Institute
FOR
Systems
Engineering
AND
Informatics

JOINT
RESEARCH
CENTRE
EUROPEAN COMMISSION

A N N U A L · R E P O R T · 93

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Systems
Engineering
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Informatics

G. CASINI

JOINT
RESEARCH
CENTRE
EUROPEAN COMMISSION

1994

Cataloguing data can be found at the end of this publication

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1 EXECUTIVE SUMMARY

INTRODUCTION TO THE INSTITUTE

The Institute for Systems Engineering and Informatics is one of the eight Institutes which constitute the Joint Research Centre (JRC) (see *fig. 1.1*). It was born in 1990, through the fusion of two Institutes, the Institute for Systems Engineering and the Centre for Information Technologies and Electronics.

The Institute has two main missions:
– contribute to the execution of the 1992-1994 JRC programme activities
– provide informatics services to the other Institutes and to the Administration Units of the JRC.

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Fig. 1.1. The Joint Research Centre in the Organisation of the European Commission

The 1992-1994 JRC programme activities are as follows:
- research and development in the frame of the European Framework Programme (1990-1994)
- scientific technical support to the Commission policies
- exploratory research
- contractual work for third parties.

The ISEI contribution to the Framework Programme is made through the following lines (specific programmes):
- Working Environment
- Measuring and Testing
- Environment
- Nuclear Fission Safety
- Controlled Thermonuclear Fusion
- Human Capital and Mobility.

The scientific-technical support to the Commission policies is organised according to customer/contractor principle. The multiannual actions are covered by contracts with the interested Directorates calling for work assignment and resource accountability.

Exploratory research projects have the purpose of improving the scientific vitality and potential, exploring suitable and promising avenues, testing new ideas or concepts on a small experimental scale and improving opportunities for visiting scientists and research fellows.

Contractual work for third parties is intended as a mean for JRC to valorise the results of its research and, at the same time, to measure its competitiveness in the public and private market.

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                    │      ISEI       │
                    │   Directorate   │
                    │                 │
                    │   R. W. Witty   │
                    └─────────────────┘
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| Industry Environment | Non-Nuclear Energies | Safeguards | Management Support |

| Electronics and Sensor Based Applications | Corporate Informatics Services | Distributed Informatics Services | Energy Environment Interaction |
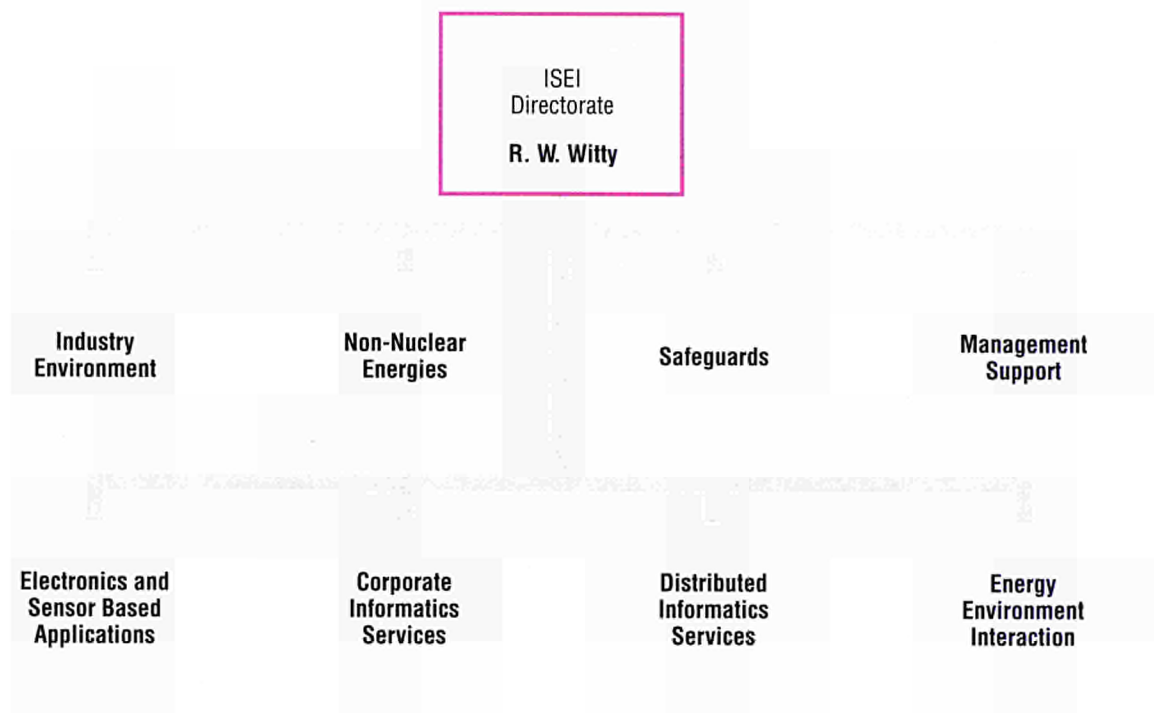
Fig. 1.2. Structure of the Institute for Systems Engineering and Informatics

