Esprit

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for Research and Development in
Information Technology

Synopses

Basic Research

Actions and Working Groups

Volume 8 of a series of 8

September 1989

Directorate General XIII
Telecommunications, Information Industries and Innovation
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Basic Research

Actions and Working Groups

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XIII/321/89

LEGEND

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S	Sub-Contractor
A	Associate Contractor

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THE ESPRIT BASIC RESEARCH ACTIONS

INTRODUCTION

There is a growing consensus that supporting basic research in Information Technology (IT) is a solid investment whose payback, even if it does not come in the form of short-term industrial applications, will be great. Such research, carried out at universities, research institutes and industrial research laboratories, serves the dual role of providing new knowledge and helping to ensure the future availability of high-calibre scientists and engineers. Both are key elements in the long-term ability of Europe to compete in global markets.

Research ideas conceived without thought to applications have often led to technological developments with major industrial, economic and social impact, and now provide essential tools for IT and all engineering areas that rely on a capability for rapid and massive computing and automated logical inference.

The importance of basic research is amply recognised in the USA and a recent Congress bill (aimed at "maintaining US supremacy in computer science") increases funding of basic research in computer science and high performance computing to a rate of about $100M annually, in addition to an approximately equal sum provided by the US Department of Defence through DARPA.

Public funding of basic research in national programmes in Europe has shrunk in inverse proportion to the growing emphasis on industrially oriented research. In the light of this, the ESPRIT Basic Research Actions represent a modest effort to ensure that the reservoir of knowledge and skills needed for the continued health of industrial R&D will keep being replenished. The aim is to provide an opportunity for international collaboration at the European level and to enable research efforts, often inter-disciplinary, that would otherwise be too ambitious to undertake.

BASIC RESEARCH IN ESPRIT II

The preparation of the ESPRIT Basic Research Actions started in 1987 through meetings attended by top European researchers representing a broad range of research interests. These contributed to a consensus on the range of areas to be covered and the cooperative schemes needed to carry out the work. The following objectives were established:

- to support collaborative fundamental research in selected IT areas

- to increase the involvement of leading research teams in ESPRIT.

It was agreed not to spread available resources too thinly over all possible areas of interesting, or even exciting, research; areas had to be selected. The main criteria used to select the areas that define the scope of the Basic Research Actions were established as:

- that they should have the potential to produce future breakthroughs or important advances even though they might not have any immediately visible applications

- that they should fall in areas where collaborative research on a European scale brings added value

- that they should be clearly upstream from main ESPRIT precompetitive R&D.

The first call for proposals was announced on March 25, 1988. By the closing date (13 June), about 300 proposals were received, requesting total funding of 485 MECU, and representing a research effort in excess of 1 BECU. They involved about 1400 participants from universities (74%), research establishments (20%), and industry (6%).

This response was much larger than had been anticipated. Furthermore, the proposals were generally of a very high quality and involved most European teams working in the forefront of basic IT research. The large number of proposals meant that only those of exceptional quality could be funded.

After evaluation by the Commission and recommendations by the ESPRIT Management Committee and by the ESPRIT Advisory Board, 61 proposals involving 285 different organizations were selected. In addition, 13 proposals were joined in working groups and given limited support to facilitate cooperation through travel and workshops. In total, a funding level of 63 MECU is expected to cover work over a 30-month period.

OVERVIEW OF LAUNCHED ACTIONS

A brief description of the work launched in each of the three main areas follows, giving an indication of the actions launched in each.

Microelectronics (MEL)

In the area of microelectronics, 26 actions and 2 working groups have been launched. Many different disciplines are needed to come together for the launched actions, including physics, organic, inorganic and physical chemistry, electronic engineering, material science, and metallurgy. Experimental, theoretical and integrated approaches are presented to tackle the long-term research needs. The main targets of the actions are:

Low-Noise and High-Speed Devices through the use of low temperatures, including fabrication and validation of low dimensional structures, and through new high T_c superconducting materials. The latter comprises studies of lattice dynamics, the influence of impurities, and the preparation and characterisation of films and single crystals.

Fundamental In-Depth Studies of Structures based on silicon III-V and II-VI compounds or other advanced substrates, exploring quantum effects or tailoring of electrical properties.

Nanometre-Scaling of Circuits amongst other fabrication techniques through realisation of organic molecule assemblages. The electrical properties of organics are under investigation. Carrier transport control and electronic switching capabilities are receiving major emphasis.

Preparation of Superfast and Massively Parallel Computing Systems developing optoelectronic elements and other related optical devices.

Next-Generation Design Systems Development of Formal Methods and algorithms, covering formal verification, behavioural synthesis, real-time VLSI, architecture optimisation, and power timing optimisation.

Computer Science (CS)

A total of 15 actions and 6 working groups have been launched. The actions provide a broad and coherent coverage of basic research in computer science and should provide results of wide applicability. A sub-area not sufficiently covered is that of architectures; this may reflect a gap in the computer science scene in Europe to be addressed in the near future.

Formal Systems: The two main components of the foundation of computer science, logic and algebra, are addressed, providing the framework for the development of specification and verification techniques and programming languages.

Concurrent Systems: The actions launched in this area investigate the relationships between competing schools and theories trying to provide an adequate framework for the description and analysis of concurrent systems. The aim is the unification of these theories (eg logics, languages, models) towards their application in specification and verification tools.

Specification and Verification: Actions cover the design of a specification language with the necessary system support, the use of logics as a foundation for specification techniques in concurrent systems, and ultimately a complex system, which is amenable to automatic verification and deals with multiprogramming and real-time.

Algorithms and Integration of Programming Styles: The efforts in this domain are focused on the definition of high-level declarative programming languages, and the challenge of integrating aspects of functional, logic and object-oriented programming is taken up.

Dependability, Data Bases and Distributed Computing: Actions cover the prototyping of an integrated systems architecture, and the software technology

to provide integrated database services and programming language capabilities. Concepts underlying design decisions and development techniques for assessing, predicting and validating dependability are dealt with in a unified manner.

Artificial Intelligence and Cognitive Science (AI/CGS)

A total of 20 actions and 5 working groups have been launched. The actions are classified into sub-areas, but individual projects may span more than one of them and also have close connections with computer science and microelectronics.

Robotics and Vision: The issues of uncertainty, of representation of space and movement, and of adequate functioning in real-world domains are addressed by trying to understand the characteristics of systems that deal with natural environments.

Neural Networks: The actions deal with problems such as the development of suitable hardware (VLSI) implementations of neural networks and a deeper understanding of the relationship between classical AI and CS techniques and neural network techniques.

Knowledge Representation: Actions deal with computer-aided tutorial environments, uncertain reasoning, automated deduction in non-standard reasoning, and the building of a framework for a reflective system able to reason about its own competence and to apply its knowledge flexibly.

Speech and Natural Language Processing: Some actions address the ultimate goal of robust, speaker-independent recognition of continuous speech, exploring neural network techniques and natural speech production, while others address large multi-lingual knowledge bases, the integration of speech and natural language, and the handling of discourse.

Formal Theories of Automated Manufacture: The major need for a unification of the field's fragmented theoretical foundations is addressed, aimed at formalising a conceptual model of product design, production and production management.

Human-Computer Interaction: Actions cover computer modelling of users interacting with computers, cognitive modelling and investigation of user behaviour in the laboratory, and cognitive modelling of user behaviour in complex IT work domains.

CONCLUSIONS

This volume contains a first description of the launched actions. The actions themselves, taken as a whole, provide a coherent coverage of the intended areas,

and a broad range of interdisciplinary links. They are carried out by teams of very high quality.

Looking into the future, the tasks set are to maintain dynamically the coverage of key areas, to reinforce interdisciplinary links which open new ways of looking at major problems, to ensure that the scarce qualified manpower needed for basic research is available, and to make certain that the results of research are transferred downstream to industrial research.

Concerning the latter aim, that of technology transfer, stronger links between industry and academia need to be established, and the form and suitability for transfer of Basic Research results must match the speed of their dissemination. To this end:

- A workshop will be held by each action once a year. Invitations to workshops will be issued to participants in other relevant Basic Research Actions as well as to other industrial researchers who could provide feedback on the suitability of results for addressing industrial problems.

- Some workshops will encompass activities of several actions in related areas. They will also act as focal points for the development of special training schemes on emerging topics where qualified research manpower is scarce.

The actual work in ESPRIT Basic Research Actions is just beginning. Time will have to pass before plans and hopes begin to be replaced by solid achievement. As a start, the actions described in this volume aim to provide a solid basis for the sustained effort that lies ahead.

MICROELECTRONICS:

ACTIONS AND WORKING GROUPS

HIGH TEMPERATURE SUPERCONDUCTIVITY: CONCEPTS, MODELS AND METHODS (HTSC THEORY)

ACTION NUMBER: 3014

The aims of the action are:

- to foster the critical analysis of current theoretical understanding of the microscopic physical mechanisms essential to the occurrence of superconductivity in the new class of high-temperature superconductor metal oxides

- to promote the formulation of a theory encompassing in a unified picture the variety of properties of these new materials

- to explore how the extension of the current understanding of high-Tc superconductivity bears on applications (particularly in microelectronics), on the prospect that other high-T_c superconducting materials may be discovered, and on the acquisition of new knowledge in related branches of basic physics.

The Action consists of three extended "think-tank" workshops, in which a critical mass of scientists (approximately 20 researchers, mostly theoretical physicists and materials scientists, representing the most relevant trends in high-T_c superconductor theory) work together in an environment conducive to productive, stimulating and efficient interaction, as well as with the instruments for the performance of sophisticated numerical calculations or simulations (such as Quantum Monte Carlo).

Expected results include:

- critical comparison of present theories of strongly interacting electrons in two dimensions; new results on dynamic mechanisms and electron pairing, phase transition mechanism and critical properties, role of magnetic and spin glass order; simulation and numerical results

- identification of the relevant pairing mechanism; construction of a unified theoretical scheme; checking of the new theoretical predictions with new experiments

- classification of possible new high-T_c superconductors; evaluation of the upper limit for critical temperature; evaluation of parameters for experiments (scattering cross-sections for light and neutrons; electrical conductivity and upper critical magnetic field, and their anisotropy).

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Start Date	**Duration**
01-JUN-89	*30 months*

ELECTRICAL FLUCTUATIONS AND NOISE IN ADVANCED MICROELECTRONICS: SUBMICRON, 2-D GAS AND LOW TEMPERATURE DEVICES (NOISE)

ACTION NUMBER: 3017

The objective of this Action is the study of electrical fluctuations and noise in the following electronic devices:

- submicron MOSFETs at room or at low temperature
- submicron bipolar devices on Si
- HEMTs, HBTs and 2-D gas devices (on III-V materials).

The goals of the Action are:

- identification of noise sources
- correlation between noise and quality as well as between noise and reliability of the devices
- identification of limitations of performance (due to noise)
- insertion of noise models into CAD programmes.

The approach and the method of work are:

- fabrication of devices
- noise measurements at room and low temperature, in low and high frequencies
- theoretical interpretation, development of noise models, and comparison with general theories
- conclusions concerning operating limits (due to noise) and correlation of noise with technology
- insertion of noise models into CAD industrial programmes.

Achievement of these goals will have an important impact on the fundamental understanding of the operation and the limits of VLSI devices, devices for space applications, and low temperature electronics, based on 2-D electron gas devices.

It is hoped that important advances will be made in the knowledge of mechanisms and sources generating the 1/f noise; the sources and the types of noise at low temperatures and in 2-D gas devices will be determined; and IC CAD programmes will be enhanced by including noise parameters.

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Start Date	Duration
01-JUN-89	*30 months*

HETEROSTRUCTURES OF SEMICONDUCTING SILICIDES ON SILICON. APPLICATIONS TO SI-COMPATIBLE OPTOELECTRONIC DEVICES (HESSILSIL)

ACTION NUMBER: 3026

Recent progress in the understanding of interfaces at the atomic level suggests that electronic systems may one day be fabricated on a simple integrated chip. If components such as Si VLSI processors, GaAl/AlAs integrated optoelectronic devices, II-VI superlattice visible displays and high-speed III-V processors are to be integrated, interface formation and in-situ processing will be required at a level of sophistication well beyond what is available today. Fundamental research on new heterostructure formation has to be undertaken to achieve those future breakthroughs.

This Action will search for new binary and ternary semiconducting silicides epitaxially grown on silicon substrates using a novel technology, molecular beam epitaxy by gas, associated with in-situ and post-situ surface techniques. Potential candidates are $FeSi_2$ (semiconducting ß phase) and its related ternary compounds, which could be epitaxially grown on silicon.

The structural properties of these heterostructures will be studied by means of a variety of complementary methods.

The electronic properties will be studied with in-situ electron- and photo-emission methods and other complementary post-situ characterisation techniques.

Once the physical mechanisms of the formation of the semiconducting silicide-silicon heterojunction are well understood, light emitters and detectors based on silicide-silicon heterojunctions compatible with Si technology will be investigated.

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Start Date	Duration
01-JUN-89	*30 months*

POSSIBLE MECHANISMS FOR HIGH-T_C SUPERCONDUCTIVITY AND PHENOMENOLOGICAL APPROACHES (MESH)

ACTION NUMBER: 3041

Electrons in certain materials, such as narrow band systems, translate in a highly correlated way. As a result, their electric and magnetic behaviour exhibits unexpected features, the most striking of which is the recently observed high-T_c superconductivity. The objective of MESH is to contribute to the development of a thorough quantitative understanding of the electronic motion in these materials. Such an understanding would allow the identification and possibly the control of the mechanism(s) responsible for high-T_c superconductivity.

In a coordinated effort by five groups with experience in a variety of different theoretical techniques, systematic studies will be carried out on models of strongly correlated electrons, such as the large-U Hubbard model and its various extensions, with or without incorporation of more traditional aspects like lattice vibrations. By a comparison of results obtained in the framework of the same model by different techniques, models will be eliminated and the search narrowed down to those which seem promising for explaining the mechanism of high-T_c superconductivity. At the same time, analytical and computer simulation work will provide a phenomenological understanding of the electromagnetic and glassy properties of the materials.

The results of this Action are expected to contribute significantly to:

- The understanding of the role of strong electron correlation effects in narrow band materials which may cause high-T_c superconductivity and antiferromagnetism as well as the interplay between the two phenomena. If the basic pairing mechanism turns out to be an electronic one, this action will make a significant contribution towards creating the theoretical framework for the explanation of high-T_c superconductivity and, consequently, to facilitate the fabrication of improved high-T_c superconductive materials, as it may provide an understanding of the crucial factors determining the critical temperature T_c.

- A quantitative assessment of the influence of electron-phonon interactions, oxygen deficiency and disorder on the superconducting properties.

- A basic theoretical understanding of the phenomenological aspects of the materials that will be of importance in device design and performance.

