs will be implemented and demonstrated. The complementarity of projects 418 and 477 and the involvement of a common partner in both 477 and 688 ensures that work in this area of CAM takes account of and implements key developments in open systems architectures.

Project 932 (Knowledge-Based Real Time Supervision in CIM, started January 1986) is concerned with real time scheduling of products through manufacturing systems using knowledge based techniques. Detailed analyses have been completed of the decision-making networks for production planning and control, quality control, maintenance and process development in two different industrial environments. These are motor tyre manufacturing at a Pirelli plant and car radio manufacture at a Philips plant. At Philips, the results of the analysis have led to re-budgeting to improve the efficiency of future operations. The results have been instrumental in the development of knowledge based simulation systems for modelling production flows through manufacturing cells in Philips and another industrial partner - BICC. These systems have already shown themselves to be valuable in optimising throughput and reliability of production. Conformance of the work with OSA and emerging communications work is ensured by the common partners in projects 932, 688 and 955.

For successful dynamic control of manufacturing systems, timely availability of accurate and meaningful plant data is required. Project 504 (Plant Availability and Quality Optimisation, started January 1985) is developing the data capture and interpretation tools to provide the necessary information. It has used a machine tool environment as a focus for developing and progressively implementing the project's key enabling technologies. In June 1986 process monitoring, using model based diagnostics techniques to interpret multi sensor inputs, was successfully implemented in complex metal cutting operations. The prototype system can rapidly identify faults in the manufacturing process, establish their causes and instigate the necessary remedial actions. This is the first known application of these techniques to the discrete parts manufacturing environment and there is strong exploitation potential for the project results for both vendors of monitoring systems and industrial users.

3.5.4. Selected CIM Technologies

Contributing to improvements in product quality, plant reliability, faster throughput and reduced work in progress.

The implementation of information technologies in CIM require changes in the technologies used on the shop floor; these enabling technologies need to be developed jointly with the vendors of IT equipment. The timescale foreseen leads to more highly automated supervision of processes inside flexible automated factories. To ensure maximum exploitation potential, priority has been given to the development of technologies which either present strong market opportunities for European vendors or they lie on the critical path for the successful implementation of CIM systems. Thus there is considerable investment within ESPRIT in integrated multi-sensor systems, for use in Flexible Manufacturing Systems (FMS), Flexible Assembly Systems (FAS), welded fabrication, and other subsystems for supporting CIM.

Project 118 (General Purpose Sensory Controlled Systems for Parts Production, started October 1983) is developing a sensor-controlled system for flexible automated assembly. The project partners include major vendors of control systems and complete manufacturing systems who are well placed to exploit the technology developed in the project. A range of sensors has been developed in prototype form by Siemens, IPA and SINCON. Demonstration systems integrating these sensors with robots into a car wheel assembly station and on electromechanical sub-assembly stations are being developed by Comau and Olivetti.

A major area where market potential for advanced subsystems to CIM exists is welded fabrication. Project 9 (Exploitation of Real-time Imaging for Arc Welding, started September 1983) addresses the adaptive control of arc welding tasks to accelerate fabrication times and improve quality of finished goods. An early result has been the development of a robot-based welding system, equipped with a structured light vision sensor for automatic seam tracking. The system has been constructed and evaluated in an industrial environment by RWTH (Aachen) and Messer Griesheim.

Flexible manufacturing system work is addressed by Project 278 (Integrated Sensor-based Robot System, started January 1985). It is led by a small company (MARI, Newcastle) and has major industrial involvement from Bosch and Vickers. The project has developed new methods for the handling of sensory data by existing robot controllers. Based on these the project is developing multi-sensor systems for robots, that combine vision and tactile sensors. A first demonstration system integrating a vision system with a robot is operational in IPA Stuttgart, where the prototype tactile sensors and robot gripper are in the process of integration with the demonstrator.

Monitoring the current location and status of either single parts or assembled products in flexible manufacturing and assembly requires an electronic information capture on storage, and transmission system (transponder) and software for its integration.

Project 975 (Transponders for Real-time Activity Control of Manufacturing Links to CIM Information Technology Systems, started April 1986) has already produced a prototype version, a transponder, for the tracking and follow-up of discrete parts or assemblies in a CIM environment. The transponder is being tested under hostile environmental conditions, eg heat, noise. In addition to this, the specification of software needed to deal with the information captured by transponders has been completed by Redar and Volkswagen who will provide the industrial testbed for the system.
The outputs from these projects, together with those from others which support CIM applications (eg project 496, which has produced and demonstrated a set of software tools in Ada for shopfloor decision

support) are expected to be integrated with higher level subsystems and overall CIM systems, such as the more complex ESPRIT projects on FMS/FAS. Communication protocols for robot sensor integration in ESPRIT projects 118 and 278 have already been established on the basis of ISO recommendations on Open System Interconnection (OSI).

3.5.5. Conclusions

There are already signs that vertical collaborations between Community vendors in the chain of supply are being encouraged and that links are being forged between vendors and users in innovative and ambitious projects. For many companies, the project results contribute to the formulation of corporate manufacturing strategy and to the design and implementation of innovative CIM systems. For example, Philips (Wetzlar) and BICC (London) are exploiting project 932 results in the area of dynamic scheduling to plan and optimize return on investment of plants under development. Kuka and Renault use early results from project 623 to reduce the development times and hence increase the profitability of manufacturing systems which they market. Comau (I), Digital (IRL), and Renault (F) exploit interim results of project 477 in factories at Turin, Clonmel and Cleon, respectively, where the concepts and tools based on production activity control underpin the manufacture of such diverse products as machining centres, electronic components, and motor cars. It should be noted that many of the large IT vendors are also users in the context of CIM.

Small IT vendors already exploiting marketable spin-offs from ESPRIT include Mentec (IRL) (Project 319 - MIS software), Leuven Measurement Systems (Project 322 - CAD Interfaces). Other organisations known to be exploiting interim results include Adersa (F), AEG (D), Aerospatiale (F), Bull (F), British Aerospace (UK), Cap Sogeti (F), CSD (UK), Fraunhofer IPK (D), Logica (UK), MARI (UK), Nixdorf (D), Procos (DK), Siemens (D), Stewart Hughes (UK), and the Welding Institutes of UK and Denmark.