For the execution of the programme activities, the Institute is organised in Units (see *fig. 1.2*).
The human resources made available include the following categories of persons:
- authorised statutory staff, scientific-technical and administrative;
- young visiting researchers (grantholders), mainly chosen and financed in the frame of the Human Capital and Mobility programme;
- senior visiting scientists and staff seconded from organisations (detached experts) in the Member States, mainly financed within the envelope of statuary staff credits;
- visiting stagiaires, mainly students hosted in the laboratories for training and educational.

The staff distribution among the various categories (August 1993) is shown in *fig. 1.3*.

The ISEI Financial Resources, staff excluded, were in 1993 11.33 millions of ECU, of which about 41% for Specific Programme activities, 18% for support to Commission Services, 2% for Exploratory Research, 33% for Informatics Services and Support to other Institutes and 3% for Third Party Work (see *fig. 1.4*).

	Staff nr.
Statutory Staff	215
Grantholders	25
Visiting Scientists	4
Detached Experts	5
Visiting Stagiaires	43
Total	**292**
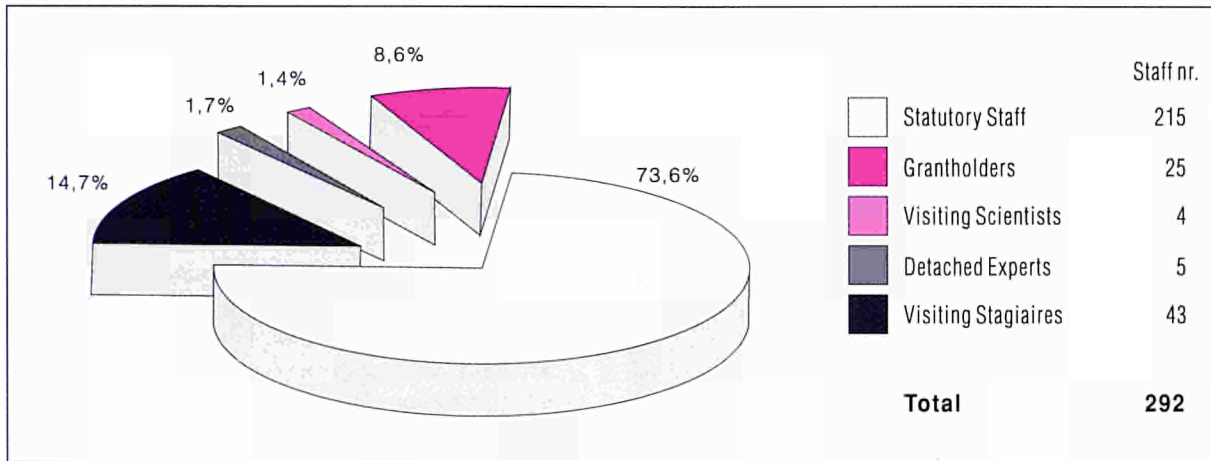
Fig. 1.3. ISEI Human Resources (August 1993)

	Mio ECU
Framework Specific Programme	4.70
Exploratory Research	0.21
Support to Commission	2.08
Informatics Services	3.50
Support to Other Institutes	0.15
Third Party Work	0.30
Management	0.39
Total	**11.33**

Fig. 1.4. ISEI Financial Resources (1993), staff excluded

SUMMARY OF THE ACTIVITIES

Specific Programme

Working Environment

Accident Prevention

The activity has been focused on the following areas:
- Cognitive Ergonomics and Organisational Factors for the study of the human element by direct observation of working environments, during normal and critical conditions;
- New Technologies and Safety at Work, for the evaluation of the impact of Information Technology on the design of control system and accident management procedures and for the assessment of the human factor during abnormal situations;
- Process Diagnostics, for the early fault detection and diagnosis of malfunctions of plants, focusing on components and instrumentation.