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Start Date	Duration
01-FEB-89	*24 months*

PERFORMANCES AND PHYSICAL LIMITS OF HETEROSTRUCTURE FIELD-EFFECT TRANSISTORS (NANOFET)

ACTION NUMBER: 3042

The objective of the Action is to investigate the dynamics of non-stationary parallel transport at high electric fields in 2-D electron gas structures scaled down to ultra-submicron dimensions. A central problem is the physical limit of carrier transit time in these structures. Heterojunction field-effect transistors are the demonstrators in the project. The results should allow the drawing up of guidelines for scaling down devices in the next generation of HFETs for information technology.

The Action involves the combined investigation of AlGaAs/GaAs and pseudomorphic AlGaAs/InGaAs structures grown by molecular beam epitaxy on GaAs substrates. The AlGaAs/GaAs structures will be used to assess the ultimate performance of HFETs with a gatelength of 0.1 micron. The pseudomorphic layers will be used for devices with gatelengths scaled down below 0.1 micron.

These investigations are supported by an extensive device simulation and characterisation programme. Simulations are based on the Monte-Carlo technique and focus on specific problems of ultra-submicron devices. High frequency characterisation with improved sensitivity is used to characterise devices with very small dimensions. Ultra-fast laser spectroscopy is employed for investigating electron transport over submicron distances.

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Start Date	Duration
02-JUN-89	*30 months*

LATERAL MICROSTRUCTURES: FABRICATION, LOW DIMENSIONALITY EFFECTS AND APPLICATION TO III-V DEVICES (LATMIC)

ACTION NUMBER: 3043

The objectives of this Action are to investigate fabrication processes for lateral nanometer structures in III-V compounds and to explore one- and zero-dimensional effects in such structures. Also, the characterization of the limits of actual devices and the fabrication of entirely new devices will be undertaken.

GaAs/AlGaAs and InGaAs/InGaAlAs materials will be grown by Molecular Beam Epitaxy (MBE). Metal-Organic-Chemical-Vapour-Deposition (MOCVD) and Metal-Organic-Molecular-Beam-Epitaxy (MOMBE) will be used for the generation of InGaAs/InP layers.

Fabrication at the nanometre scale will be carried out using high-voltage high-resolution electron and ion beam lithography. The latter will also provide localised implantation. Lithography, etching techniques, implantation and alloy mixing are subsequently applied to make quantum wires, boxes and gratings. The formation of Ohmic and Schottky contacts will be investigated, and applied to ultra-small devices.

Both electrical and optical measurements will be made on appropriate structures down to very low temperatures (0.01 kelvin) and at high magnetic fields (14 tesla). The results will be correlated with theoretical studies.

Nanometre-scale fabrication will be used to characterise the limits of actual devices such as very short gate Field Effect Transistors (FETS), and the limit of very small resonant tunnelling structures. Novelties in fabrication techniques, such as non-uniform doping in the gate region and/or gratings and grids in the gate, will be employed.

Benefits of this long-term research and development in the field of microelectronics are:

- lithography and associated pattern transfer technology at scales as small as 0.03 micron
- understanding of the properties of semiconductors with effectively one- and zero-dimensions
- some knowledge of the low scale limits of actual III-V devices and of prospects for novel devices, possibly based on new concepts.

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Start Date	Duration
01-MAY-89	*30 months*

LOW DIMENSIONALITY STRUCTURES FOR FUTURE QUANTUM SEMICONDUCTOR DEVICES

ACTION NUMBER: 3086

Low dimensionality structures based on III-V compound semiconductors are of high technological interest for a wide variety of applications including optical telecommunication, optical computing and quantum electronics. In the past, the fabrication of such structures has implied the epitaxial growth of lattice-matched semiconductor layers of controlled composition and thickness for the tailoring of the band structure. Recently it has been shown that a new degree of freedom in band structure tailoring can be provided by strain, particularly in the case of mismatched layers, as long as the thickness is kept below a critical value. Strain results in a band-gap shift, in addition to that due to quantum confinement, and is expected to affect the valence band splitting and the density of states.

The objective of this Action is to investigate the fabrication and basic physics of InP/GaInAs/InP and AlInAs/GaInAs/AlInAs strained structures, including the evaluation of potential applications such as multichannel FETs.

Two growth techniques will be developed and compared: Molecular Beam Epitaxy (MBE) and Hybrid Vapour Phase Epitaxy (HVPE). These processes will be optimised in order to control the composition and related thicknesses of GaInAs layers and the formation of abrupt interfaces between layers.

The collaborating laboratories will apply a wide variety of complementary in-situ and post-situ characterisation techniques.

The guidelines for the interpretation of the physical properties will be provided by theoretical modelling of the electronic band structure. The basic methods used will be tight bonding (TB), extended by an empirical pseudopotential calculation (EPM) for strained layers of small period.

To evaluate the potential application of multichannel FETs, High Electron Mobility Transistors (HEMTs) and Metal Insulator Field Effect Transistors (MISFETs) will be processed and tested.

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Start Date	**Duration**
01-JUN-89	*30 months*

PROGRAMME FOR MOS PROCESSING TECHNOLOGY (PROMPT)

ACTION NUMBER: 3109

The growth of silicon dioxide on Si is a fundamental processing step during the manufacture of all silicon microelectronic devices. The electrical properties of MOS devices depend on the impurity and defect structures in the oxide and at the oxide/silicon interface. The main goal of this Action is to gain an improved understanding of the influence of these materials processing steps on the electrical behaviour of MOS devices.

The partners in this Action bring specialist skills in ultra-clean processing of materials, examination of defects and impurities and in the electrical characterisation of MOS devices. The strategy of research is to carry out a range of studies, varying process variables and impurity levels to determine their effect on MOS device performance.

It is envisaged that the results of this work will be exploited for improved process design and fabrication of MOS devices, particularly as process parameters become more critical at the increased packing densities required for modern very large scale integrated devices.

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Start Date	Duration
01-JUL-89	*30 months*

CONDUCTING ORGANIC MATERIAL AS MOLECULAR COMPONENTS FOR MICROELECTRONICS (MOLCOM)

ACTION NUMBER: 3121

The goal of this Action is to create a foundation for the extended use of some molecular solids as microelectronic components. Molecular solids to be studied belong to the series of charge transfer of donor (and/or) acceptor organic molecules exhibiting long-range crystalline order in all three dimensions and low dimensional electron delocalization (metallic-like conductivity) in one or two dimensions. The low dimensional character of the conductivity of these conductors confers on this series of materials some new physical properties, not usually observed in ordinary isotropic metallic conductors. Among them, superconductivity in low dimensional conductors, very narrow electron-spin resonance, metal-insulator transitions, magnetic field-induced semimetallic phases and large sensitivity of conductivity in relation to disorder are properties which will be considered, with the specific objective that they may serve in the future electronic industry as superconductors, Josephson devices, light detectors, radiation, magnetic fields, pressure or chemical sensors.

It is planned to investigate all factors (proper choice of the molecule as building brick and of the crystal structure) governing the electronic conductivity of conducting molecular crystals. The influence of various sources of disorder in the structure will be investigated carefully, because the low dimensional conductivity of these materials is particularly sensitive to the breaking of long-range order. Series of compounds with varying degrees of "one dimensionality" and disorder will be prepared, and their properties (crystal structure, conductivity, magnetic susceptibility, etc) will be studied in a wide range of temperatures (300 - 1 K) and by varying the pressure parameter, because these "soft" conductors are remarkably sensitive to the application of high pressure. Computer simulation of crystal structures will be used in the design of new compounds as a guide to synthetic chemists to obtain an a priori idea of crystalline arrangements of molecules in the solid.

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Start Date	**Duration**
01-MAY-89	*30 months*

NANOSTRUCTURES FOR SEMICONDUCTOR DEVICES (NANSDEV)

ACTION NUMBER: 3133

The aim of this Action is to investigate the phenomena revealed by patterning semiconductors into structures with dimensions less than 100 nm. Once we attempt to control electrons within such structures, we enter a regime where the length of the electron wave is comparable to the size of the structure. The transport of electrons (current flow) and the optical properties of the device are now modified by the interaction between the electron wave and the structure. If the device is operated at low temperature, the electron may pass through it without scattering and without randomising its phase. Under these conditions there is a strong affinity between electron transport and the propagation of light or microwaves along waveguides and related devices; the principles of geometrical and physical optics become applicable to electronics.

We will study the motion of electrons in quantum waveguides; the formation and steering of "beams" of electrons; the interaction between electrons and periodic structures such as gratings, which serve as energy-dependent reflectors or filters; and the optical properties of these systems. The experiments will be carried out in prototype devices made from precisely defined layers of different semiconductor alloys (heterojunctions) patterned by electron-beam nanolithography and reactive dry etching techniques, and buried, in some cases, by epitaxial overgrowth. Specifically, it is intended to:

- Investigate electron transport phenomena in 1-D semiconductor nanostructures, with specific reference to quantum interference and beam formation.

- Study the optical and optoelectronic properties of simple quantum wires and quantum wire arrays. Attention will be paid to the effects of size quantisation on spectral shifts and oscillator strengths.

- Apply novel techniques, notably atomic layer molecular beam (ALMBE) and chemical epitaxy, to the growth of high quality, high mobility layers for 1-D nanostructures.

- Develop processes for etching and epitaxial overgrowth on a nanometre scale. Overgrowth will be attempted by Metal Organic Chemical Vapour Deposition (MOCVD), Molecular Beam Epitaxy (MBE) and ALMBE/CBE techniques on nanostructures prepared by wet and low damage dry etching.

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Start Date	**Duration**
01-JUN-89	*30 months*

STUDY OF THE INFLUENCE OF IMPURITIES ON THE PROPERTIES OF HIGH TC SUPERCONDUCTORS (DIRTYSUPRA)

ACTION NUMBER: 3146

The objective of this Action is to study the effect of magnetic and non-magnetic impurities in bulk samples and in 20-200 micron thick films of high T_c superconductors.

Modifications of the crystal phases and their stoichiometry as well as the appearance of new superconducting phases will be observed in-situ and correlated with the incorporation of impurities. Depending on the position of the substituting impurities in the superconducting phase, on their state of ionisation, and on their electronic interactions with the other elements present in the structure, the measurements of the resulting modifications of fundamental superconducting properties should give important information on the underlying mechanism of high T_c superconductivity.

Furthermore, the characteristic superconducting parameters in the doped materials will be studied in relation to:

- the grain size distribution (in bulk and thick film materials)
- twinning in single crystals
- the electrical metallic contacts and the protective coatings in thick film preparations.

Various characterisation techniques will be employed to assess:

- physico-chemical properties (stoichiometry, crystalline and microstructural characterisations)
- superconducting properties.

After completion of the initial studies by tunnel measurement investigations, it is expected to derive, from the integrated results, a consistent interpretation of the mechanism of high T_c superconductivity and of current transport in these systems, taking into account the various theoretical models already proposed.

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Start Date	**Duration**
01-JUN-89	*30 months*

LIMITING FACTORS IN III-V SEMICONDUCTOR DEVICES DUE TO DONOR-RELATED DEEP STATES (DX CENTRES)

ACTION NUMBER: 3168

This Action aims at the understanding of n-type dopant behaviour in high band gap III-V semiconductor materials and devices. The electronic structure, and the electrical and optical properties of Si, Sn, Se, Te and Pb donors in AlGaAs alloys, will be systematically studied. The nature and origin of the deep donor states (DX centres) will be investigated. The ultimate goal is to determine processing conditions and device structures to avoid or minimise DX centre formation.

In the first phase, optical and space charge spectroscopy, carrier transport, and atomic structure characterisation techniques will be applied to the above set of dopants, for Al compositions ranging from $x=0$ to $x=1$. Theoretical models will be derived, and donor parameters for computer device simulation will also be determined. In a second phase, neutron transmutation doping, planar doping, doping with interstitial donors, high temperature metal-organic vapour phase epitaxy (MOVPE), and strain will be used as possible routes to avoid deep donor formation.

It is expected that the knowledge obtained on the nature and origin of the DX centres can be applied to other high band III-V alloys. Guidelines for donor selection according to the application, computer models for device design, and new concepts about interstitial dopants and low-dimension device structures, will be developed.

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Start Date	Duration
01-APR-89	*30 months*

ULTRATHIN Si/Ge SUPERLATTICES

ACTION NUMBER: 3174

Ultrathin superlattices (SL) can be considered as man-made semiconductors with novel optical and electronic properties. For the Si/Ge superlattice system spectacular modifications of the optical properties are predicted, which might be exploited for silicon-based optoelectronic devices. The important technological perspective lies in the marriage of today's silicon-based microelectronics with future optoelectronics based on superlattice material on a silicon substrate.

The objective of this Action is to investigate the Si/Ge superlattice system (SLS) by Molecular Beam Epitaxy (MBE) growth, different characterisation techniques and theory. This work should answer the question of whether the proposed material system can deliver both receiver- and transmitter-type optoelectronic devices or not, and what limitations must be considered.

The approach of the Action is:

- To synthesise ultrathin Si/Ge superlattices on Si substrates.
- To assess the superlattice structure by characterisation methods such as TEM and X-ray analysis, Raman spectroscopy and electroreflectance spectroscopy.
- To improve the theoretical understanding of this material system. Theoretical models will be developed which are able to predict the optical and electrical properties of the Si/Ge superlattices as a function of their composition.

Simple device structures will demonstrate the progress obtained during the course of the Action.

The expected results are the synthesis of Si/Ge superlattice semiconductors with periods of atomic monolayers of sufficient quality for device applications, and the theoretical understanding of the optical and electrical properties of the Si/Ge superlattices as a function of their composition. Novel optical receiver and transmitter devices, in particular the realisation of Si/Ge photodiodes and LED type devices on silicon wafers with currently available Si IC technology, can be seen as a breakthrough in microelectronics, implying a substantial change in the fabrication of optoelectronic semiconductor devices.

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Start Date	**Duration**
01-JUN-89	*30 months*

INVESTIGATION OF OPTICAL PROBE TECHNIQUES FOR INTERFACE CHARACTERISATION (EPIOPTICS)

ACTION NUMBER: 3177

The development of new electronic and optoelectronic materials based on ultrathin layers have made new demands on materials growth and characterisation techniques. These will include growth under vacuum conditions and from gas, liquid and solid phases. In particular, the perfection of the thin-layer interface is becoming increasingly important in determining device performance.

The main goal of this Action is to develop a new field of surface and interface characterisation, which we shall call EPIOPTICS, using the photon as both probe and signal. All growth environments will be accessible to EPIOPTICS in contrast to existing surface characterisation methods. EPIOPTICS will not contaminate or damage the material, and can be applied to the analysis of both insulating and conducting layers.

The novelty of this approach lies in combining a variety of optical techniques with sub-monolayer sensitivity. These are polarisation-dependent reflectivity (ellipsometry, reflection difference spectroscopy), Raman spectroscopy and optical second harmonic generation.