In addition to regular programme management tasks, the area has developed an infrastructure activity, 'CIM Europe', which is designed to consolidate and enhance the effects of project work by fostering interaction between ESPRIT projects and co-workers in the field. CIM Europe is based on eight Special Interest Groups (SIGs) dealing with topics as diverse as architectures, artificial intelligence, human factors, design for automation, control and management for production systems, production systems design and engineering, advanced robotics and vision and shipbuilding. The activity is event-driven, based on conferences and internal workshops. CIM Europe was launched in September 1985, and its first public event was a technical workshop as part of SITEF Toulouse in October of the same year. The last major event (May 1986) was a conference in Bremen, held in conjunction with the regional Technology Exhibition/Transfer Congress BREMTEC. In May 1987, CIM Europe plans to hold a conference in the UK, jointly supported by the Department of Trade and Industry, and in close conjunction with AMTEC, a UK joint initiative in Advanced Manufacturing Technology.

COMPUTER INTEGRATED MANUFACTURING (CIM)
Referenced Projects

No	Title	Participating Organisations
9	Exploitation of Real-Time Imaging for ARC Welding	The Welding Institute (UK) Babcock Power (UK), RWTH (D), Messer Griesheim (D)
118	General Purpose Sensory Controlled Systems for Parts Production	Siemens AG (D), Fraunhofer IPA (D), COMAU SpA (I), Sincon SpA (I), OCN Sistemi SpA (I)
278	Integrated Sensor-Based Robot System	MARI Advanced Microelectro-nics (UK), Univ.of Newcast-le (UK), Nat'l Techn. Univ. of Athens (Gr), Fraunhofer IPA (D), Joyce Loebl Ltd. (UK), Robert Bosch GmbH(D), Univ. Nova de Lisboa (P)
319	Data Transfer between Computer Integrated Manufacturing Systems and Management Information Systems	MENTEC (IRL), Computer Systems Development Ltd. (UK), Trinity College Dublin (IRL)
322	CAD Interfaces	BMW (D), Cranfield Inst(UK) Leuven Measurement (B), GFS (D)
338	ProductDesign for Automated Manufacture and Assembly	Cranfield Institute (UK) Comau Spa (I), Renault Automation (F)
418	Open CAM System Allowing Modular Integration into Factory Management of a Workshop Structure in Functional Cells with Various Levels of Automation	Fabrique Natle.Herstal (B), Olivetti Contr.Numerico (I) Olivetti Inst.RTM (I), Cen-tre d'Informatique Gén.(B), Logica (UK), Procos A/S(Dk) Univ. de Bordeaux (F), Matra S.A. (F), TH Aachen (D)
477	ControlSystems for Integrated Manufacturing: The CAM Solution	Comau SpA (I), Digital Equip.(D), Renault Automa-tion (F)
496	Designand Specification of Configu-rable Graphics Subsystem for CIM	Signal Computer GmbH (D), Generics (Software) Ltd. (Irl), GTS GmbH (D)

N°	Title	Participating Organisations
504	A Systems Technology for Optimising the Tradeoffs between Plant Availability, Product Quality and Safety	Stewart Hughes Ltd (UK), GRS GmbH (D), Adersa/ Gerbios (F), AMTRI (UK), Technische Hochschule (D), Battelle Institut (D)
623	Operational Control for Robot System Integration into CIM	Fraunhofer IPK (D), KUKA Schweissanlagen (D), FIAR SpA (I), Renault Automation (F), Univ. of Karlsruhe (D), Unv. College Galway (Irl)
688	AMICE, A European Computer Integrated Manufacturing Architecture	Cap Sogeti Innovation (F), SNI Aerospatiale (F), Bull (F), Tech.Univ.Aachen (D), Siemens AG (D), Philips & MBLE Ass (B), Italsiel (I), Dornier (D), AT&T Philips Telecom (Nl), ICL (UK), Cap Gemini Belgium (B), GEC (UK), CGE (F), British Aerospace (UK), Comp Res. Int'l (Dk), Selenia (I), AEG (D), IBM Germany (D), Digital Equipment (D), Vokswagen (D)
932	Knowledge Based Real-Time Supervision in CIM	Philips GmbH (D), AEG AG(D) Fraunhofer IPA (D), FIAR SpA (I), Industrie Pirelli SpA (I), SGN Graphaël (F), CGE/TITN (F), BICC (UK), ARS (I), CEA (F), CFT (Nl), FZI Karlsruhe (D), Polytec Milan (I), SIS AV (I), Univ. of Savoie (F)
955	Communication Network for Manufacturing Applications	British Aerospace (UK), BMW AG (D), Olivetti SpA (I), Peugeot PSA (F), Aeritalia SAIPA (I), Siemens AG (D), Bull (F), CGE-TITN (F), GEC Electrical (UK), Nixdorf Computer (D), Fraunhofer IITB (D),
975	Transponders for Real-Time Activity Control of Manufacturing Links to CIM Information Technology Systems	Redar GmbH (D), TM Technics Dieren (Nl), Polydata Ltd (Gr), Volkswagen AG (D)

4. SIZE AND COMPOSITION OF CONSORTIA

With an average of 5.1 partners per consortium, it is clear that the ESPRIT programme has been successful in its objective of bringing about collaboration on a European scale. In each of the 201 consortia, there are at least two industrial partners from two different Member States.

The overall average may appear to be on the high side, but this includes non-industrial partners, who participate in 150 of the 201 projects. There is a particularly high non-industrial participation in AIP (in 39 out of 42 consortia, or an average of 2 per consortium), since in the knowledge engineering and advanced database fields, the expertise within Europe still primarily resides within the universities and research institutes (Table 8).

The presence of academic institutions is to be welcomed, especially now that some start-up problems, largely due to the different accounting procedures adopted by companies and academia, have been overcome. On occasion, successful consortia may be led by universities or research institutes. Examples are project 390 "Program Development by Specification and Transformation (PROSPECTRA)" in Software Technology, headed by the University of Bremen, and project 443 "Molecular Engineering for Optoelectronics" which has CNET (F) as prime contractor. But these are very much exceptions, and are likely to remain so.

ESPRIT is an industrial programme, and an overwhelming majority of projects are led and carried out by industrial concerns. So it is legitimate to examine the level of industrial participation in greater detail. The average number of industrial partners per project is 3.5. In the individual sub-areas, this ranges from 3.1 in AIP to 4.1 in CIM.