The research on Cognitive Ergonomics and Organisational Factors has been addressed to Air Traffic Control. Methods involved were: observation of individual and team behaviour in real setting, video and audio recording, application of rating scale of stress. Data have been analysed using Cognitive Task Analysis and Verbal Protocol Analysis techniques. Two models of stress and of distributed decision making have been developed and related to previous modelling development.

Activities in the area New Technologies and Safety at Work were dealing with specific projects, as System Response Generator and Human Error Analytical Taxonomy, as well as with Methodology Analysis on Human Factors .Real accident cases have been studied in the civil aviation domain in order to analyse the causes of human errors and simulation of systems responses to human actions have been performed for theoretical evaluation of models of operator/pilot behaviour.
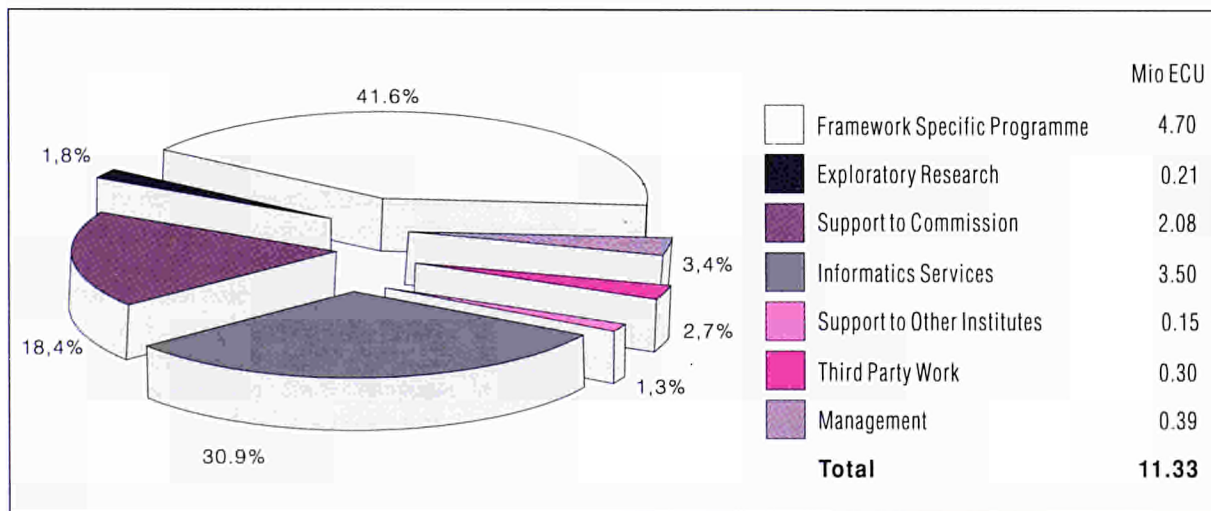
In the area of Process Diagnostics, a guide to a typical integrated diagnostics design has been proposed and applied to a large scale system of reference.

Measurement and Testing

Reliability Models of Structures

The two main lines of activity were structural diagnostics by optical and volumetric techniques.

The main results obtained in the first field were as follows:
- visualisation of bending waves in composite material plates by pulsed holographic interferometry. These bending waves and their propagation behaviour can give valuable information for characterising the material properties.
- Development of a high speed ambient light reduction device for pulsed holographic interferometry and thermoplastic processing system. This system, tested both in laboratory and industrial environment, was demonstrated to be very reliable and to allow holographic registration and reproduction work all day long, without depending on light conditions, with a reduction of the process time by a factor 100.
- Successful microdeformation tests (detection of hidden defects on a 15th century mural fresco) by a portable ESPI (Electronic Speckle Pattern Interferometer) system , using a small diode laser and fibre optic technology.
- Fabrication of an improved fiber-optic interferometer for ESPI has been realised achieving the automatic compensation of unavoidable ambient induced phase fluctuations in the fibres and setting-up of a fully automatic phase stepping technique for the quantitative evaluation of interferograms.
- Mechanical characterisation of stone materials by by ESPI in order to obtain a full-field map of deformation and to extract some important parameters of the inspected material.
- Static deformation measurement, by ESPI ,for the study of structures where non-homogeneous mechanical properties are difficult to predict on a pure theoretical basis.
- Easier and faster measurement of stationary vibrations for diagnostic analysis of structures: classical laser interferometric techniques can be replaced by ESPI techniques which allow a simple and real-time monitoring of vibrations.
- Real time monitoring of micro structural changes of stone surfaces by a new method, based on digital correlation of speckle images, for the diagnosis of stone surface modification.