Arsenic and GaAs grown on low index silicon surfaces will be studied, together with nickel silicide on silicon. A multi-technique approach will be adopted wherever possible in investigating these technologically important systems. Conventional surface probes will be used in the vacuum studies to aid interpretation of the EPIOPTICS response.

EPIOPTIC techniques should shed light on the complex area of nucleation and growth at surfaces under non-vacuum conditions. Their application could be extended to organic and ceramic thin-layer growth as well.

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Start Date	Duration
01-MAY-89	*30 months*

FOUNDATIONS OF OPTOELECTRONIC COMPUTERS (FOCUS)

ACTION NUMBER: 3180

The FOCUS Action is targeted at the study of a particularly promising area of optical and optoelectronic techniques in information processing, retrieval and pattern recognition, namely the implementation in optical or optoelectronic form of neural-type networks that draw upon some of the characteristics of the human brain to perform tasks that are currently particularly difficult for conventional digital computers.

A successful implementation is likely to involve a number of discrete operations. The "neuron", carrying out a non-linear thresholding and amplification function, may be achievable either in a single monolithic optoelectronic device or in a hybrid form using electronics more overtly. Large arrays will be required to achieve competitive complexity levels for real problem solving. Complex interaction patterns must be formed between neurons, and these may be in guided wave or free space formats. Learning also plays a key role, and direct optical control of interconnection patterns is likely to figure highly here. At present, one can observe that optics offers extremely interesting possibilities in each of these areas, but as yet nobody has described a plausible technique for fully exploiting them, largely because there remain serious limitations at the materials and components levels. Accordingly, this programme places a heavy emphasis on studies of the basic devices with a small over-layer of studies of systems and architectures to ensure that adequate assessment of them is possible.

The study falls broadly into three areas. The first concerns III-V optoelectronic devices and materials potentially suitable for use as active non-linear elements in a future machine. A second area involves the properties and formation of interconnection networks written in photochromic materials, whilst the third area embraces a range of studies aimed at understanding better what a complete "machine" should seek to do, how it should be partitioned and structured, and hence what device properties would be most desirable. The Action is expected to benefit from participation in the ESPRIT Basic Research Computers and Optics working group (number 3350). There will also be interaction with the ESPRIT OLIVES Action via common partners (Plessey, UCL, IMEC) and with ESPRIT PYGMALION (IPS Project 2059).

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Start Date	Duration
01-AUG-89	*30 months*

QUANTUM NOISE REDUCTION IN OPTICAL SYSTEMS (NOROS)

ACTION NUMBER: 3186

The only real limitation to the processing of arbitrarily weak signals is the inevitable existence of noise. One of the main advantages of optical signal processing over conventional electronics is that optical systems are relatively immune to interference from external noise sources, while at the same time their internal noise can often be reduced to the "standard quantum limit" (SQL), also known as "shot-noise", imposed on all the usual light sources (lamps, lasers) by the quantum mechanical nature of light.

Recently quantum noise reduction below shot noise (called "squeezing") has been achieved either by systems involving non-linear optical processes (such as parametric emission, four-wave mixing, or optical bistability), or by optical sources excited by electronic currents with very low noise. Up to now, the observed noise reduction factors are moderate (20% to 60%), but much higher factors are to be expected in the near future.

The objectives of this Action are to investigate more thoroughly the processes which can reduce the noise in a light beam below the standard quantum limit and to assess their potential for future practical use. In particular:

- to improve the noise reduction factor of existing "squeezing" systems, whose operation is yet far from optimum

- to investigate noise reduction on the existing systems in different regimes of operation than the usual ones and to look for new squeezing systems

- to specifically explore materials which would be amenable for applications, anticipating the advent of a new device, the "squeezer".

Light beams with reduced fluctuations should find numerous applications in precision optical measurements and in optical information processing.

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Start Date	**Duration**
15-Jul-89	*30 months*

ESPRIT OPTICAL COMPUTING (EOC)

WORKING GROUP NUMBER: 3199

The objectives and goals of this Working Group are:

- to identify applications best suited to optical information processing technologies
- to develop algorithms and architectures that most efficiently satisfy the application
- to advance the technologies of 2-D optical interconnection and 2-D optical processing as required in order to implement the architectures.

The joint efforts of the consortium and the input of the participants are focused and organised by the following actions:

- meet at least annually to disseminate information and coordinate as far as possible the European thrust in the area
- foster working visits and longer-term exchanges
- monitor investigations of other groups working in this area
- produce a final report incorporating recommendations for further activities (a) in areas of significant technological success and (b) in areas of perceived future potential.

Four sub-groups have been established which will work specifically on:

- processing techniques for II-VI, Si and liquid crystals
- processing techniques for III-V
- architectures and algorithms
- interconnects.

The expected results and impact of the Working Group are:

- a clear statement of the state of the art at the end of the Working Group and the future directions and trends in optical computing
- strengthening of individual collaborations and of a coherent European programme.

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Start Date	Duration
01-JUL-89	*30 months*

STRUCTURE AND TRANSPORT PROPERTIES OF ORGANIC LOW-DIMENSIONAL SYSTEMS FOR APPLICATION TO IT (OLDS)

ACTION NUMBER: 3200

The aim of this Action is to explore the structure and physical properties of mono- and multi-layers of organic materials to assess their potential for the ultimate development of a new generation of devices for use in information technology. This involves the development of organic low-dimensional structures (OLDS) with novel electronic and opto-electronic properties that may eventually be exploited in devices operating at or near the molecular scale.

First, existing materials and assessment techniques will be employed in parallel with the development of new materials and techniques, in particular scanning tunnelling microscopy (STM). The synthesis of new materials will be aided by the theoretical modelling of OLDS to elucidate the important factors in the production of organic mono- and multi-layers of high structural perfection. The Action will then focus on the assessment of novel materials using the newly developed microscopical and analytical techniques. Throughout the project the physical properties of low dimensional structures will be investigated with the emphasis being placed on charge transport within and between individual layers in the OLDS. Theoretical studies will also be undertaken into potential device architecture, eg cellular automata.

The final target of this Action is to establish a basis for the selection and manipulation of materials in device demonstrator formats along with techniques for the detailed characterisation of such structures. These developments towards molecular electronic devices will require further work beyond the scope of the present Action.

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Start Date	Duration
01-Jul-89	*30 months*

HIGHER ORDER LOGIC-SUPPORTED DESIGN FOR COMPLEX DATA-PROCESSING SYSTEMS (CHEOPS)

ACTION NUMBER: 3215

The overall objective is to combine the research efforts of the three partners in the area of using the HOL (higher order logic) system for proving the correctness of complex data processing systems that are synthesised by the CATHEDRAL-II silicon compiler.

The realization of the proof method for correctness has two goals. The first is to develop a cross-check for systems synthesised using automatic methods. The second and more important goal is to extract the meta-knowledge that is required for general digital system verification, supported by a powerful theorem-proving environment like HOL.

This research Action will allow a synergy between formal methods, theorem-proving systems and hardware designs.

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Start Date	Duration
01-AUG-89	*30 months*

CORRECT HARDWARE DESIGN METHODOLOGY: TOWARDS FORMAL DESIGN AND VERIFICATION FOR PROVABLY CORRECT VLSI HARDWARE (CHARME)

ACTION NUMBER: 3216

This Action intends to develop a methodology, called design for verificability, for the formal proof of the complete correctness of digital systems before manufacturing. A plan will be worked out on how this methodology must be incorporated in design activities and CAD systems in order to obtain error-free designs at low cost. The results should be significant to future VLSI design.

To achieve this goal the Action is divided into two complementary workpackages.

The first workpackage is about verification methodology and its integration in hardware design in order to apply appropriate formal verification techniques as early as possible in the design process. A specific effort will be made on high level design languages suitable for formal verification and more generally on the effect of introducing formal verification methods into design methodologies and CAD tools. A promising approach, consisting of using design constraints to facilitate the verification process, will be investigated, resulting in "Design For Verificability" methodologies. This approach is reminiscent of "Design For Testability". Real applications of full digital system design will be selected by the participants in order to provide an experimental basis for these methodological investigations and to evaluate them. This will allow the development of methodologies for formal verification that will be applicable to practical hardware design.

The second workpackage is related to efficient formal verification technologies. The methodology has to be supported by appropriate tools for correct design and verification. Therefore new methods will be developed and promising approaches will be elaborated further and experimented with. The workpackage will identify and develop the techniques best suited for the formal proof of hardware, starting from already existing ones developed by the participants, extending them, or developing new ones when required. It must be noted that no unique formal tool is able to describe and validate all the different aspects encountered in complex digital system designs. Therefore, different complementary formal techniques are to be developed.

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Start Date	Duration
01-JUN-89	*30 months*

POWER AND TIMING MODELLING, OPTIMISATION AND SPECIFICATION (PATMOS)

ACTION NUMBER: 3237

The overall goal of the Action is the development of a method of modelling, optimisation and specification of power and timing in very high speed integrated circuits (VHSICs) using technologies such as GaAs, CMOS, BICMOS, SOS, SOI, ECL and others. It is planned to develop, implement experimentally, validate, and evaluate a new technology-adaptable method for:

- performance modelling for VHSICs
- performance optimisation for complex VHSICs
- performance test generation for VHSICs
- design for performance (DFP) of clocked systems also including PCBs (printed circuit boards).

All these methods should also work with conservative technologies, such as non-high-speed ones.

First, it is planned to find methods for modelling interconnects and devices in the power/timing domain, a language for performance specification, a notation for method adaptation to different technologies, and a method to extract all data needed for this from the layout. Next, mixed level modelling methods will be developed to be experimentally implemented in an optimiser (OPTIMA), an extractor (PATEX), and a test-pattern generator (PARAT). Eventually, all of this will be validated and evaluated with respect to selected GaAs and CMOS circuit design examples.

The expected results are the ingredients of a design for performance (DFP) method for complex VHSICs adaptable to a wide variety of technologies. The expected impact on design practice is the substantial reduction of the frequency of reimplementation of an important class of CAE tools.

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Start Date	**Duration**
Not yet specified	*30 months*

DISORDER AND ELECTRICAL PROPERTIES IN SILICON OXYNITRIDES

ACTION NUMBER: 3247

The principal objective of this action is to understand how disorder has an effect on the electrical properties of insulating amorphous silicon oxynitride films prepared by Plasma Enhanced Chemical Vapour Deposition (PECVD) at low temperature. These films find a large variety of applications in VLSI technology for low temperature fabrication of devices, in intermetallisation, and final passivation layers.

The amorphous state results in a structural and topologic disorder which introduces tails of localised states at the top and the bottom of the valence and conduction bands. The synthesis of off-stoichiometry composition may allow the tailoring of the band gap in a wide range to suit the applications. However, not all possible chemical bonds are created in a random way during growth, and the actual films are therefore not randomly bonded amorphous networks but rather partially chemically ordered. The partial chemical disorder adds to the structural and topologic disorder. Finally, actual films present coordination defects which introduce electronic deep states in the band gap. These states give rise to charge exchanges with the valence and conduction bands, and the presence of these bulk traps is responsible for electrical instabilities in the devices.

The correlation between the structural and electronic properties is essential for the understanding of amorphous state properties.

The samples will be prepared by PECVD using SiH_4, N_2O, NH_3 with and without helium dilution of the gases. The refractive index and the thickness will be obtained from ellipsometry. The atomic density profiles will be measured by Rutherford backscattering spectrometry, elastic-recoil detection and nuclear reaction analysis. The chemical and structural disorders will be studied by infrared spectroscopy, UV optical absorption, interference-enhanced Raman spectroscopy and light-induced electron-spin resonance. The electrical properties will be obtained by means of high frequency and quasi-static capacitance-voltage measurements, ramp breakdown tests, and current voltage measurements. The barrier heights will be determined using optical methods.

The expected result is the generation of an extended database of the deposition parameters and of the corresponding properties.

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Start Date	**Duration**
01-JUL-89	*30 months*

TRANSVERSE OPTICAL PATTERN (TOPP)

ACTION NUMBER: 3260

The nonlinear character of the radiation-matter interaction strongly affects the transverse configuration of the radiation field in passive nonlinear optical systems and in lasers. It can produce spatial patterns of remarkable complexity. The results obtained in the last few years in this field of research suggest that the detailed analysis of transverse optical patterns may become practically relevant not only in the trivial sense of avoiding undesired effects, but also in the direction of achieving positive and fruitful application in the framework of information technology and quantum electronics.

The Action will therefore focus on the study of suitable model systems with a well-defined transverse multimode structure. This allows for both experimental realisation and adequate theoretical description. The formation and the stability of the spatial patterns that can be delivered by such systems will be analysed. Possibilities of controlling and manipulating transverse radiation patterns will be investigated in order to realise logical functions.

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01-SEP-89	*24 months*

NOVEL PARALLEL ALGORITHMS FOR NEW REAL-TIME VSLI ARCHITECTURES (NANA)

ACTION NUMBER: 3280

The main theme addressed in this action is a central problem in computational mathematics: the development of novel parallel algorithms and real-time VLSI architectures for multi-dimensional (mostly numerical and algebraic) signal processing (MDSP). This includes the impact on computer-aided synthesis environments.

The proposed work is of major importance in the development of efficient multi-dimensional subsystems for video, image processing, robotics, radar, seismic processing, telecommunications, factory automation, vision, advanced process control, biomedical technology, and adaptive beamforming. The techniques needed in these domains are algebraic and numerical techniques for multi-dimensional problems such as linear system solving; least squares solution of overdetermined systems such as result from measurement data; eigen- or singular-value computation and their application as a subsystem in other algorithms; finite element modelling; coordinate transformations in robotics; solid modelling in computer graphics; mathematical modelling and identification of physical systems and industrial processes; and Fourier and other transforms.

Five partners with complementary expertise will alleviate the problem of designing time- and/or space-critical parallel processing algorithms. Firstly, they will study and propose novel algorithms for the main classes considered. Secondly, they will thoroughly investigate the implications of the choice of processing architectures. Classical solutions such as general-purpose standard machines are too wasteful in terms of area-cost and power dissipation for a given throughput, as the algebraic operations are typically not well suited to traditional computers. Moreover, the communication and memory size bottlenecks are not removed. Therefore, efforts will be made towards synthesis strategies starting from very high-level behavioural descriptions, in order to reduce the design time.

Results can be expected in terms of novel parallel algorithms, architectural methodologies, and their impact on synthesis strategies which are efficient in terms of chip area and off-chip memory, and which comply with the throughput, power and pin-count limitations of VLSI realisations.

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Start Date	**Duration**
01-MAY-89	*30 months*

BEHAVIOURAL SYNTHESIS, PARTITIONING AND ARCHITECTURAL OPTIMISATION FOR COMPLEX SYSTEMS ON SILICON (ASCIS)

ACTION NUMBER: 3281

The research in this Action is vital to the design of future ICs, which will contain the equivalent in logic of 16 million memory cells. Currently, complex systems are mapped onto silicon, starting at an architectural description level. However, the bottleneck in such mega-chip designs lies not in realising the layout from this register-transfer level description, but in mapping the behaviour intended onto a suitable architecture. Therefore, to fully exploit the integration complexity of future fabrication technologies it is crucial to provide a specification at the highest system level. Problems related to this change of specification level are fundamental in nature.