The average number of industrial partners in each of the areas is inflated by taking into account those projects whose principal goal is to contribute to the preparation of international standards of European origin. In all areas, the groundwork leading to the acceptance of such standards requires the active participation of as many of the major industrial actors as is practical. The maximum number of these is 20 in

P688 "AMICE: A European Computer Integrated Manufacturing Architecture", but more often 9 or 10 partners, as in the Office Systems project 43 "Standardisation of Integrated LAN Service and Service Access Protocols". Based on the experience of programme management, good cooperation occurs in these standardisation oriented consortia, whatever the size, since the large European industrial partners appreciate that management in this field is naturally an international affair.

The distribution of industrial partners in projects is shown in Table 8. This demonstrates that the majority of projects (115) have just 2 or 3 industrial partners. These are the consortia which are conveniently manageable, where a small number of partners all contribute significantly. This maintains the maximum benefits of the Programme, ensuring a balance between the dissemination of results and the protection of the individual partner's commercial interests.

Even excluding standardisation oriented work, there is a significant minority of projects containing 4 or more industrial partners. In most of these cases, the consortium functions in a balanced manner industrially. However, it cannot be denied that in some instances, the quality of collaboration has been adversely affected by the numerical imbalance of contribution between different partners in a large consortium. For instance, one major project in microelectronics experienced difficulties of this very nature. The problem was resolved by implementing a distributed management to create better synergy for the allotment of tasks. Although the situation has not yet arisen , an unequal distribution of the workload will increase the risk of friction when it comes to the commercialisation of results.

Taking into account the quality and timing of the initial achievements, the Commission intends to monitor closely the 20% of consortia containing 5 or more industrial concerns in order to ensure that the need for balanced collaboration and significant contribution is being respected by the individual partners concerned.

5. COST/BENEFIT AS A FUNCTION OF DIFFERING LEVELS OF FINANCIAL SUPPORT

The Community Framework Programme of technological research and development 1987 - 1991 (COM(86)430 final) lays down a simple and flexible set of modalities to be applied to the financial support of R&D actions by the Community. These fall into three categories:

- direct actions, financed 100% by the Community budget and carried out by the Joint Research Centres;
- cost-shared actions, cofinanced by the Community and the scientific and industrial partners involved;
- concerted actions, consisting of coordination by the Commission of specific research activities.

The growing realisation by industry of the advantages of cooperation, together with the limits put on available resources in the Community budget, may lead the Commission to review arrangements for cost-shared actions. COM (86)430 final indicates a range of financial participation between 20% and 80% of the total costs of a given programme, using criteria such as the degree of precompetitivity of the actions concerned, the nature of the costs to be incurred and the state of progress in the relevant research area.

Thus, all ESPRIT projects, which are precompetitive in nature and involve advanced R&D, are awarded on a split-cost basis. In other words, the rule is applied across the board to all organisations participating in a project, be they industrial concerns, research institutes, or universities, since a project is usually executed by a consortium made up of a number of industrial and non-industrial concerns.

In the Member States, R&D programmes benefitting from direct government support generally have a cost-shared element but the exact percentage can vary depending on whether the programme is precompetitive in nature or nearer to the market. Programmes in precompetitive R&D are often cost shared on a 50/50 basis. This for instance in the case of the UK's Alvey

Programme, except for participants from academia, who are funded on a "full cost" basis. Research programmes supported by the German government, normally conform to a support level of 50%; lower percentages of "indirect-specific funding" (40%) are awarded for product development and related costs.

In the USA, on the other hand, the Department of Defense normally meets the full costs of R&D, even when the results are of immediate use to industry. Arguments concerning national security aspects do not hide the fact that much of the funding which goes to IT companies results in major generalised benefits such as a strengthening of their technological base and an improvement in their competitive position.

ESPRIT, compared to national programmes in the IT sector, has the additional objective of promoting cross-border cooperation. For the participants, the burden which cross-border cooperation adds to the complexity and cost of their operations is offset by the potential benefits of access to results generated by other participants, as well as the potential Community-wide market perspectives which such cooperation opens up.

It is known that this aspect of the ESPRIT Programme adds to its attractiveness in the eyes of many potential participants. This enables the Community to limit its support to the split-cost level of 50% and still maintain its ability to attract proposals comparable in quality and worth to those submitted under national programmes offering the same level of financial participation without the requirement of cross-border collaboration.

Any increase or reduction in this level of 50% would need to be made in conjunction with a careful reconsideration of the property-rights issues in the context of the requirement for information dissemination and technology transfer. Such action would also require reconsidering the level of funding in related national programmes. This task is clearly beyond the scope of this report. For ESPRIT the Commission does not envisage a change in the current 50% level of funding..

6. COMPARISON OF THE HUMAN RESOURCES INVOLVED IN ESPRIT WITH THE GENERAL RESOURCE SITUATION IN THE COMMUNITY

ESPRIT projects currently underway comprise a maximum figure of almost 3000 researchers and engineers at work in cooperative R&D, making an average of 2000 for the first phase of the Programme (Table 4). These numbers correspond to roughly 6% (maximum level) and 4% (average level) of the total R&D capacity in IT in Europe available for projects of an industrial type.

This estimate is based primarily on the R&D expenditure of the top 18 data processing and semiconductor manufacturers in Europe, which totals to some 2.7 to 3 Billion ECU per year[1]. It is furthermore estimated that this figure needs to be increased by about one third in order to take account of R&D in the IT sector executed by other companies in Europe. The estimate does not take account of IT specialists working at user sites nor the large number of small engineering and software houses supporting these users. The total R&D expenditure derived from this estimate can be translated into a manpower level of about 40,000 researchers and engineers working in industry.

In order to obtain a complete picture of the human resource situation in the IT sector, the researchers working in public R&D institutes and universities need to be added. Detailed data are not available. A large number of these researchers work, however, in basic research and only a fraction of them can be expected to work in projects of an industrial nature.

Taking the experience of non-industrial participation in ESPRIT projects as a rough guideline, the upper limit for the total number of researchers and engineers available for working on industrially oriented R&D projects in the IT sector may be estimated at 45,000 in the European Community. It cannot be expected that this number can be raised to a large extent in the short term. Measures undertaken in education and training will only bear fruit in the medium and long term.