On volumetric techniques the main results were as follows:
- Performance of a Bench-mark exercise on the use of Acoustic Emission techniques during the adhesive joint curing process in order to assess the quality of

an aluminium bonding with epoxy resin adhesive. The results of preliminary tests been performed are encouraging as they show three different patterns of activity corresponding, respectively, to the heating-up, the constant temperature and the cooling-down phases of the process .

– Development of a methodology, based on laser holographic interferometric techniques, for measuring damage accumulation in material via identification of vibrational modes and estimation of modal damping. Tests, performed on aluminium and steel beams and circular plates with clamped boundary conditions,showed satisfactory agreement with theory.

– Setting-up and testing of a new methodology for high cycle fatigue damage assessment, based on microscopic approach. A collaboration with the Centro Ricerche Fiat has started.

Photovoltaic Systems

The activity was concentrated on pre-normative research on photovoltaic devices, as a part of the ESTI (European Solar Test Installation) mission.

A flash radiometer development has been initiated, which enables ESTI to measure the spectral irradiance of the large area pulsed solar simulators simultaneously with each calibration of a photovoltaic device. This will increase measurement precision significantly as any spectral mismatch occurring with thin-film devices can be corrected for. The mechanical construction of this new device has been completed. Integration of the narrow band-pass filters was taking place.

The development of the multiplexed read-out electronic was discontinued, as a PC-based system is now available.

Thin-film modules have been annealed after the light-soaking test as prescribed in ESTI specifications. The annealing procedure has been applied to a new set of large-area amorphous Silicon modules. Instead of measuring all modules simultaneously, only one was installed at the Simulator, whereas the remaining three were kept in the light-soaking facility at the same temperature , but in the dark. The results show that annealing took place much faster (some 2 or 3 days) than expected. At this point of experience one can consider to reduce annealing time in order to decrease total testing time.

In the frame of the Working Group n.2 of IECT82, an activity was carried-out on thin-film measurement procedures and new safety standards for commercial modules. Results of experiments at ESTI were assessed, in view of their possible standardisation, and other proposals concerning the light- soaking tests have been adopted. Open issue is the standardisation of the ultra-violet exposure test.

Environment/Remote Sensing

Centre for Earth Observation (CEO)

The feasibility phase of the project has been successfully completed. It consisted in a feasibility study, carried-out by an international Consortium, accompanied by two feasibility demonstrators developed by the Remote Sensing and Environment Institutes of JRC to illustrate some basic concepts of the proposed functional architecture.

The following CEO phase, named Pathfinder Phase, has started. The aim of this phase is basically the definition of the project design and its implementation as far as its content, organisation and funding are concerned.

Meanwhile laboratory studies have started for implementation of pilot cases in the areas of remote sensing and computer aided cooperative activities.

Data Visualisation and Animation

A hardware and software system for producing video animation of geographic and ocean modelling data has been developed in support to the Remote Sensing Institute. An on-line database of ten years of daily meteorological data from the European Centre for Medium Range Weather Forecasting (ECMWF) has been installed.

Environment/Industrial Hazards

Multicriteria Methods (MCDA) and Information Systems for Decision Support

A new multicriteria method based on some aspects of the partial comparability axiom, named NAIADE, was developed. It is a discrete multicriteria method whose impact matrix may include either crisp, stochastic or fuzzy measurements of the performance of an alternative with respect to a judgment criterion.

The empirical relevance of the method was tested by a real environment management problem in the area of the delta of the Po river. The question treated was that of the Mesola wood, where a sharp conflict exists between environmental and economical aspects.

A prototype of a group decision support system, named PRODEST, aimed at giving a detailed documentation of the history, the formal representation and conflict resolution of a given process, has been developed.

The capability and possibilities of the computer code NUSAP to assist the analysis of quality of scientific information has started to be investigated.