Specifically, the need for basic research at different levels on the design trajectory from system to architectures is seen as requiring:

- system definition in terms of a formal specification of abstract behaviour and a formal verification of correctness
- system partitioning
- mapping of subsystems onto architectures with the development of synthesis strategies for regular arrays and cooperating data-paths, including architecture exploration
- the investigation of new opimisation paradigms for use in synthesis systems, such as genetic algorithms and neural nets
- architectural synthesis for the control part with architectural optimisation and technology mapping.

Seven partners with complementary expertise will combine and coordinate their efforts to tackle this major task. They will identify basic avenues of research at each of these levels and then attempt to provide fundamentally new ways of approaching them. Efficiency in terms of throughput, chip-area and memory will be an important objective. In addition, the resulting IC designs should comply with the bandwidth, power and pin-count limitations of VLSI components.

This work is of significant importance for future designs in domains such as speech, image-processing, video, vision, telecommunications, factory automation, advanced process control, biomedical technology, radar and sonar.

"True" silicon compilation is aimed at, which allows for several mapping and architectural approaches, and which handles a broad class of applications.

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Start Date	**Duration**
01-JUN-89	*30 months*

EVALUATION OF MOLECULAR SWITCH-TYPE DEVICES: THEORY AND EXPERIMENT (MOLSWITCH)

ACTION NUMBER: 3314

MOLSWITCH aims at the development and testing of molecular materials potentially applicable in sensor, computer, and communication devices. The materials are made from organic compounds, thus the designed molecular materials are different from the inorganic semiconductive materials usually applied.

The action focuses on the possibility of preparing molecules which can be switched between two states allowing a signal to pass only in one of the states and ultimately perform as a basic transistor. Molecular structures with delocalised electrons, which may serve as connecting wires, are being studied as well.

The physical realisation of such electronic building blocks may lead to the assembly of molecular logic systems and also of sensors for the simultaneous sensing of chemical compounds in the human body for diagnostic purposes.

By including advanced calculations of a quantum chemical nature, the Action is contributing to the understanding of the theoretical basis of the design of molecular materials.

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Start Date	**Duration**
01-JUN-89	*30 months*

LATTICE DYNAMICS OF HIGH TC SINGLE CRYSTAL SUPERCONDUCTORS (SUPRADYNAMICS)

ACTION NUMBER: 3327

Despite worldwide activities in the field of the new high Tc oxide superconductors, the origin and the explanation of the mechanisms of the phenomenon are still unclear and subject to exciting debate. Experimentally, most of the activities deal with the copper-based oxides having a highly bidimensional character and superconducting transition temperatures, T_c, currently well above the temperature of liquid nitrogen. With the recent discovery of the $Ba_{1-x}K_xBiO_3$ systems that transit to a superconducting state at a temperature nearly 2.5 times higher than the best of the "old" oxide superconductors, $Ba(Pb,Bi)O_3$ with T_c = 13K, without copper and without bidimensional structure as for copper oxides, we arrive at the conclusion that the phenomenon is much more general than currently believed. The presence of isotope effects and the absence of any evidence of magnetic order of spin fluctuation, in perovskite bismuth compounds in particular, encourages us to explore the lattice dynamics in order to get information on electron-phonon coupling. Definite experimental knowledge requires inelastic neutron scattering measurements. This kind of experiment requires large single crystals. To optimise the crystal growth, detailed knowledge of the phase diagram is required.

A comparison of the main differences between the phonon dispersion curves of insulating and conducting La_2NiO_4 is also planned if the growth of insulating single crystals is achieved. The phase diagram of YBaCuO will be studied in detail to optimise the parameters of the crystal growth by pseudo-flux. As soon as large crystal are available, neutron scattering measurements will begin. In parallel with the measurements, lattice dynamics calculations based on preliminary experimental data will be performed and refined with the new data points. The structure factors deduced from the calculations will allow the optimisation of the measurements.

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Start Date	**Duration**
01-JUNE-89	*24 months*

COMPUTERS AND OPTICS STUDY-GROUP (COSTY)

WORKING GROUP NUMBER: 3350

The Working Group members have planned two different activities. First, workshops will be held at regular intervals to exchange ideas, and to report on progress in the general field of optical computing and in the specific areas of involvement of each partner. In the latter case, substantial activities are already in progress in their laboratories, funded under other programmes, including the ESPRIT FOCUS Action, number 3180. We envisage, therefore, a major information exchange exercise out of which it is likely that new collaborative links will be formed, and from which in-depth evaluations will emerge.

The second activity involves smaller numbers of longer term visits. It is envisaged that one or two members of each laboratory will visit another laboratory within this Working Group. These stays are intended typically to be for periods of 1-3 weeks, long enough for much stronger links to form, allowing for the development of strong technical bonds between selected members of the Working Group. It is also expected that a small experimental demonstration programme will be defined during the early phases of the project, to be completed by the end of the period covered.

The technical programmes are primarily concerned with two broad areas: the study of III-V quantum well optoelectronic and other devices for use in optical neural-type vector-matrix multipliers and thresholding feed-back or feed-forward networks; and the use of electro-optic and other active devices to form systolic array vector-matrix multipliers which also might function as an associative neural-type memory. Both activities thus share a strong common interest in trying to implement neural-type associative memories in the optical domain, but approach this from very different technical directions. This is expected to lead to a much sharper appreciation of how optics can best be used in this exciting field of information processing.

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Start Date	Duration
01-AUG-89	*30 months*

COMPUTER SCIENCE:

ACTIONS AND WORKING GROUPS

CATEGORICAL LOGIC IN COMPUTER SCIENCE (CLICS)

ACTION NUMBER: 3003

This Action is motivated by the belief that recent developments in category theory and the categorical approach to logic are ripe for application in a number of important areas in computer science. The goals of the Action are:

- A deeper understanding of type structures for programming languages.

- Systematic accounts of denotational, operational and axiomatic semantics for programming languages, with emphasis on the connections between these kinds of semantics and the possibilities of automatic derivation of one from another.

- The development of logics for computable functions, which exploit constructivity and the powerful machinery of categorical logic to provide a better match between the logics and the computational concepts being modelled.

- The development of a framework for logics and models of parallel computation and for theories of specification in which the highly diverse and superficially disparate work in these fields can be unified and integrated with work in other areas. This is essential if different programming and specification paradigms are to be successfully unified, and if the fundamental and enduring concepts are to emerge from the current babel of competing formalisms.

An important aspect of this Action will be to produce a supply of research workers in computer science who have a thorough grounding in categorical methods. Categorical logic is an important branch of mathematics for computer science and yet is not widely understood. Indeed, the success of its application to computer science will depend on pooling varieties of expertise from a number of European institutions. All the partners are associated with academic institutions with a number of graduate students of high quality. Their PhD students and research assistants in the Action will benefit directly. Through workshops, seminars, courses, papers and books, the next generation of mathematicians and computer scientists will be exposed to a developing branch of mathematics vital to a good theoretical understanding of many areas in computer science.

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Start Date	Duration
01-JUL-89	*30 months*

THEORIES OF CONCURRENCY: UNIFICATION AND EXTENSION (CONCUR)

ACTION NUMBER: 3006

Formal verification of software programs, protocols and chip design is becoming increasingly important, as systems become more complex, production more expensive, and testing is widely recognized as being insufficient to guard against malfunction.

Verification of concurrent or distributed systems has up till now been undertaken only on a very small scale, in a haphazard way, and with a multitude of techniques and formal theories. For industrial applicability, it is essential that some unity emerges from the competing theories of concurrency, and that the verification process be supported by reliable software tools.

Normal academic interchange will slowly bring unity into the disparate world of concurrency theories, but collaboration of a more intense kind is needed to accelerate the process. Among the many formal approaches which exist for concurrent communicating systems, the important algebraic approaches are represented in this Action.

The principal aims of the Action are to explore the relationships among these different approaches, and to develop a formalism applicable to a wide range of case studies. The possibilities for integration will be investigated, or at least the incorporation of features of one system in another. The relationship and relevant roles for algebraic and model-based theories will be elucidated. A list of open problems of agreed interest will be compiled. Methods pioneered in one group can be applied to problems originating in another, and results can be compared. In addition to collaboration at the theoretical level, there will be collaboration through the development, use and comparison of software reasoning tools. The latter will serve both to further unify and to enhance theoretical collaboration; experience has shown that development and use of software tools acts as a catalyst for theoretical advance.

Tools find many applications in case studies. Case studies are important for the comparison of theories of concurrency, since the true strength of a theory will only appear through its use in tackling substantial case studies, that is, systems of considerable size. Such systems are complex, and thus require special syntactical constructions and mechanical assistance to relieve tedium and to check rigour in reasoning. Graphical aids are often exceedingly helpful in understanding them, and therefore these should be developed. Large case studies will in all cases be relevant for the European software industry. Several of the partners already have ongoing tool-building activities.

The proposed Action provides an outstanding opportunity to coordinate the participants' well-established programmes of research into theories of concurrency.

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Start Date	Duration
1-SEP-89	*30 months*

COMPOSITIONAL DISTRIBUTED SYSTEMS (CEDISYS)

ACTION NUMBER: 3011

The overall aim of this Action is to develop a fundamental understanding of the nature of concurrency and to provide a formal framework useful for describing concurrent and distributed systems. This formal framework should support the specification and development of such systems and should lead to methodologies for proving systems correct and, more generally, for deriving their properties.

There is already a considerably successful body of knowledge about concurrency on which to base the effort. One central idea is that complex systems can be understood only by imposing structure on them in order to reason on parts separately. Another is that any successful theory of concurrent systems should come equipped with a method for abstracting from details: formalisms should be able to support descriptions or specifications of a given system at different levels of detail.

Many behavioural views of concurrent systems have been suggested. The most successful ones have one major drawback: they all interpret concurrency or parallelism as a linguistic shorthand for nondeterminism. Instead, a framework will be chosen which more correctly reflects the inherent concurrent and distributed nature of processes. This framework is sometimes known in the literature as the true concurrency approach.

A number of techniques have recently emerged in Europe, which are apt to extend the results of the classical approach to the true concurrency case and to exploit its peculiar features. We believe that the time is ripe for a substantial improvement in our formal understanding of distributed systems. The practical consequences may be far-reaching: the design of computer architecture and of system software might substantially improve, and the automatisation of large systems might be made more reliable and safer.

The planned research action will investigate various proposed formalisms for distributed systems and compositional proof methods for deriving their properties. The Action will design new languages for these systems, elucidate new semantic models which emphasise nonsequentiality, and use their models as foundations for new logical frameworks. The prototypical implementation of these new formalisms will also be considered.

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Start Date	Duration
15-APR-89	*30 months*

COMPUTATIONAL LOGIC

ACTION NUMBER: 3012

The ultimate objective of this action is to develop the foundations for an integrated, logic-based software environment. The environment would extend existing logic programming languages by the use of related techniques developed in the fields of computer algebra, deductive databases and artificial intelligence. It would also include logic-based tools for incremental development of knowledge bases and programs, for transforming programs, and for programming-in-the-large.

The objective will be tackled by investigating related developments of computational logic in the three areas of Artificial Intelligence, Deductive Databases and Logic Programming.

Computational logic is understood here as the use of logic to represent "knowledge" and the use of deduction to solve problems. The main technologies to be developed are language extensions, knowledge assimilation and meta-level reasoning.

Language extensions include constraint logic programming and object-oriented structured types. Work on knowledge assimilation will develop techniques for integrity checking, belief revision, incremental program development and hypothetical reasoning. Work on meta-level reasoning will develop metalogical language constructs, metalogical techniques for knowledge representation, programming in the large and program transformation.

The results of this work will be directly exploitable in the form of improved computer languages and software environments.

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Start Date	Duration
01-APR-1989	*30 months*

INTEGRATION

ACTION NUMBER: 3020

This Action aims at integrating the foundations of functional, logic and object-oriented programming. Functional programming has its mathematical foundations in the fields of lambda calculus and term rewriting. Logic programming is rooted in predicate logic and automatic theorem proving. The integration of these two programming styles has been pursued vigorously for several years. For object-oriented programming it is generally felt that there is a strong need for a better understanding of its mathematical nature. Also, there is ample evidence that one may profit here from the insights from functional programming, eg concerning the notions of typing and inheritance, and from logic programming, eg regarding the interplay between actions and deductions. These insights justify the tripartite integrative effort of the action, organised into three areas:

- integrating functional and logic programming
- integrating functional and object-oriented programming
- integrating logic and object-oriented programming.

Within each area, the work is organised into tasks. These have been selected such that common problems and techniques may be identified. Altogether, the workplan consists of nine tasks. In each of the three areas, tasks dealing with semantic issues have been defined, devoted to extensions of the customary declarative semantics for logic programming, to subtyping, and to parallelism in logic and object-oriented programming, respectively.

It is expected that as the action proceeds, the amount of work relying on cross-fertilisation of results from the individual areas will increase. A final integrative effort lies beyond the scope of this action.

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Start Date	Duration
01-JUL-1989	*30 months*

INFORMATION SYSTEMS - CORRECTNESS AND REUSABILITY (IS-CORE)

WORKING GROUP NUMBER: 3023

The objective of this Working Group is to explore the methodological foundations of information systems design, with the intention of achieving provably correct systems and higher levels of reusability, through the use of formal, object-oriented design techniques.

To this end, the working group will work on topics rarely addressed so far in information systems design, among them formal (logical, algebraic and categorical) methods strongly backed by a sound theory, full incorporation of dynamic aspects, static and dynamic integrity checking, as well as design in the large issues like modularisation and parametrisation. In order to overcome the deficiencies of traditional information systems design, a new approach is needed. The working group favours a formal, object-oriented approach, viewing the information system as a society of interacting objects (some passive like database records, some active like database transactions). The Working Group will also work on the comparison with other approaches and the integration with current information systems design techniques.

The Working Group will aim to deliver logical calculi as well as algebraic and categorical semantics for a broad spectrum language and methodology supporting the object-oriented, transformational, and modular design of information systems. The envisaged object orientation is essential to achieving easier-to-maintain information systems whose components are highly reusable, and leading to techniques for the design of large-scale information systems. The proposed object-oriented model allows the integration of "data" and "processes", opening the way to new architectures of information systems as object-bases, favouring concurrency and distribution. The envisaged logical and algebraic design techniques could lead to information systems whose correctness is verifiable.

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Start Date	Duration
01-MAR-89	*30 months*

FORMALLY INTEGRATED DATA ENVIRONMENT (FIDE)

ACTION NUMBER: 3070

The FIDE action will provide significant advances in the technology used to support large-scale and long-lived information systems.