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1) Derived from data provided by Booz, Allen and Hamilton 'Trends and objectives of the IT sector in the medium and long term', 1986.

In view of the figures presented, and in the light of the improved climate for cooperation, it is obvious that there is still ample room for a considerable increase in the number of researchers working in cooperative projects without, at the same time, increasing the total manpower at an equal rate.

7. ISSUES RELATING TO THE PARTICIPATION OF SMEs

The Communication from the Commission to the Council concerning the review of the Programme (COM (85)616 final) concluded that ESPRIT was laying the ground for technology transfer, and encouraging small and medium sized enterprises to participate. Over half of ESPRIT projects count the participation of at least one SME (defined as a company with under 500 employees). In fact, SMEs do more than 25% of the work in 60% of the projects in which they are present, attesting to their vitality and the key role they play in technology transfer. In the case of some small industrial organisations ESPRIT work often accounts for the greater part of their R&D activity. Without ESPRIT such organisations would not have the funds available for significant research activity nor would they be able to benefit from international collaboration.

By and large the ESPRIT Review confirmed that the relevant basic rules concerning Intellectual Property Rights and joint liabilities are, in general, adequate to the needs of smaller companies, whose interests still need to be safeguarded. This aspect of ESPRIT may indeed be regarded as of particular interest to companies with limited R&D resources, since they benefit from the rules which foster technology transfer between the partners.

Viewing ESPRIT Phase I as a totality, 420 different participants from industry, universities and research institutes are participating as partners in projects. Of these entities, over 240 are different industrial concerns.
Among these 240 industrial concerns there are:

150 industrial partners with less than 1.000 employees;
130 industrial partners with less than 500 employees.
In the latter group, which, as stated above, is considered to constitute SMEs, one out of two is a small company with less than 50 employees.

When ESPRIT was first defined, it was felt appropriate to classify projects according to type. Type A projects are preplanned individually in the annual workplan which is approved by Council. Type B projects, on the other hand, are specified in the workplan by research topic only, allowing proposers greater flexibility and room for more speculative research. It was felt at the time that Type B projects would be particularly suited for SMEs. However, small and medium-sized companies participate in Type-A projects almost to the same extent as in Type-B projects. In all, SMEs take part in precisely in 51% of the Type-A projects and 61% of the Type-B projects (Table 9).

With regard to the individual R&D areas small and medium sized companies participate in all five areas substantially. In the areas Software Technology, Advanced Information Processing, Office Systems and Computer Integrated Manufacturing their level of participation is close to or above 50%. In Microelectronics the level of participation of small and medium-sized companies is, however, considerably lower and amounts to 32.6%. This may be due to the fact that these technologies usually require large R&D resources and heavy capital investment.

Viewed on the basis of direct financial benefit arising from their participation, SMEs' share of ESPRIT funding is just under 20% (including about 3% as subcontractors).

The Commission is constantly concerned to improve the general and administrative conditions for the participation of SMEs. The Commission has checked its administrative procedures with a view to accelerating payments, an aspect which is of particular importance for SMEs. The new procedure which has been adopted for signing contracts with project partners has permitted advance payments to be made much sooner than was previously possible. Finally some SMEs may be said to suffer from a genuine hesitation about taking part in international programmes such as ESPRIT, fearing to "take the plunge". The Commission does its best to help overcome these fears by providing timely and comprehensive information to all inquirers.

In total, the level of participation of small and medium-sized companies is relatively high and reflects the high level of interest of European Industry in ESPRIT. It is essential that their high level of participation be maintained in the future course of the programme.

TABLES AND GRAPHS

TABLE 1

ESPRIT PHASE I
COMMUNITY CONTRIBUTION TO PROJECTS IN THE FIVE TECHNICAL AREAS (MECU)

Subprogramme	Year of Call for Proposals		Total	Percentage of total
	1983/84	1985		
1. Microelectronics	91.8	74.4	166.2	24.5
2. Software Technology	72.8	54.1	126.9	18.7
3. Advanced Information Processing	89.5	60.9	150.4	22.2
4. Office Systems	94.9	48.7	143.6	21.2
5. Computer Integrated Manufacturing	49.0	41.6	90.6	13.4
Total	398.0	279.7	677.7	100.0