An attempt to base the formulation of a systematic approach of MCDA theory has been developed, particularly for water quality indicators. Various water quality parameters have been formulated in relation to their different uses, taking into account the corresponding quality thresholds.

Applications of Geographical Information Systems (GIS)

Enhancement of existing hardware and software has been made including a workstation equipped with intergraph GIS products, the Oracle data base, the MAP-INFO system for personal computers and the digital cart of the world data set on CD-ROM. Various applications have started, namely:

- a prototype GIS for environmental management in the Attert Natural Park (Belgium);
- Utilisation of GIS for storing and interrogating the European Earthquake Catalogue, in view of a spatial analysis of earthquake risks;
- Utilisation of GIS for the ECOCENTRE project (see below).

Following the implementation of an algorithm within a GIS to generate alternatives for siting of facilities, the merging aspects of MCDA and the algorithm fitness function have been investigated and the method has been extended to the site of route facilities.

Risk and Environmental Management of Transport of Dangerous Goods

The XTRIM computer programme was improved, new data bases introduced, and used to evaluate the overall risk from the transport of dangerous wastes to a waste treatment plant in Denmark.
A study of the risks of transporting dangerous goods in inland waterways, restricted waters and coastal waters of Denmark was also started by implementing the accident data base, quantities and roads of dangerous goods transportation.

Environmental Impact Assessment

Preliminary studies. have been concentrated on transformation function and uncertainties analysis of environmental indicators and on the assessment of the environmental quality of the Bolzano city.

Safety and Reliability Assessments

The STARS project (Software Tool for Analysis of Reliability and Safety), started in 1989, is now completed. In the last two years a toolkit was developed that consists of knowledge bases and related tools used to build the plant model, as well as a set of safety and reliability analysis tools. A new graphical interface has also been developed to access knowledge base information and to create hierarchical object oriented representations of industrial plants. Also other tools supporting computer aided design at system level have been developed. These tools involved a fault-tree construction expert system, a fault-tree editor and a module for determining the cut-sets and performing a time dependent quantitative analysis.

Work was pursued on TOMHID, a project aimed to develop a methodology for user's assistance on high level hazard identification of chemical process plants. A specific analysis has been carried-out to investigate the impact of management factors on plant safety. The general philosophy is to employ an inductive or "bottom-up" approach starting from the events constituting the identified scenarios, assessing the managerial factors that might contribute to the occurrence of these events, and from these proceed to more general managerial practices and principles assessing the overall safety management system.

Safety Critical Computer Systems

The Safety Critical Computer Systems activity started in 1993 with a competence building and analysis phase related to the state of the art. The work is focused on setting-up a coherent group of methods and tools for the development and assessment of computer-based safety critical systems.

Expert Systems for Decision Support (FORMENTOR)

The contribution to the FORMENTOR project of the EUREKA programme, aiming at developing real time expert system software that offers on-line decision support to operators of hasardeous plant, has been pursued. The pilot phase ended in 1993 and the next phase, dealing with industrial development, is being undertaken.

Data Visualisation and Storage

Data management and data visualisation software has been developed under an inter-institute contract with the Safety Technology Institute. The software package TURCOM, which is used to visualise reacting gas flows, has been extended with a record/play back and time animation facility. Another application dealt with the visualisation of gas transport in buildings.

Fission Reactor Safety

Knowledge Based Systems oriented to Living Probabilistic Safety Assessment

The main activity has been oriented to the study of a functional model of nuclear power plant, necessary for the construction of event trees and execution of failure mode and effect analysis.

Feedback from Operating Experience: Data Analysis

A new non parametric empirical Bayes estimator for individual component failure rates has been derived. The estimator is applicable for components with different observation periods and with no failures observed, asymptotically optimal and robust.

Man-Machine Interaction and Dynamic Reliability Studies

The development of dynamic reliability methodologies was focussed on the analysis of systems, operational procedures in normal and abnormal conditions and human errors. The analysis was based on the use of the code DYLAM and of a plant simulator. The package permits the analysis of a system by coupling its reliability assessment with the study of its physical evolution in nominal and in failed states, taking into account also the operator intervention.

Improved Version of the Component Event Data Bank (CEDB)

A first version of CEDB for personal computer is near completion. This version will have the same features of the CEDB which operated in the JRC main frame.