Information systems are currently supported by a set of loosely connected heterogeneous software components: database systems, programming languages, programming environments, etc. Each one of these components was designed and built using a specific technology (database technology, programming language technology, etc.). The inconsistencies between the components make programming much more difficult.

A first-level of integration is currently being accomplished by groups building integrated systems using these existing technologies (object-oriented database systems or deductive database systems are examples of these efforts). This first level is insufficient since these separate technologies do not mix well (query optimisation techniques and compilation techniques or scheduling algorithms of database transactions and operating systems processes are examples of this mismatch).

This action will attempt the ambitious task of building a new integrated technology to replace these several separate ill-fitting ones.

The consortium has a three-level solution to the problem of providing better integration:

- a better formal understanding of the contributing technologies will be developed so that their fundamental properties may be understood and combined
- a new single integrated technology will be specified and developed
- this technology will be evaluated and demonstrated through the design and implementation of experimental prototypes.

Because the current size of the project does not permit the addressing of all three levels exhaustively, it will instead concentrate on the following points:

- type systems
- object stores
- design methodology
- transactions.

The success of this Action could have a major impact on the construction of large-scale data-intensive systems. It could lead to better systems to support CAD, CASE, Office Automation, CIM and AI applications.

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Start Date	Duration
01-MAY-89	*30 months*

THE SEMANTICS AND PRAGMATICS OF GENERALISED GRAPH REWRITING (SEMAGRAPH)

ACTION NUMBER: 3074

The principal objective of this action is to develop knowledge relevant to the semantics and pragmatics of generalised graph rewriting. Our rather general notion of graph rewriting theory extends the term to include sharing, multiple non-root rewriting and explicit control of reduction order. These can be used for optimised reduction, side effects, and process communication and synchronisation. Taken together, these extensions provide a potentially unifying framework for a variety of models of computation including:

- functional languages
- logical languages
- object-oriented languages
- parallel generalisations of imperative languages.

A number of computational models have been considered as a possible basis for a "common virtual machine" to support work on various symbolic and other languages. While no common model is presently known, one based on graph rewriting might succeed. An important aspect of the action is that it brings together participants from various European IT programmes in a united attempt to develop further basic knowledge about graph rewriting. Industrial participation at observer level will aid in establishing priorities for the various investigations, and provide a channel via which relevant results can be rapidly fed to shorter-term research projects.

This Action is a programme of investigation into the foundations of graph rewriting, which will bring together and enhance knowledge in the following areas of generalised graph rewriting systems (GGRS):

- formal descriptions and abstract models
- relating other models to GGRS
- controlling reduction order and typing
- static analysis
- efficiency of normalising lambda graph reducers.

Significant progress is expected in identifying those results which carry over from the term world to the graph world. The project will lead to a better understanding of the constraints on a rule system necessary for efficient implementation. Such

results will be of direct interest to larger ESPRIT II projects, particularly those concerned with general and special purpose rewriting formulations of both symbolic and numeric problems for parallel machines.

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Start Date	Duration
01-JUL-89	*30 months*

ALGORITHMS AND COMPLEXITY (ALCOM)

ACTION NUMBER: 3075

The aim of the ALCOM action is to advance and strengthen research on the design and analysis of efficient computer algorithms, and on the intrinsic difficulty of computational tasks, for the purposes of precompetitive R&D.

Efficiency considerations play a crucial role in the design of all information processing and software systems and in most problems of scientific computing. The search for efficient algorithms and for techniques to achieve optimal or near-optimal computations or computer communications is part of any programming effort aimed at the design and development of computer applications in all branches of the computing field. ALCOM is focussed on a coordinated action of the participants in the following seven areas of algorithm-oriented research:

- data structures
- computational geometry
- graph algorithms
- probabilistic methods and average case analysis
- complexity theory
- parallel algorithms
- distributed algorithms and protocols.

The overall objectives of the Action are: coordinated front-line research on specific themes within each of the seven areas; scientific exchange between the participants; and the dissemination of information. Examples of research themes included are: the design and analysis of data structures for complex objects (in primary and secondary memory); algorithms for 3-D geometric problems (in computer graphics and robotics); algorithms for dynamic graphs and hypergraphs; techniques for the expected-case analysis of computer algorithms; the study of the theoretical limits of resource-bounded computations; the design and analysis of efficient processor interconnection schemes and parallel algorithms; and the design and analyses of correct and efficient techniques for the control and coordination of processes or processors in a distributed system.

The ALCOM Action brings together twelve leading research groups from nine EC member states, in a cooperative effort to increase research activity in the field of algorithms and complexity. The dissemination of results and know-how will be achieved through open summer schools and advanced courses, publications, and the distribution of prototype implementations.

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Start Date	**Duration**
27-MAY-89	*30 months*

PREDICTABLY DEPENDABLE COMPUTING SYSTEMS (PDCS)

ACTION NUMBER: 3092

The objective of the PDCS action is to make the process of designing and constructing dependable computing systems more predictable and cost-effective than it is at present.

Dependability is a prime example of a "systems issue" and the notion of predictably dependable computing systems encompasses many different topics in computing science, such as software engineering, fault tolerance, reliability modelling, formal verification, systems architecture, etc. It is not practical even for a large Basic Research Action to make substantive progress on all of these topics, so it was decided to concentrate on what is seen as the critical, and neglected, aspects of the predictable dependability of computing systems.

The action will develop:

- unifying concepts underlying dependability, which should support design decisions involving trade-offs between different approaches to dependability and draw together technical work within both this Action and other related research projects

- means for the establishment and validation of dependability requirements, including those related to the timing properties of so-called "hard real-time" systems

- stochastic techniques for assessing and predicting dependability, covering all means of attempting to prevent, remove and tolerate all types of faults, including design faults and deliberate attacks.

The ultimate long-term objective is to produce a design support environment which is well-populated with tools and ready-made system components and which fully supports the notion of the predictably dependable design of large real-time distributed systems. This is, of course, extremely ambitious, and not something one would expect to achieve within the time-span of the Action. It is, however, believed that significant progress towards this objective can be made.

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Start Date	Duration
01-May-89	*30 months*

FORMAL METHODS AND TOOLS FOR THE DEVELOPMENT OF DISTRIBUTED REAL-TIME SYSTEMS

ACTION NUMBER: 3096

The aim of the Action is to obtain a framework for the development of distributed real-time systems which is both practically adequate and theoretically sound.

Recent research has produced specification formalisms and associated development and verification tools that have been successfully applied to small systems. For instance, temporal logic, automata, process algebras and assertional methods have all been used with some success. The main insight is that existing formalisms are mainly complementary and that combining these formalisms can be very effective.

For this reason, the problem of building bridges between different theories or applying them in combination to moderately large systems will be studied.

Besides combining formalisms, the research will proceed in two major directions: broadening the scope of existing formalisms, and of narrowing the gap between formal specifications and executable code. The former direction involves basically the handling of real time. The work of narrowing the gap between specifications and executable code involves, on the one hand, methods for deriving implementations from specifications, and on the other hand, the study of executable subsets of declarative specification languages, especially of executable temporal logics.

The proposal emphasises development and verification tools. One of its main motivations is to test the applicability of formal methods to the development of reactive systems. These methods will be applied to paradigms taken from various application domains such as digital hardware systems, communication protocols, and real-time process control.

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Start Date	Duration
01-MAY-89	*30 months*

PROVABLE CORRECT SYSTEMS (PROCOS)

ACTION NUMBER: 3104

The objectives of this Action are to advance the state of the art of systematic design of complex heterogeneous systems, including both software and hardware; in particular, to reduce the risk of error in the specification, design and implementation of embedded safety-critical systems.

To approach this goal, the development of a concrete system consisting of the following five major components is planned:

- a specification language
- a programming language
- a definition of a hardware machine
- a compiler from the programming language to the instructions of that machine
- a kernel supporting the execution of compiled programs on that machine.

The syntax and semantics of these components will be formalised, and their formal interrelationships will be established.

The work will be based on the CSP/occam/transputer tradition. During a first 15-month phase, a simple occam subset and a simple transputer-like RISC machine will be selected and formalised as far as possible. During the second 15-month phase, the employed methods will be generalised and improved, and the system design reiterated.

The work will furthermore be supported by:

- case studies of requirements for and development of safety-critical systems
- experiments in computerised verification support
- liaison with a number of related projects.

An early result of the action is expected to take the form of a book on principles of constructing provably correct systems using the developed system as a special case.

The book could be the scientific basis of the software side of a larger-scale commercial or precompetitive project for the design and production of a thoroughly validated system, suitable for application in a safety-critical environment.

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Start Date	Duration
01-MAY-89	*30 months*

SEMANTICS-BASED PROGRAM MANIPULATION TECHNIQUES (SEMANTIQUE)

ACTION NUMBER: 3124

Despite over thirty years of development, software "engineering" is still fundamentally a handicraft. Every line of software in most systems is still written by hand, inspected by eye, and maintained by a skilled craftsman. Our aim is to emulate the industrial revolution, by developing technology for manufacturing software under human guidance, but with much less detailed human involvement.

We will pursue three interrelated approaches:

Firstly, to develop further methods for automatic program transformation. In this area partial evaluation has shown great promise: it has already been used to manufacture prototype compilers and compiler-generators. We plan to improve its power and applicability, investigate binding-time transformation, and use it to manufacture parts of highly optimising compilers. We will also study other automatic optimising transformations.

Secondly, automatic program manipulation depends on the automated "understanding" of programs - semantic analysis. Our work here is based on abstract interpretation, a soundly based method which has proved widely applicable over the past decade. We plan to extend its scope to new semantic frameworks and new problems: for example, to analyse parallel and logic programs. We will be concerned to develop efficient analysis algorithms, and to find ways of making good use of the more sophisticated understanding of programs that the latest analysis techniques can provide.

Thirdly, a major application area of these techniques is the efficient implementation of declarative languages. This will be a testing ground for the efficiency and power of the methods of analysis and transformation which will be developed in the course of this action. This work will be focused on the incorporation of program manipulation methods into a prototype compiler for Haskell (the newly defined standard functional language).

The principal results of this work will be ideas and understanding, rather than implemented systems. On the other hand, the approach of all participants is characterised by a continual crossing of the boundary between theory and practice, and many of the ideas and understanding accomplished will be realised in the form of, and be tested by means of, prototype computer programs.

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Start Date	**Duration**
01-MAY-89	*30 months*

HIERARCHICAL INTEGRATION OF LOGIC AND FUNCTIONAL PARADIGMS: SPECIFICATION, REFINEMENT, AND IMPLEMENTATION (PHOENIX)

ACTION NUMBER: 3147

This action supports a coordinated programme of research aimed at developing the technologies necessary to make a practical declarative programming language which combines and extends current logic and functional languages.

This combination will be investigated, not only at the language level, but also at all levels in the hierarchy necessary to provide a practical method of mapping high-level system description into efficient executions on a range of target machines, including parallel ones. Thus, as well as investigating and integrating language concepts and their respective semantic models, we compare and develop transformation and refinement techniques aimed at converting high-level specifications into efficiently executable forms, and abstract machines capable of supporting efficiently the transformed and compiled programs.

The action will investigate, among other aspects of declarative programming languages:

- semantic models for integrating logic and functional language concepts
- the role of unification techniques in a combined logic and functional language
- support for programming-in-the-large
- declarative ways of providing descriptive features currently provided non-declaratively
- source-to-source transformation techniques including partial evaluation and algebraic techniques necessary to convert high-level descriptions into efficiently executable forms
- intelligent analysis and compilation techniques
- comparison of logic and functional abstract machines and derivation of an abstract machine capable of supporting efficiently combined languages, as well as of parallel evaluation.

Particular emphasis will be placed on the use of formal description techniques. These will be used to clarify and formalise our ideas, and provide a basis for the generation of prototype interpreters and compilers.

It is the hierarchical approach which allows for the consideration of both: the features of combined logic and functional languages which aid system

description, and the forms which are efficiently implementable. Thus, the main results of the Action are expected to be:

- a hierarchy of language concepts with the full power of these languages available at the higher level, and an identified, efficiently supportable subset at the lower level
- the transformation and compilation techniques to convert between the levels
- the abstract machines, allowing efficient execution of transformed and compiled programs.

A coherent technology for declarative programming on all levels will bring more efficiency in software development and more reliability of the resulting software systems. This research action will yield the techniques and methods for efficient use of declarative languages.

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Start Date	**Duration**
01-APR-89	*30 months*

DESIGN METHODS BASED ON NETS (DEMON)

ACTION NUMBER: 3148

The general objectives of this action are to explore a spectrum of important theoretical issues involved in formal reasoning about concurrent systems, and to develop a formal framework supporting the specification, design and verification of large, sophisticated concurrent, and possibly decentralised, systems. The basis for this work will be: the Petri-net model, which benefits from a graphical representation that is intuitively appealing for informal use; and a supporting formal theory, which captures the essential characteristics of concurrency and locality of state and action, and is general enough to subsume all other formal models of concurrent systems. The focus of the action is to enhance Petri-net theory, laying the foundations needed for a complete and effective design calculus for concurrent systems, including:

- composition, refinement and abstraction techniques
- algebras and proof rules
- appropriate notions of equivalence and implementation
- associated formal analysis techniques.

From a practical viewpoint, the essential contribution of the theoretical enhancements will be support for modular system construction and refinement of high level designs. In this way, the current frequent use of Petri nets as a graphical and analytical tool in the early stages of the design of individual parts of concurrent systems can be extended to include and integrate formal methods for all stages and aspects of the specification, construction, and analysis of entire systems.

The work will be organised into two closely interrelated parts. The central part will be concerned with providing a few carefully chosen and thoroughly developed classes of nets with modularity and other properties required for the envisaged design calculus. The second part will involve more general theoretical work, case studies and other input to the development of the required net classes and to the understanding of their relationship to other approaches.

The direct visible outcomes of the action will principally be academic publications and workshops reporting on the theoretical work carried out, plus detailed examples of applications of Petri-nets to concurrent systems design. It is also anticipated that the necessary foundational work of this action will later be enhanced by the construction of prototype design tools, including a textual Petri-net programming language, and the Action will involve some preliminary consideration of such tools.

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Start Date	**Duration**
01-APR-89	*30 months*

ALGEBRAIC AND SYNTACTIC METHODS IN COMPUTER SCIENCE

WORKING GROUP NUMBER: 3166

The aim of this working group is to bring together a collection of researchers from various parts of Europe to collaborate on problems of mutual interest in algebraic and syntactic methods in computer science. Indeed, the need for research in the area of "mathematical tools for computer science" is widely and deeply felt by all those who are involved in the design and realization of all sorts of computer systems. Furthermore, the problems to be solved imply that this research is fundamental in nature, ie not linked with a given precise application.