30-6-1986

TABLE 2

ESPRIT PHASE I
MAN-YEARS ALLOCATED TO PROJECTS AND PERCENTAGE OF WORK EXECUTED BY AREA

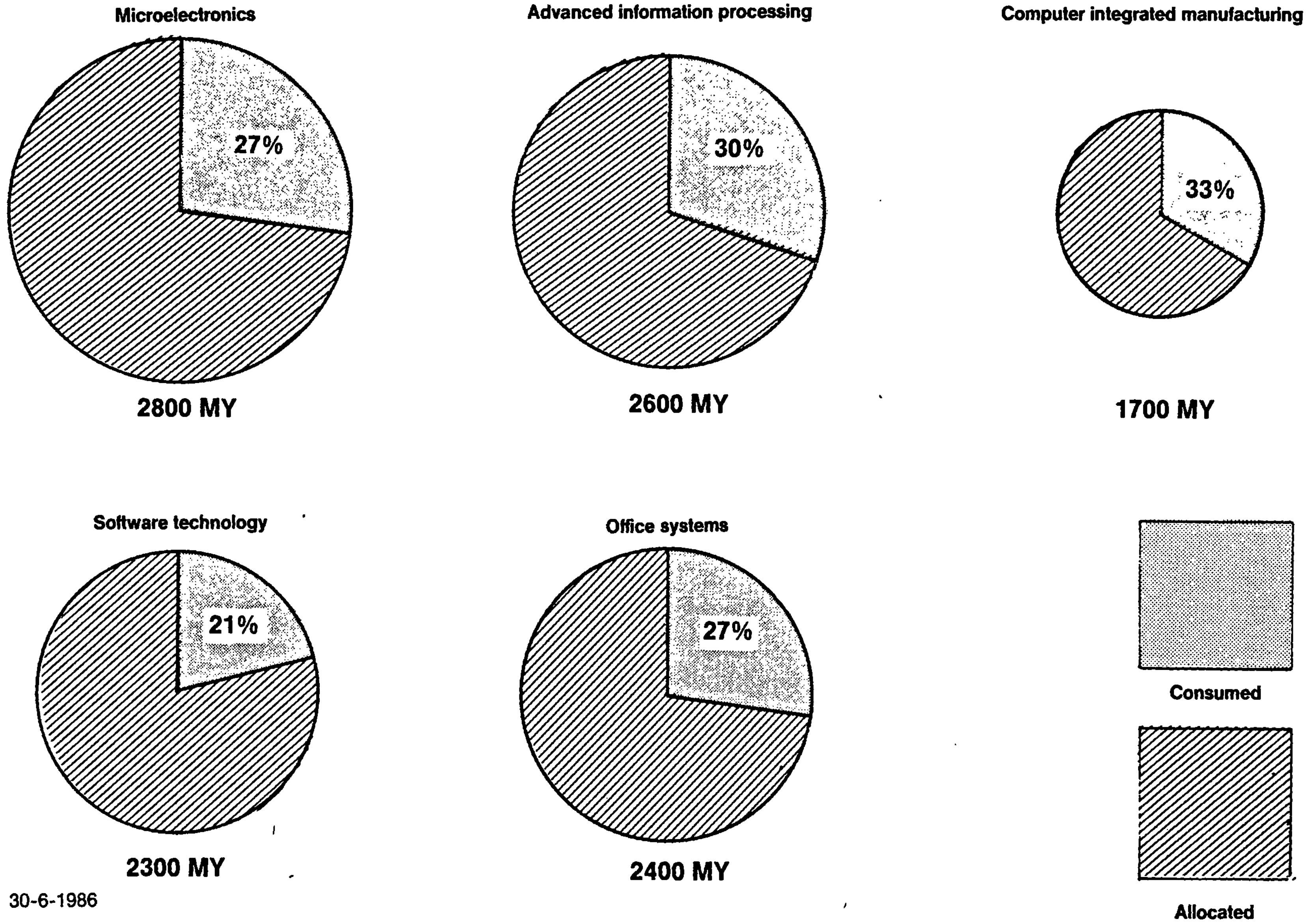

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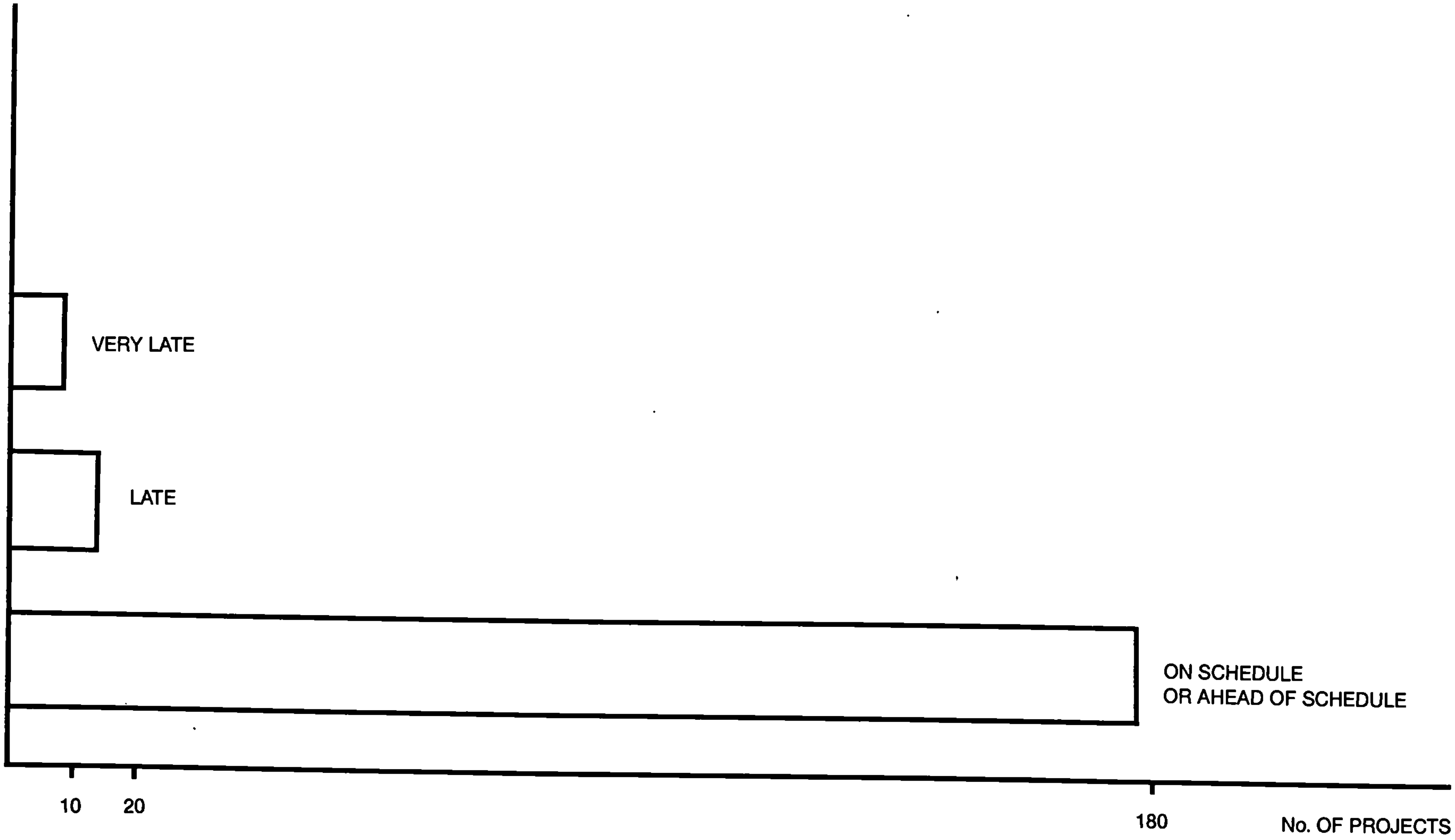
TABLE 3

ESPRIT PROJECTS 1983-1986 : DEVIATIONS FROM PLAN



ON SCHEDULE/AHEAD OF SCHEDULE:	179 PROJECTS
LATE:	14 PROJECTS
VERY LATE:	8 PROJECTS

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TABLE 4

ESPRIT PHASE I — DISTRIBUTION OF WORK EFFORT IN TIME (PROJECTED)