The research to be undertaken in this Working Group can be divided into four subareas:

- Combinatorics on words and the theory of codes:
    - String-matching algorithms and problems linked with data transmission: data compression, structure of codes, equations in words, etc.
    - Modelling of parallelism by "partially commutative" words.
    - Words also allow the encoding of a large variety of problems: algorithms, data structures, counting problems, tiling problems, planar maps, generation of combinatorial objects, etc.
- Formal language and grammar theory:
    - Decision problems related to rational expressions. Properties of grammars and rewriting systems: presentation of structures by means of confluent rewriting systems. Extension of the standard theory of languages and grammars on words to trees and graphs.
    - Validation of distributed systems and algorithms via subsets of the free partially commutative monoid.
    - Syntax mappings and syntax-directed translations.
- Theory of automata:
    - Mathematical tools of automata theory: semigroups, formal power series, dynamical systems and discrete iteration theory, combinatorics and graph theory, formal logic (model theory, games).
    - Automata on words, on infinite words, on trees and graphs, automata with output, automata with multiple inputs, alternating automata, connections with logic and circuit complexity, etc.

  - Modelling of parallel and distributed systems by automata networks and cellular automata: performance analysis, synthesis and optimization of networks.

- Process algebras, infinite behaviours of parallel programs and systems:

  - Algebraic topological and algorithmic properties of sets of infinite behaviours of processes and of automata, temporal logic, and automata proof techniques.

  - Axiomatic definitions of process algebras, traces and event structures. Study of standard calculi like CSP and CCS.

  - Efficiency measures of synchronisation mechanisms.

All participants of this project would greatly benefit from increased contacts with their colleagues. Therefore the main objective of the working group will be to organise workshops and joint seminars, and, more generally, to provide the opportunity for participants to work together.

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Start Date	Duration
15-MAY-89	*30 months*

BASIC RESEARCH ACTIONS FOR A GEOGRAPHIC OBJECT-ORIENTED DATABASE SYSTEM (BASIC GOODS)

WORKING GROUP NUMBER: 3191

The Basic Goods working group will have as its main objective the formulation of better theoretical foundations for the representation and management of geographical information.

In particular, an extensive analysis of the object-oriented (OO) approach to the definition, representation and management of geographical data, with special regard to the treatment of pictorial information, will be performed.

The main basic research problems which will be studied are:

- Definition of object-oriented data models and data definition languages for the specification of geographical data: such models should allow the representation of both the characteristics of the represented entities and the constraints defined over them.

- Definition of object-oriented data manipulation languages for geographical information querying and management.

- Definition of advanced access methods for data consisting of geometric and descriptive information at the physical level. These methods should support the efficient access to geographic data during the resolution of "hybrid" queries, that is, queries referring to both geometric and descriptive characteristics of data.

- Definition of basic frameworks for the design and implementation of advanced geographical information systems.

The Working Group aim will be the definition of general methodologies for integrated geographical data representation and management within an object-oriented environment. The development of small prototypes of limited parts of a geographical OO database system and of an environment for the design of an OO geographical database is expected. Such prototypes will be developed by means of a general OO database system and an OO programming environment.

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Start Date	Duration
15-JUL-89	*30 months*

COMMON FOUNDATIONS OF FUNCTIONAL AND LOGIC PROGRAMMING

ACTION NUMBER: 3230

The common foundations of Functional and Logic Programming are to be found in the roots of logic itself, that is, in the proof theoretical results of the 1930s (Gentzen, Herbrand). The Curry-Howard isomorphism of formulae as types, and of proofs as functionals, can be adopted as a common paradigm for various approaches to declarative programming.

Two different activities may be distinguished within this paradigm at present:

- given a type (proposition), find a program (proof) of the given type
- given a program (proof) of a given type, transform it to obtain another program of the same type.

Up to now the Logic Programming approach has seemed more attractive, but its implementation requires control (cut, negation, etc) which is not formulated in a pure logical way, losing one of the main properties of Functional Programming, namely modularity. What is missing at present in Logic Programming is the consideration of the internal logic (of execution) as opposed to the external logic (of specification). In other words, Logic Programming does not require new ad hoc solutions, but a solid mathematical theory at the level of, say, typed lambda calculi.

On the other hand, the Functional Programming approach has potential which has not, up to now, fully been exploited, namely the use of functionals.

Our aim is, instead, to make a deeper use of combinators in Functional Programming specifications, algorithms and implementations.

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Start Date	**Duration**
01-SEP-89	*30 months*

LOGICAL FRAMEWORKS: DESIGN, IMPLEMENTATION AND EXPERIMENT

ACTION NUMBER: 3245

Recently, there has been a steady increase in research towards systems that can provide assistance with reasoning about a variety of problems, particularly systems for the development of hardware and software. Such systems must be usable by programmers and hardware designers who are not experts in logic, and so must provide a comfortable, problem-specific environment for developing formal proofs.

A wide variety of formal systems is of interest to system designers (such as operational semantics, lambda calculi, sequent calculi, type theories, and first and higher order logics). The task of implementing a proof development environment for a given logic is daunting, and there is considerable duplication between implementations of different logics. It is therefore desirable to develop a unifying theory of formal systems that allows one to give a concise specification of a given logic. The proof development environment can then be logic-independent, accepting a specification of the logic to be used. This eliminates to a large extent the redundancy between implementations, and one can rapidly prototype systems for a variety of logics. A "logical framework" is such a unifying theory of formal systems; it provides a notation and calculus for specifying logics.

The proposers are currently experimenting with various AUTOMATH-related type theories with variants of Church's higher-order logic, and with a general system of operational semantics as frameworks in which to conduct formal proofs. One aspect of the proposed research is to understand the relationships among these systems. It appears, on present evidence, that some form of typed lambda calculus is a basic component of such a framework. A common feature of implementations is their ability to provide the user with proof-search procedures. It is expected that the experience gained in such endeavours will be among the principal results of the proposed collaboration. Most prototype software is written in ML (a functional programming language oriented toward symbolic computation). This will enhance collaboration among the participants. In addition to scientific publications, the expected result is a demonstration of the feasibility and usefulness of "developing certified software-in-the-large".

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Start Date	Duration
01-JUN-89	*30 months*

A COMPREHENSIVE ALGEBRAIC APPROACH TO SYSTEM SPECIFICATION AND DEVELOPMENT (COMPASS)

WORKING GROUP NUMBER: 3264

The main focus of this Working Group is on formal methods for system specification and development. A major emphasis in software technology is currently on methods and development environments for the construction of generic, reusable software. The state of the art in this area allows specification and checking of the syntactic aspects of interfaces of system components. A major breakthrough can be expected through the algebraic approach that supports precise specification of the semantic aspects of interfaces and their formal verification. The algebraic approach also provides a conceptual basis and practical tools for the stepwise formal development of correct system components from their specifications, and this covers the whole software development process from the specification of requirements to the finished system. These methods are potentially applicable to the development of correct hardware systems as well.

Originally the algebraic approach was most suited to the development of first-order applicative programs. Recently, new programming paradigms such as object-oriented, logic and higher-order functional programming, corresponding theoretical concepts, and new application areas such as VLSI verification, net theory, concurrency, and distributed systems, have all merged. An important aim of this Working Group is to generalise the foundations and applications of algebraic methods in a comprehensive way, so that they accommodate modern programming methodologies and meet the requirements of the aforementioned application areas.

It is intended to provide a comprehensive algebraic approach to system specification and development, to consolidate the theoretical background, to increase the power of support tools, and to encompass new programming paradigms and application areas. This will be a guideline for subsequent technology transfer, and could be the basis for a uniform European language and environment for system specification and development.

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Start Date	**Duration**
01-MAR-89	*30 months*

COMPUTING BY GRAPH TRANSFORMATIONS

WORKING GROUP NUMBER: 3299

This Working Group intends to bring together members of the most important schools for graph grammars and graph transformation on the international scene in order to make scientific contributions towards the following aim: the use of graph transformations to improve the efficiency, reliability and correctness of computing at all levels from hardware to software, where computing includes specification, programming and implementation by graph transformations as well as computational models and computer architectures for graph transformations.

As a result, improvement of the state of the art in the following four areas is expected:

- foundations
- concurrent computing
- executability of algebraic specifications and graph transformations in other areas
- algorithmic and implementational aspects.

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Start Date	Duration
01-MAR-89	*30 months*

ARTIFICIAL INTELLIGENCE AND COGNITIVE SCIENCE:

ACTIONS AND WORKING GROUPS

VISION SYSTEMS FOR A NATURAL HUMAN ENVIRONMENT (INSIGHT)

ACTION NUMBER: 3001

The main objective of this action is to study visual processing at the intermediate and high levels from the point of view of several disciplines including neuroscience, psychophysics, brain theory and computer vision, in order to yield a description which can be implemented in a machine or a brain.

By trying to understand better the functioning of the biological systems both at the neuronal and the perceptual level and by confronting the biological solutions to those developed in computer vision, the project should generate new knowledge that can be transferred to artificial vision systems. Biological visual systems are assumed to achieve their superiority by generating complex and flexible representations based on the combination of multiple cues extracted through local higher order operators. Therefore, interdisciplinary research will concentrate on

- higher order operators, especially those related to dynamic changes and to 3-D
- the combination of multiple cues for generation of depth and for image segmentation
- surface and object representations.

Expected immediate results of the Action include on the one hand the improvement and formalisation of collaboration between the disciplines involved in understanding complex vision systems, and on the other hand the development of new concepts about the functioning of vision systems able to operate in a human environment (as opposed to a blocks world). In the longer term we expect this project to help in paving the way for the development of artificial vision systems able to operate in the fluctuating 3-D world in which humans naturally function.

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Start Date	Duration
01-JUL-89	*30 months*

ACQUISITION OF LEXICAL KNOWLEDGE FOR NATURAL LANGUAGE PROCESSING SYSTEMS (ACQUILEX)

ACTION NUMBER: 3030

The aim of this Action is to develop techniques and methodologies for using existing machine-readable dictionaries (MRDs) in the construction of lexical components for natural language processing (NLP) systems. The main focus of the Action will be on extending existing techniques for processing single MRDs in a monolingual (and currently mostly English) context to the extraction of lexical information from multiple MRD sources in a multilingual context; the overall goal will be to construct a single multilingual lexical knowledge base. The techniques developed will be either fully automated or automated, to the extent that they represent a significant saving in resources compared to the manual construction of similar lexical components.

Machine-readable dictionaries are just one type of lexical resource. Recent research has demonstrated, however, their potential utility for the rapid and cost-effective construction of some aspects of the lexicons required by NLP systems. Research on MRDs has both computational and linguistic aspects. On the one hand, advanced computational techniques for modifying and exploring textual databases need to be developed, which are specifically geared to the organisation of dictionaries and which are capable of transcending the limitations of the conventional alphabetic organisation of the printed version. On the other hand, the insights of theoretical linguistics and artificial intelligence are essential in order to develop adequate and general-purpose representations for lexical systems across languages and to ensure that this information is usable by a wide variety of NLP systems.

The long-term research goal is the development of a multilingual knowledge base containing the most general and domain-independent aspects of lexical knowledge represented in a fashion which makes it maximally reusable. The knowledge base will be rooted in a common conceptual/semantic structure which is linked to, and defines, the individual word senses of the languages covered and which is rich enough to be able to support a deep knowledge-intensive model of language processing. The knowledge base will contain a substantial general vocabulary with associated phonological, morphological, syntactic and semantic/pragmatic information capable of deployment in the lexical components of a wide variety of practical NLP systems.

The Action will explore the feasibility of this long-term goal by further developing techniques for the (semi-)automated extraction of information from monolingual MRDs for English, Italian and Dutch, and bilingual MRDs for English-Italian and English-Dutch. These MRDs will be loaded into a standardised lexical database system used by all the participants in the Action, and research will be undertaken to enable the linking, comparison and merging of information between separate dictionaries, and the construction of improved derived lexicons which remove

some of the unreliability in individual MRD sources. Separate semantic taxonomies will be derived from monolingual dictionaries for English, Italian and Dutch for a common vocabulary subset, and these taxonomies will be merged to create an integrated lexical knowledge-based prototype.

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Start Date	Duration
01-JUN-89	*30 months*

VISION AS PROCESS (VAP)

ACTION NUMBER: 3038

The objective of this Action is to demonstrate that the paradigm of "vision as process" is basic to the functioning of a high-level vision system. Such a hypothesis can only be demonstrated within the context of a complete vision system, in which the potential benefits of continuous control of perception and of associated temporal context are evident. The consortium will adapt and refine existing vision techniques for integration and combine them in a first step towards a general-purpose vision system.

This objective requires the development of techniques for interpreting a dynamically changing, quasi-structured environment. These techniques will exploit the goal-directed focus of attention involving controlled sensor motion. Processing will be directed by goals which change dynamically in reaction to the needs of the perceptual task as well as to events in the scene. The motivation for this approach is to limit the computational complexity of the perception process by limiting the size of the internal models. These models must be continuously updated to describe the environment in terms of a number of qualitatively different phenomena, such as image phenomena, 3-D scene geometry, and the symbolic interpretation of objects and events.

The techniques will be developed in the context of an integrated vision system which will serve as a vehicle for testing the fundamental hypothesis of this Action. The research issues which will be addressed include:

- the role of contexts and goals in the control of perception
- use of multiple resolution in the representation of 2-D and 3-D shapes
- description at multiple levels of abstraction.

The effort will be based on a range of techniques present across the vision community; from pattern recognition and image processing through 3-D scene analysis, to knowledge-based reasoning.

The Action is expected to achieve results that help close the gap between current vision approaches and techniques, and that move towards a true general-purpose vision system. In particular, the demonstration of the above hypothesis will enlarge the potential applications of machine vision, opening new opportunities for downstream precompetitive research and industrial applications.

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Start Date	**Duration**
01-JUN-89	*30 months*

INNOVATIVE ARCHITECTURES AND VLSI IMPLEMENTATIONS FOR NEUROCOMPUTING (NERVES)

ACTION NUMBER: 3049

The aim of this Action is to develop both the theoretical tools and the technical means for the design of algorithms, machines, and VLSI circuits for neurocomputing. The Action therefore has three research axes:

- Connectionist algorithms and architectures for adaptive information processing, pattern recognition and learning.

- Design of a neurocomputing machine suitable for distributed algorithms with high speed and parallelism abilities. Various technologies will be studied, based either on specific arithmetic accelerators inside a reconfigurable architecture, or on custom pulse stream modulation circuits.

- ASINCs (Application-Specific Integrated NeuroCircuits) dedicated to particular applications: both analog and digital basic cells will be designed.

Expected results of the Action include: machine architectures suitable for simulation of general connectionist algorithms, and integrated circuits for machines and for specific applications.

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Start Date	**Duration**
01-SEP-89	*30 months*

DEVELOPMENT OF REPRESENTATION FOR MACHINE LEARNING FROM IMPERFECT INFORMATION (ECOLES)

ACTION NUMBER: 3059

The objective of this Action is to tackle fundamental problems in machine learning and to aim towards the long-term goal of focusing and uniting this field.