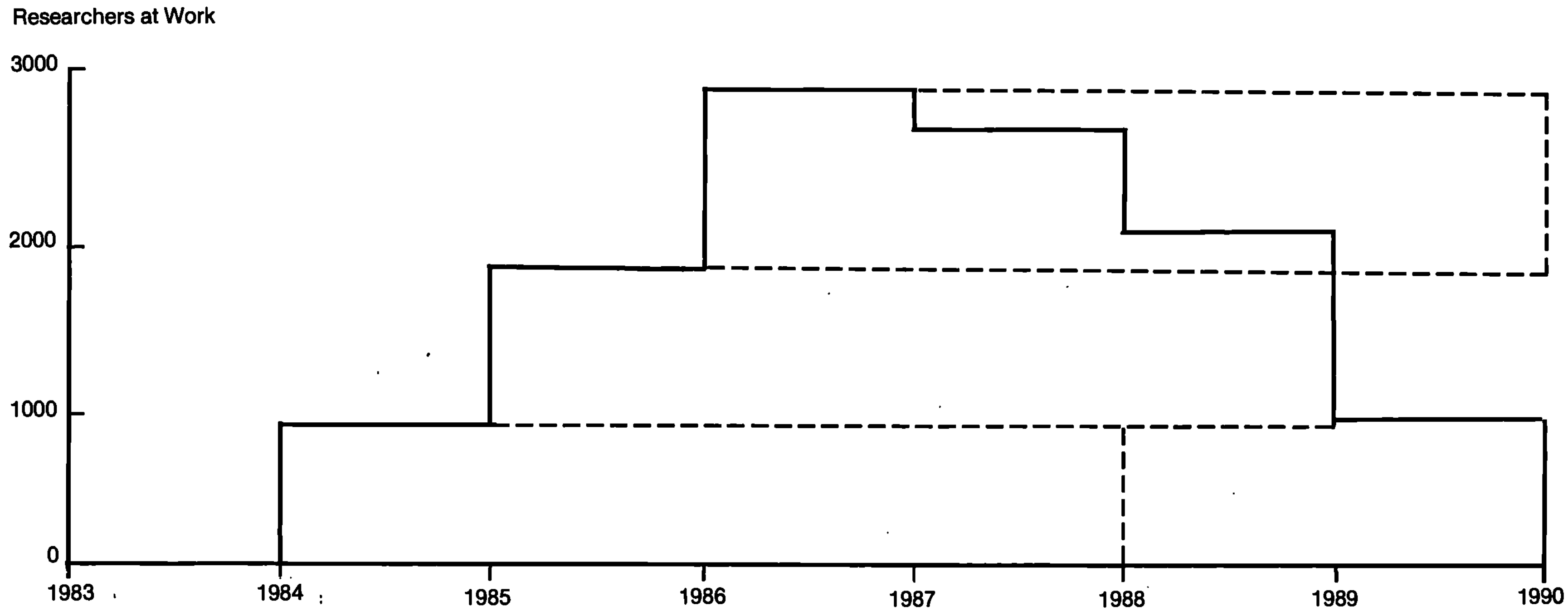

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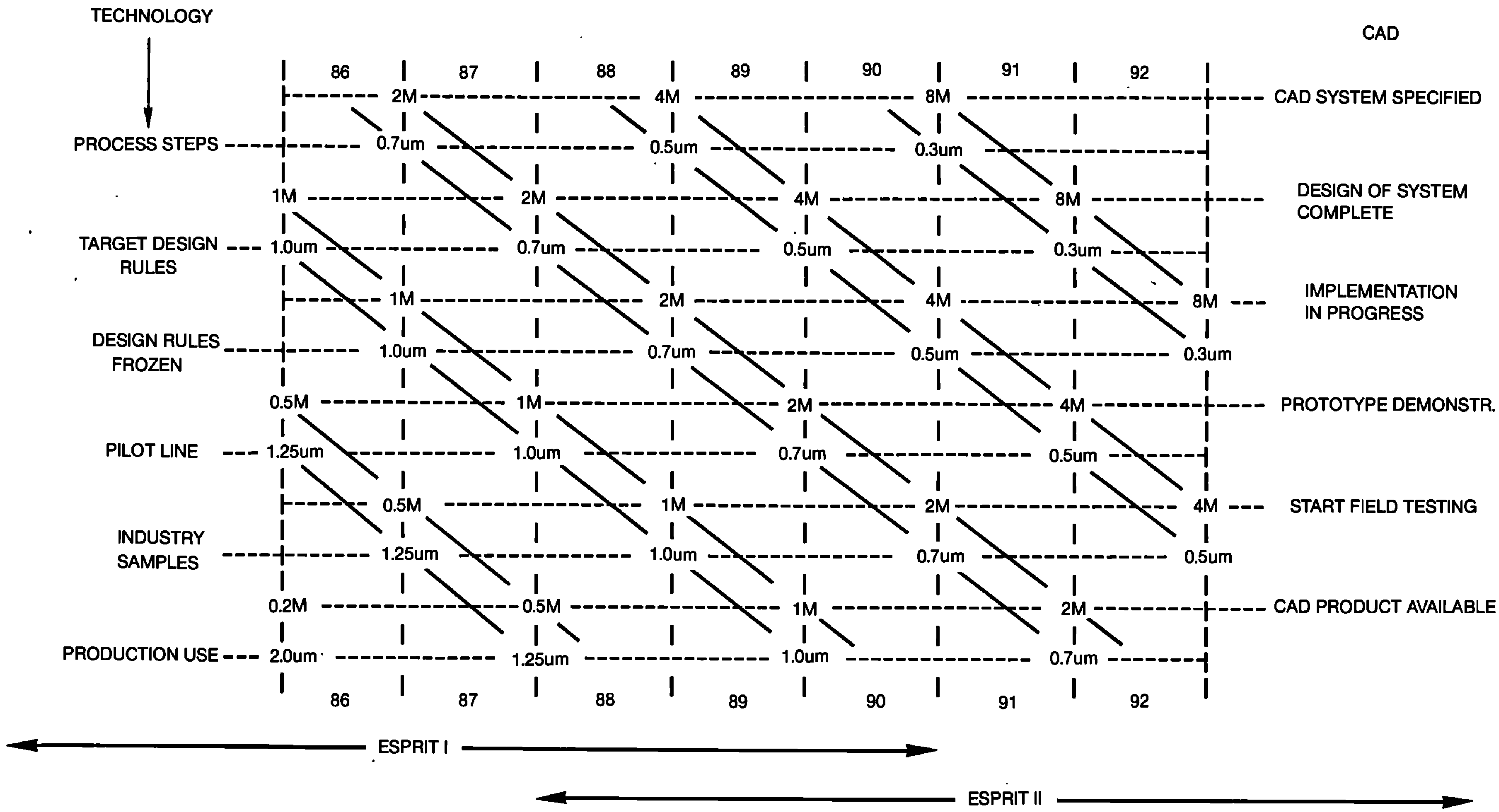
TABLE 5