Intelligent systems applied to various areas (for example process control) are playing an increasing role within industrial society. This intelligent behaviour relies on the machine use of knowledge concerning the task in hand. There is however a bottleneck: how do we acquire knowledge and maintain it within computer systems? The "intuitive" nature of human know-how presents a seemingly insuperable barrier, particularly in control tasks. Machine learning, one of the fastest growing areas in Artificial Intelligence, promises a solution. By constructing systems which are able to learn from various data sources, machine learning aims to overcome the knowledge acquisition bottleneck in software technology. Results already achieved show cost-effective solutions to large problems regarded in the past as extremely hard or impossible to solve. State-of-the-art methods in machine learning are critically limited by the representation of given problems. Automatic construction of new representations is a main thrust of this Action.

The approach taken in the Action is to develop logic-based machine learning techniques which will enable the repair of knowledge bases and databases which are either:

- incomplete, ie there exist questions whose answers are not derivable given the present state of knowledge, or
- incorrect, ie there exist questions which will be answered incorrectly with the present state of knowledge, or
- ineffective (operationally), ie there exist questions which can in theory be correctly answered, but for which the derivation is intractable within the given computational resource limits.

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Start Date

15-JUL-89

Duration

30 months

ASSIMILATING MODELS OF DESIGNERS, USERS AND SYSTEMS (AMODEUS)

ACTION NUMBER: 3066

In order to make information technology truly effective, a massive spectrum of issues must be addressed concerning users, systems and their interactions. User behaviour is undoubtedly governed by complex interrelationships among the many factors that influence cognition and action in dynamic interactions with technology. The design and implementation of systems is also an intricate process which must take into account interdependencies between system and user considerations as well as practical development constraints. In the past, issues have typically been researched from the perspective of specific disciplines within behavioural or computer science. Although there has been some interchange between disciplines, research outcomes in terms of modelling concepts, empirical results and demonstrator tools have typically been of strictly limited scope and utility.

This Action brings together teams from different disciplines with three general objectives:

- to extend the scope of modelling techniques, in order to provide analytic leverage on the problems of user-system interaction
- to bridge the conceptual gaps between behavioural and computing disciplines
- to establish a bridge from theory to the practicalities of designing software artifacts.

In the domain of modelling, computer scientists will work on formal representations of system behaviour in terms of abstract interaction models and techniques for refining interaction models into implementations. Psychologists will work on two techniques for modelling users. One technique is based upon the simulation of a constrained cognitive architecture. The other is based upon the use of expert system technology to reason about cognitive resources and the processing of knowledge. In the domain of design, there will be work on semi-formal means of representing properties of interfaces and reasoning about design choice. Empirical studies will investigate how designers and design teams, operating in commercial companies, reason about interfaces and arrive at particular decisions.

To establish bridges among models and to the practicalities of design, the Action's methodology will focus upon the iterative analysis of common exemplars. Separate groups (eg system and cognitive modellers) will analyse "shared" exemplars capturing established phenomena of user-system interactions. These exercises can be expected to highlight and inform local inter-relationships. Public "scenarios" will be defined and systematically sampled for a range of core behavioural and design issues in human-computer interaction. Each group will

provide an analysis of that material which will be communally evaluated in two workshops. These exercises are intended to force a major attack on the problems of scope, integration and utilities of all the techniqiues being developed within the project. Yet wider concerns with other analytic and empirical methods will be considered by a joint task force drawn from the three Actions on human computer interaction (3066, 3105 and 3219).

By conducting basic research on representational techniques, their properties and inter-relationships, the project should lay a firm conceptual foundation for future pre-competitive research on design support tools. This foundation will be communicated through scientific reports and demonstrations of modelling techniques.

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Start Date	Duration
01-SEP-89	*30 months*

DEFEASIBLE REASONING AND UNCERTAINTY MANAGEMENT SYSTEMS (DRUMS)

ACTION NUMBER: 3085

The aim of this Action is to study the integration of several forms of non-standard logics and models that could be applied to problems of defeasible reasoning and uncertainty management. Research is oriented more toward the valid use of non-standard logics and models for handling uncertainty in combination, than toward the study of these logics and models for themselves.

The following logics and models will be considered:

- default logic, non-monotonic logic, autoepistemic logic, circumscription, subimplications, supposition-based logic
- fuzzy logic, possibility logic, fuzzy quantifiers logic
- Bayesian models, upper and lower probabilities models, Dempster-Shafer's model, transferable belief model
- endorsement models for reasoning about uncertainty.

The combination of symbolic, qualitative and quantitative methods is necessary to realise an expressive uncertainty management system. None covers the whole domain alone

The Action will be realised through an interdisciplinary and collaborative approach, bringing together representatives of several schools of thought to reflect the variety of models and techniques needed.

The ultimate goal of the Action is the integration of the logics and models studied into a general model able to cope with the various forms of ignorance, and its implementation in inference engines. In appropriate cases experimental implementation will be pursued.

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Start Date	Duration
01-SEP-89	*30 months*

MODELS OF HUMAN ACTIONS IN WORK CONTEXTS (MOHAWC)

ACTION NUMBER: 3105

The aim of this Action is the development of models of human behaviour in complex environments which can serve the design of advanced information systems.

The Action includes closely coordinated efforts within the following areas:

- methods for analysis and representation of knowledge about complex work domains
- analysis of cognitive control, mental models and heuristics applied for operation in complex domains
- distributed decision-making, ie cooperation among individuals at work
- modelling tacit knowledge
- the development of methods for testing models of cognitive performance by means of computer simulation.

The main body of research, which is the basis of MOHAWC, consists of research projects funded by national sources. The MOHAWC effort takes the form of an integrating project, additional to the national activities. This Action will serve to effectively coordinate concepts and approaches, to generalise and transfer results and models among the groups, and to re-evaluate and supplement the results of the individual groups, so that an integrated conceptual framework for man-machine systems analysis and design may be formulated as a result of the Action.

Other expected results include:

- models of human cognitive performance in complex environments
- a forum for cross-disciplinary research including related ongoing work in Actions 3066 and 3219
- a textbook and other material designed to serve both university and industry courses.

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Start Date	**Duration**
01-SEP-89	*30 months*

MECHANISING DEDUCTION IN THE LOGICS OF PRACTICAL REASONING (MEDLAR)

ACTION NUMBER: 3125

The purpose of this Action is to further develop the capacity in Europe for automated deduction in non-standard logics. These are of central importance in reasoning about time and action, the beliefs and knowledge of agents, their intentions and their obligations. The logics occur naturally in interactive environments, such as those for changing temporal databases or for controlling actions and data in robotic systems. They are aptly called the logics of practical reasoning.

The objectives are to:

- characterise a class of logics capable of handling some central, problematic aspects of practical reasoning with time, action and intent
- develop good techniques for mechanised deduction with the logics of practical reasoning.

Those aspects of practical reasoning to be covered will be focused by the Action's case-studies in human-computer interaction and robot planning. The aim is to produce a general framework for deduction, based on the internal analysis of different logics, which will make it possible to mix different logics and deduction calculi.

Expected results include:

- contributions towards the design of a deduction workstation in which special purpose problem solvers cooperate
- providing know-how for the design of more specific automated reasoning systems, like robot action planners and interrogatable databases
- advancing the science of automated reasoning.

A series of technical workshops will be used to manage the gathering and dissemination of information throughout the consortium and within the wider scientific community.

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Start Date	Duration
01-SEP-89	*30 months*

FACTORY OF THE FUTURE PRODUCTION THEORY (FOF)

ACTION NUMBER: 3143

The ultimate goal of this Action is to obtain a designer's workbench for the development of CIM in production systems. Such a designer's workbench requires a method to describe operations in a production system. These operations include product design, tendering, logistics, quality control, etc.

There are many methods for describing the operations in production systems, but they are all fragmented in nature, being based on a set of fragmented theoretical notions. The major part of available theory is based on questionable assumptions such as:

- complete and reliable information is available before design or production operations take place
- CIM-components are installed once and for always
- boundaries between such operations as product design, process planning, manufacturing, and logistics are fixed and identical for all companies.

The Action consists of five workpackages. In the first package, current theory for describing operations in production systems is examined, ordered, and described. Four real world production systems will be analysed. In the second package, a unified description model will be developed - the conceptual model. It will be multi-disciplinary in nature. In the third package, existing workbenches (specification methods, languages, tools) for implementation of the conceptual model will be examined. In the fourth workpackage, the conceptual model will be made operational to make it suitable for the design of real-world or simulated production systems. In the last workpackage, the use of the conceptual model will be demonstrated on a simulated industrial testbed.

The Action will focus on production systems providing the market with one-of-a-kind products. The question about the generalisation of results to other production systems will be studied towards the end of the Action.

The main result of the Action will be a more powerful and complete theory of production management, based upon the reality of today and the visions for tomorrow. The development of the structure of manufacturing industries leads to operations that are carried out in a complex network of production sites and plants. To strengthen customer orientation, it will be necessary to make small industrial units more efficient and to connect them closer together. Furthermore, material and information flow across corporate boundaries are becoming stronger, so that operation decisions and communication have to react accordingly.

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Start Date	Duration
01-FEB-89	*30 months*

MULTISENSORY CONTROL OF MOVEMENT (MUCOM)

ACTION NUMBER: 3149

The objective of this Action is to understand how the brain builds an internal representation of space and movement in order to allow navigation, orientation, and action, and to link this understanding to current work in machine vision and robotics. This objective involves studying the questions of fusion of sensors, sensorimotor coordination, perception of movement, control of posture and limb movement in biological systems.

The first problem to be addressed concerns the cooperation of sensors in building a representation of space and movement. Investigations will focus on visual vestibular interaction but will also consider the integration of this information with haptic and proprioceptive information for navigation and sensorimotor coordination.

The second problem to be addressed is orientation. This problem will be studied both from the point of view of the basic neuronal operations which underly orientation reactions and from the point of view of behaviour.

The third problem concerns the organisation and possible algorithms which underly the control of multi-joint movements and posture in humans. Three main systems will be studied: eye-head coordination, visuo-manual control and control of posture.

The workpackage on navigation includes the following eight studies: 1) visual input for stabilising reflexes, 2) compensatory eye movement generation, 3) retinal and extra-retinal signals for stereopsis, 4) 3-D transformations, 5) 3-D reflex oculomotor control, 6) head movement trajectory, 7) optic flow, 8) visual-vestibular interaction for the perception of the environment.

The workpackage on orientation includes six studies: 1) gaze mechanisms in the cat, 2) spatio-temporal transformations in the tecto-reticular neuronal networks, 3) the parabigeminal nucleus, 4) basal ganglia and gaze control, 5) rapid eye movement generation, 6) neural interface between internal representation and saccade generation.

The workpackage on action includes seven studies: 1) hand movement in 3-D space, 2) manipulator trajectories, 3) redundant manipulators, 4) visually guided arm movements, 5) haptic perception, 6) visuo-manual coordination in humans, 7) bimanual coordination.

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Start Date	Duration
01-JUL-89	*30 months*

FOUNDATIONS OF LEGAL REASONING

WORKING GROUP NUMBER: 3152

This Working Group brings together, for the first time in a collaborative project, an international team of computer scientists, mathematical logicians, legal theorists and philosophers of law.

The task is to carry out a fundamental analysis of legal reasoning in mathematical, computational, philosophical and juristic terms. The goal is to find the best formal models of legal reasoning.

The approach is to analyse a variety of important and common kinds of legal reasoning, and to develop formal theories, mathematical logics and computational models which preserve logical, computational and legal validity. The legal reasoning in question is not just that of courts and lawyers, but also that of other bodies concerned with the administration or interpretation of rules. The work planned includes theoretical analysis and empirical surveys of the practice of legal reasoning inside and outside courts in several European jurisdictions.

It is intended to apply the research to the development of several related legal expert systems. One of these is to be based on "argumentation theory", another on first-order logic and "institutional" predicates, and another on the "theory of legal consequences". It is intended to develop AI programmes which concern the application of general principles to particular situations and the formal structure of a legal system, and an inference environment that is generally powerful and particularly suited to the legal domain.

The work is expected to have a serious impact on the application of AI to law. It is expected to go some way towards setting standards of soundness and effectiveness in the development of legal expert systems. By helping to determine the respects in which legal reasoning is amenable to computation, the project will serve to identify the proper role of AI in law, and enable it to be filled.

Law involves many forms of human reasoning that are of interest to researchers in the foundations of AI. The project is therefore expected to make a contribution to AI as well as to the legal applications of it.

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Start Date	Duration
01-JAN-89	*30 months*

INTERACTIVE DIALOGUES FOR EXPLANATION AND LEARNING (IDEAL)

ACTION NUMBER: 3160

This Action aims to create a unifying framework of dialogue and discourse for explanation and learning in the context of computer-aided instruction systems. The three main themes are theoretical investigations into discourse models for conversation control and role-taking in didactic situations; experimental study of optimal explanatory strategies and communications media for different types of explanation; and creating a framework of models and processes to link explanatory requirements to appropriate domain knowledge structures, the strategic control of explanation and choice of appropriate media, and the tactical control of discourse for generation of explanations and analysis of speech acts in educational contexts.

The workprogramme approach includes:

- analytic studies of natural explanatory discourse
- theoretical developments of discourse modelling for explanatory/didactic contexts
- an experimental investigation of the effect of didactic strategies and choice of media on transfer of knowledge in learning
- development of domain knowledge structures and access mechanisms
- development of prototype models in software to demonstrate and evaluate the practicability of the theoretical framework of discourse and dialogue models.

A further theme of the work is the integration of visual and verbal communication, with development of a common representation scheme to support generation of explanations as images or language. The Action will focus on teaching computer applications and programming as an exemplar domain. A sound theoretical basis for intelligent computer-aided learning (CAL) systems will be provided, by developing tactical dialogue control models based on discourse theory, extending the theory of task knowledge structures as a model of domain knowledge and retrieval processes, and developing strategic models of tutor/learner interaction based on the experimental study of pedagogical styles and teaching media. The prototype models and theoretical developments will be exploitable within such frameworks as the DELTA programme and in advanced human/computer interfaces.

The Action involves multidisciplinary research in linguistics, cognitive science, and computer science (knowledge engineering and human/computer interaction). The linguistic strand contributes discourse analysis to provide a more natural means of controlling human computer conversations in natural language, ie mixed

media interfaces. The work does not involve language or graphics generation but will address analysis, planning and synthesis of information at the semantic level. The cognitive science strand involves modelling domain knowledge for explanation, the means of analysing requirements for and mechanisms to retrieve domain knowledge, and strategic control of explanatory style and choice of delivery media in dialogues. Computer science supplements both strands by examining the integration of visual and verbal media and conversational control. Prototype implementation of an integrated set of models will be undertaken to demonstrate the applicability of the research in intelligent CAL environments.