PARALLEL EVOLUTION OF CMOS TECHNOLOGY AND CAD IN ESPRIT



TECHNOLOGY SPECIFIED BY DRAWN GATE LENGTH IN MICRONS.
CAD SYSTEMS SPECIFIED BY MATCHING MAXIMUM COMPLEXITY IN MILLION TRANSISTORS

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TABLE 6

ESPRIT MICROELECTRONIC PROJECTS PERFORMANCE VS TECHNOLOGY

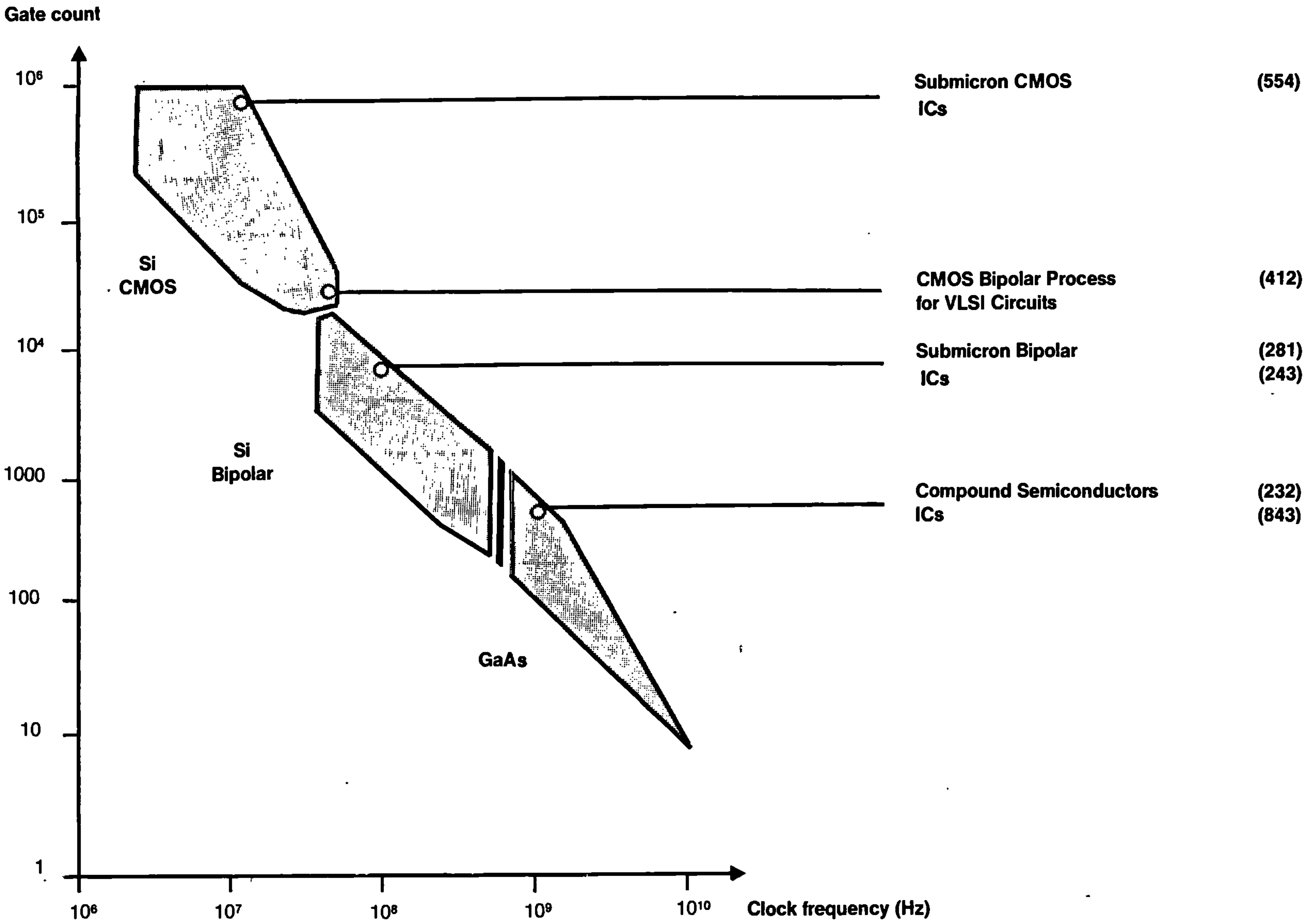

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TABLE 7

ESPRIT PHASE I
AVERAGE AND MAXIMUM NUMBER OF PARTNERS IN PROJECTS PER AREA

	MEL	SWT	AIP	OS	CIM	All Areas
Industrial Partners						
Average	3.2	3.4	3.1	4.0	4.1	3.5
Maximum	7	8	8	9	19	19
Non-industrial Partners						
Average	1.6	1.2	2.0	1.3	1.4	1.5
Maximum	5	5	6	4	6	6
All Partners						
Average	4.7	4.4	5.4	5.3	5.8	5.1
Maximum	11	9	11	9	20	20