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Start Date	Duration
01-OCT-89	*30 months*

DYNAMIC INTERPRETATION OF NATURAL LANGUAGE (DYANA)

ACTION NUMBER: 3175

This Action is concerned with research towards the development of an integrated model of the dynamic and incremental nature of natural language interpretation. The research is divided into three interdependent themes:

- Grammar development, speech and prosody. The general emphasis is on the development of formal models, and on the abstract specification and parametric variation of linguistic structure. In the area of speech, the emphasis is on the incorporation of intonational structure into the representation of utterances, and the investigation of the interplay of intelligibility, predictability and discourse context in speech recognition and production.

- Meaning, discourse and reasoning. Under this heading, further developments will be made on the dynamic and partial models of meaning that have been emerging in the past decade. In addition, non-monotonic logic will be used to build an account of conditional reasoning and defeasibility in lexical concept combination. Also, analysis will be made of the logical basis of default interpretation of various aspects of linguistic structure in the face of partial information.

- Logic and computation. The research under this theme is directed towards the development of formal mathematical and computationally tractable models of natural language, encompassing recent extensions of unification formalisms.

In addition to technical reports, work will be carried out on prototype implementations. In the final phase of this project, work on classes of algebraic description spaces and a comprehensive unification formalism for linguistic applications will be incorporated and implemented, as well as a proof theory for temporal formalisms. Other deliverables include a prototype intonational parser, and a (nearly) deterministic parser.

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Start Date	**Duration**
01-FEB-89	*30 months*

REFLECTIVE EXPERTISE IN KNOWLEDGE-BASED SYSTEMS (REFLECT)

ACTION NUMBER: 3178

The overall goal of this Action is to lay foundations for the construction of second-generation expert systems which are knowledgeable of the limits of their competence, and are more flexible in the ways in which they employ their knowledge. The fundamental premise that underlies the Action is that such advanced functions can only be realised by creating a reflective system, ie a system that is able to reason about its own knowledge of a problem domain, its problem solving strategies, and its history in terms of solved cases. The main objective is to develop and to demonstrate a skeleton architecture for knowledge-based systems with such reflective capabilities, together with an associated theory concerning knowledge-level modelling of reflective reasoning. REFLECT focuses on the construction of systems that realise a certain class of reflective functions, viz, those based on competence assessment.

The REFLECT Action aims at realising its objectives through the following steps: (i) formalisation of object-level knowledge; (ii) conceptual modelling of the knowledge for reflection; (iii) developing specification concepts and a skeleton architecture for reflective knowledge-based systems; (iv) building experimental modules that carry out a specific reflective function; (v) producing a demonstrator that performs integrated reflective computation.

The intended results of the Action will influence industrial practices in knowledge-based systems construction, by delivering techniques, guidelines and concepts for building more advanced and more flexible knowledge-based systems than presently possible. The demonstrator systems will contribute to laying the basis for architectures of expert systems of the next decade. From a more theoretical point of view, the REFLECT Action will establish a framework for the analysis and description of reflective reasoning both at the knowledge and at the implementation level.

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Start Date	**Duration**
01-AUG-89	*30 months*

HIGH-RESOLUTION SPEECH RECOGNITION: AUDITORY/CONNECTIONIST TECHNOLOGIES FOR SPEECH (ACTS)

ACTION NUMBER: 3207

The performance of machines designed for automatic speech recognition (ASR) does not bear comparison with the ability of the average human, and there is reason to believe that existing speech algorithms have inherent limitations which mean that they cannot be extended to produce a general ASR machine. To circumvent these limitations, some speech scientists have increased the resolution of the front-end processor with the aid of auditory models, and others have increased the power of the recognition process with the aid of connectionist models, or neural networks. Speech systems including one or other of these components have provided encouraging results but, to date, those that include auditory models are hampered by oversimplified recognition systems and those with competent connectionist models are hampered by excessively simple preprocessors. The purpose of the research proposed here is to assemble a balanced auditory/connectionist speech system that takes its direction from cognitive research on speech perception and memory.

With regard to the development of the individual modules in the auditory model, hearing scientists in Cambridge and Grenoble will compare their models of hearing and develop a detailed but efficient, functional model of human hearing. The model will consist of approximately five modules to perform spectral analysis, neural transduction, phase alignment, pitch extraction, and image stabilisation, which are the processes dictated by psychoacoustic research.

With regard to the development of the individual modules in the speech recognition model, connectionists and psycholinguists from Cambridge, Lisbon and Edinburgh will analyse the recognition process and develop a staged connectionist model of the recognition process. Psycholinguistic research would indicate that at least three processing modules are required to perform speech feature extraction, conversion of speech features to some form of phonology, and conversion of the phonology into word candidates. Here again, the emphasis will be on the development of a functional model based on the psychological principles observed in cognitive speech research.

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Start Date	Duration
01-JUL-89	*30 months*

KNOWLEDGE ACQUISITION AND USE IN DYNAMIC TASK ENVIRONMENTS (KAUDYTE)

ACTION NUMBER: 3219

Modern technology frequently requires human beings to control complex systems, which involve a number of variables, and which show dynamic changes even in the absence of any decision by the person. Work of this kind is importantly different from many traditional occupations.

The Action is intended:

- to provide empirical knowledge about four main factors that may affect human knowledge about a system

- to contribute to a general theoretical understanding of the whole problem, which in turn should have practical implications.

The factors to be studied are the nature of the system itself, the conditions of learning, the way in which knowledge is tested, and the relationship between the current system and some past system previously encountered by the operator.

The typical method is experimental: people will be asked to perform tasks using systems devised in the laboratory. Their performance can then be measured, and their understanding of the system assessed by various methods such as asking them to answer questionnaires, to instruct other people verbally, or to predict future events in the system. Such assessments often disagree with each other and with the actual performance of the operator.

Approximately twelve experiments are planned, each relevant to at least two of the areas of study, and all planned to be completed within two years. The experiments will include comparisons of performance of concrete meaningful tasks after abstract ones, and vice-versa; comparison between monitoring largely automatic processes and undertaking control oneself; changes of system structure between training and performance; and the provision of various forms of verbal instruction or guidance.

It is hoped that in the fifth six-month period a general theory of the control mechanisms within the person will be produced as a result of the Action. With this in mind, some computational modelling of these mechanisms will take place, to be tested against the experimental data.

The research is intended to be applicable to methods of training operators, to methods of assessing them once trained, and to some design choices in the construction of systems.

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Start Date	**Duration**
01-OCT-89	*30 months*

SPEECH PROCESSING AND RECOGNITION USING INTEGRATED NEUROCOMPUTING TECHNIQUES (SPRINT)

ACTION NUMBER: 3228

The objectives of this Action are to explore the particularities of neural networks (non-linearity, self-organisation, parallelism) in order to extend the capability profile of an automatic speech recognition system in important directions, such as adaptation to new environments (speakers, channels) and noise reduction.

Instead of trying to solve the speech recognition problem as a whole, the Action is viewed as a set of tasks, each addressing a part of the speech recognition process. Speech is divided into levels of representation, and in this framework, each task consists of going from one level to another. For each of them, neural networks will be designed, and results compared to standard techniques.

The relevant levels of representation considered in the Action are: signal, parametric, phonetic, sub-lexical, and lexical. The transformations that we consider of interest, and their processing, are signal to parametric; parametric to parametric; parametric to phonetic; phonetic to sub-lexical; and parametric to lexical.

In each task, neural networks will be investigated, including the choice of network architecture and of training method, and experimented on, bearing in mind the general problem of improving the capability profile. Performance comparisons will be made with current standard methods. Emphasis will be on research on the time dependency of neural networks.

This analytical approach should lead to:

- a deeper understanding of the behaviour of neural networks, especially as applied to a temporal phenomenon such as speech
- an appreciation of how and where neural networks are useful in speech recognition
- the achievement of interesting results in speech separation from noise, and in speaker adaptation.

Throughout the Action, specialists of speech processing and specialists of neural networks will work on common tasks to ensure quality and interdisciplinarity.

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Start Date	Duration
10-APR-89	*30 months*

SELF-ORGANISATION AND ANALOGICAL MODELLING USING SUB-SYMBOLIC COMPUTING

ACTION NUMBER: 3234

The overall objective of this Action is to try out a new approach towards sensorimotor intelligence and common sense. The fundamental idea is to explore sub-symbolic mechanisms for achieving intelligence. More specifically, two mechanisms will be investigated:

- Analogical representations: representations that keep parts of what needs to be represented implicit in the representation, ie without prior or with only limited categorisation.

- Analogous dynamics: dynamics that exploit the implicit properties of the analogical representation to derive new information.

These two mechanisms are seen as alternatives to symbolic representations which rely on full categorisation of the world, and to symbolic inference, which solves problems by transforming symbolic representations.

Some key questions in need of further investigation are:

- How can analogical representations be derived? The Action intends to explore the construction of Kohonen-style feature maps.

- What kind of dynamics should be used? The Action intends to develop a repertoire of dynamic mechanisms derived from physics, chemistry and biology. Examples are pushing and pulling, which can be implemented with diffusion, strings, or sticks. For each mechanism it is proposed to introduce a schema. A modular architecture would allow the combination of different schemata to solve more complex problems.

- Where is this approach effective? It is suggested that the approach would be particularly effective in the area of sensorimotor intelligence, although higher level areas such as problem solving and world modelling are also relevant. Demonstrations relating to vision and motor control are scheduled for the end of the one-year definition phase of this Action.

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Start Date	Duration
01-MAY-89	*12 months*

USE OF CHILDREN'S AND TEACHERS' EXPLANATIONS IN THE SPECIFICATION OF SYSTEMS OF EXPLANATION FOR INTELLIGENT LEARNING ENVIRONMENTS

WORKING GROUP NUMBER: 3267

The objectives of this Working Group are:

- To develop a theoretical framework for the area of explanation, based on work in expert systems, cognitive science, and intelligent tutoring and education
- To carry out a small number of pilot studies in areas such as:
  - microbiology (for example, the transmission of disease)
  - reversible and irreversible phenomena
  - causality in history.

  These studies will be done with a view to examining children's and teachers' explanations, possibly modifying software to incorporate a range of prepared explanations, and testing the acceptability of such explanations with children.
- Other possible areas of study include ecological issues and physical and chemical transformations.

The approach will follow two complementary directions: one centred on the acceptability and utility to learners of currently implementable explanation systems; the other centred on diagnosis and categorisation of types and mechanisms of explanation as sought by, interpreted, and produced by learners.

Expected results include the description of a theoretical framework for explanation and the testing of its ability to classify data in pilot studies of children's explanations. It is then envisaged to proceed to a partial implementation of prototypes of explanation to run alongside existing CAL software.

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Start Date	Duration
15-MAY-89	*30 months*

FUNDAMENTALS OF INTELLIGENT RELIABLE ROBOT SYSTEMS (FIRST)

ACTION NUMBER: 3274

Robotics is an interdisciplinary subject spanning task planning, geometric reasoning, control, and many different kinds of sensing, including vision, force, and touch. Usually, a typical robotics research project is restricted in scope and concentrates on one or two of these topics, simplifying or ignoring the requirements of the others. When complete systems are constructed from the results of such projects, therefore, they are either unreliable or unintelligent. The FIRST Action is designed to counter this trend, and studies the pairwise interactions between planning, control, and sensing.

The three work packages in the FIRST Action consist of research programs that explore the integration of:

- sensing and planning
- sending and control
- planning and control.

Sensing is rarely an end in itself in robotics; instead, the use of sensors is an essential component of a system that must plan and execute actions intelligently and reliably. Similarly, intelligent manipulation must be based on the relationship between non-local sensing such as vision and hand-eye coordination, and between local sensing and grasping. Finally, control actions need to be related to task descriptions and the shape representations that support planning.

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Start Date	Duration
01-MAY-89	*30 months*

ARTICULATORY-ACOUSTIC CORRELATIONS IN COARTICULATORY PROCESSES: A CROSS-LANGUAGE INVESTIGATION (ACCOR)

ACTION NUMBER: 3279

For many applications in speech technology decisive progress would result from the availability of an articulatory representation of speech utterances. For example, in automatic recognition of continuous speech, one of the greatest barriers to robust speaker-independent systems has been the great variability in the relationship between the acoustic level of representation and the phonological structure of a given utterance.

Variability can itself become a productive source of information if we learn to model the underlying physiological and linguistic constraints on the dynamics of articulation. The main source of systematic variability on the segmental level is undoubtedly coarticulation. Recent theoretical and experimental work on speech production strongly indicates the need for a comprehensive cross-language research programme to expand our knowledge of the language-specific and language-independent regularities involved.

The definition of the scope of the Action as a whole has been guided by the observation that while the acoustic mapping of the geometry of the human vocal tract during speech articulation is well understood today, the solution to the inverse problem, ie the problem of reconstructing articulatory processes from acoustic information, is still unsolved. Coarticulatory phenomena as a source of information have been almost entirely neglected. This Action will integrate investigation of the coarticulatory regularities themselves with research into new and improved ways of exploiting these regularities in deriving articulatory representations through the acoustic analysis of speech.

The knowledge gained in this way will contribute to the selection of the most promising paths to follow in many speech technology applications, particularly in the development of more robust speech-recognition systems.

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Start Date	**Duration**
01-APR-89	*30 months*

DIALOGUE AND DISCOURSE (DANDI)

WORKING GROUP NUMBER: 3351

The major research interest of this Working Group is the investigation of how the flow of information in dialogue and discourse is structured and controlled. This involves the study of how information encapsulated in the speaker's message is integrated in a coherent way in the listener's expanding knowledge base. It is a process of continuous information growth where all participants in the discourse try to maintain a partial, yet consistent, model of the world and of the dialogue they are participating in.

The main aim of the Working Group is to increase the fruitfulness of current research through the enhanced interaction and cooperation between the 18 participating research centres. This will be achieved primarily through viits between the various centres, through the exchange of research results, and through the organisation of special interest group meetings and workshops.

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Start Date	**Duration**
01-MAY-89	*30 months*

ESPRIT BASIC RESEARCH WORKING GROUP ON VISION

WORKING GROUP NUMBER: 3352

The objective of this Working Group on vision is to forge a solid scientific community concerned with the problems of machine and natural vision. This community includes researchers in computer vision, pattern recognition, signal processing, artificial intelligence, machine learning, parallel architectures, and neural networks, and is intended to serve as a spawning ground for future European machine vision projects. The mechanisms by which the Working Group will accomplish its objective include the organisation of interdisciplinary meetings, workshops, conferences and scientific exchanges, as well as the publication of a book.

The Working Group will arrange workshops at a rate of roughly one every six months, on topics to be proposed by its members. In addition, the Working Group proposes to organise a larger conference to be called "The European Vision Conference". The intention is to include representatives from other ESPRIT Projects and Actions in the organisation of this conference. A book is to be published of the conference proceedings.

Workshop topics will include:

- control of perception in a high-level vision system
- vision algorithms with parallel environments
- parallel feature extraction and tracking
- synchronisation and associative schemas for high-level vision
- matching strategies
- acquisition of behavioural knowledge.

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Start Date	**Duration**
01-JUL-89	*30 months*

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