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TABLE 8

ESPRIT PHASE I
DISTRIBUTION OF PARTNERS IN PROJECTS PER AREA

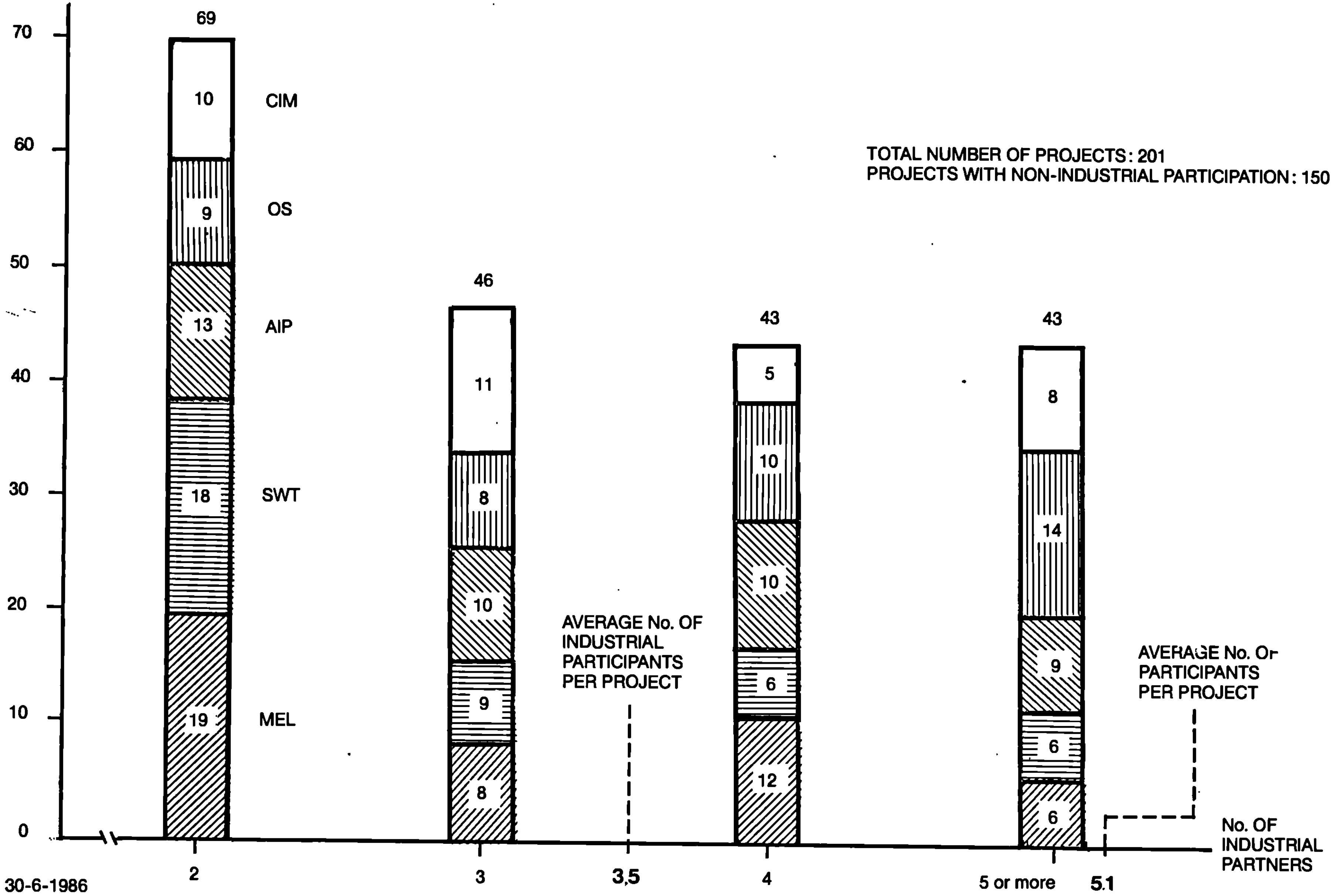

TABLE 9

ESPRIT PHASE I

PROJECTS WITH PARTICIPATION OF SMALL AND MEDIUM SIZED ENTERPRISES

(As a Percentage of total number of projects, per area and project type).

AREA	A PROJECTS	B PROJECTS	
1. MEL	31.2%	33.3%	32.6%
2. SWT	42.8%	75%	64.3%
3. AIP	72.7%	76%	74.4%
4. OS	47.0%	63.6%	56.4%
5. CIM	50.1%	69.2%	58.1%
ALL AREAS	50.6% (A)	61.4% (B)	56.7%

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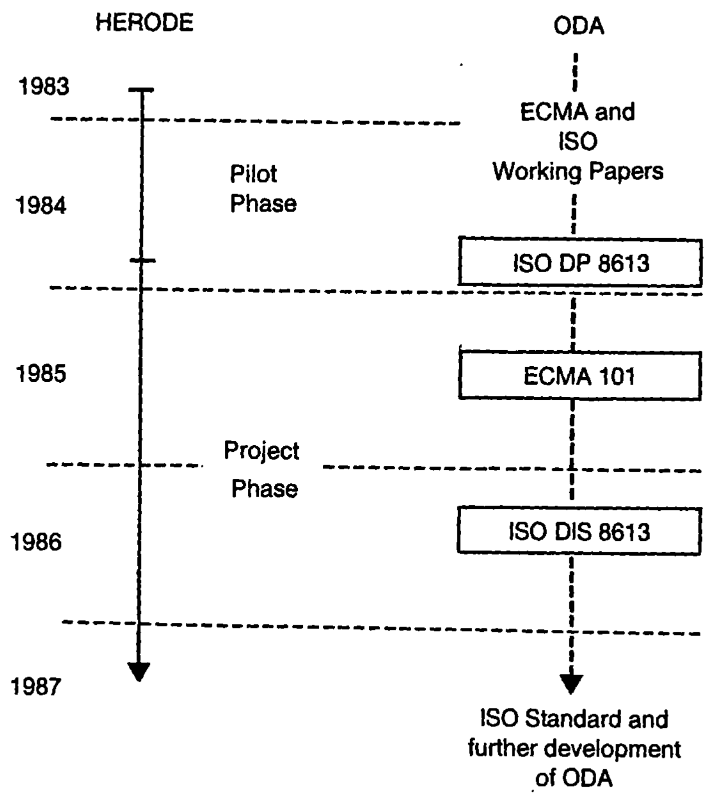
TABLE 10

PARALLEL DEVELOPMENT OF ODA STANDARDS AND ESPRIT PROJECT HERODE



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(v) particular problems relating to the participation of small and medium-sized undertakings (SMEs).

Specific results and progress are summarized in Chapter 1 of the report (Executive summary). Chapter 2 deals with the status of the programme as a whole, Chapter 3 with the detailed results and progress of the individual projects, and Chapters 4 to 8 with the issues of general relevance.

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