Information of Public on Risk

Research on the information on risk to be given to public according to the European Communities legislation and on how this can influence the acceptance of risk related to new technologies has been started. Areas selected for investigation are nuclear safety and environmental management.

Structural Reliability

The thermal shock experimental campaign on pressure vessels has been completed by two series of tests, namely;
- severe mechanical loading tests in order to raise crack tip sharpness by fatigue propagation,
- tests at low temperature to simulate the neutron embrittlement effect on the material fracture toughness.

The first type of tests was made through an actuator capable to apply two hundred fifty thousand cycles under a constant force of two thousand kilo Newton. The second test was involving a variation of temperature from 100 °C down to the temperature of liquid nitrogen (-197°C).

Fission Safeguards

Surveillance and Remote Verification

In the area of surveillance the activity dealt with active vision techniques and computer assisted reviewing of surveillance images. In the field of remote verification a laboratory prototype of a mobile robotics system has been developed and tested. The development work concerned the software architecture, vehicle navigation, visual perception system and the environment modelling using range images.

Sealing and Identification Techniques

The software used for the identification of the ultrasonic seals has been rationalised, so simplifying the inspection procedures.

Quality assurance study has been launched on a bolt system to seal concrete or cast iron nuclear containers used for transport and storage of spent fuel.

Containment and Surveillance (C/S) Performance Evaluation

The setting-up of the equipment and operation tests in the LaSCo laboratory has been pursued. The Mechanical Test Area has been extended by installating a second vibration unit, driven by a special calculator which enables the generation of complex random vibration profiles.

Specific tests have been carried out on an inclinator used for trucks, a video camera system for surveillance, an ultrasonic seal and a compact surveillance system developed in Japan.

Experimental facilities to investigate the performance of the C/S devices and systems, used by the inspectors, have been enlarged. A multi-sensor for the surveillance of the strategic areas has been assembled. Different scenarios for the use of C/S systems in the Advanced Storage Area have been investigated. Monitoring of the Storage Area, Storage Unit and Individual Nuclear Material Containers has been pursued.

Integration of individual sensors and of the monitoring system with the computer aided video system, has been started.

Integration of Safeguards Techniques

The activity to develop tools for nuclear fuel cycle

evaluation and assessment of the trend cf safeguards R/D techniques, in particular in the area of fabrication and reprocessing plants, has been pursued with the collaboration of ESARDA (European Safeguards Research and Development Association) partners. Support was also given to the organisation of the 15th ESARDA Symposium on Safeguards and Nuclear Materials Measurements, held on May in Rome.

Mass and Volume Measurements

In conjunction with the Safety Technology Institute the construction of the Tank Measurement Facility (TAME) has been advanced and a relevant part of it has already been commissioned. An expert meeting with representatives of reprocessing plants, research laboratories and safeguards inspectorates has been organised to identify requests for tests to be performed in the facility.

Fusion Technology and Safety

Activities have been carried-out in support to the Next Step (ITER) and to the Safety and Environmental Fusion Power Assessment (SEAFP).

Structural Integrity during Disruption Off-normal Events

Various investigations of the plasma disruption mechanical effects on Next Step internal components have been carried out. The feasibility of internal reinforcement systems on blanket segments has been assessed. The ELBA facility for transient mechanical tests and validation studies has been installed and the implementation of the measurement systems is in progress.

Operational Safety and Reliability during Remote Handling Maintenance

The package for visual simulation developed at ISEI has been linked to the new CAD system CATIA. A Computer Simulator for Robotics, developed at KfK, has been installed. Computer tests of various candidate commercial packages for 3-D kinematic computer simulation have been carried out. The development of a remote handling workstation has been undertaken.

Experimental validation tests, in collaboration with ENEA, have been focussed on the design of the blanket handling device (BHD).
The Robertino facility has been used for a test campaign on reduced scale mock-ups of various types of grippers, with appropriate sensors. Dynamic analyses of the facility have been performed and the relevance of the reduced scale BHD mock-up (1/3) has been verified.

A reliability analysis of the BHD is in progress. An upgrading of the Robertino facility and of its control system has been undertaken.

A collaboration with JET aiming to the improvement of the overall reliability of the articulated boom, through the direct participation of an engineer on the JET Site, has led to with the definition of the test cases specifications for diagnostic tasks of the control system.

Envelope Accident and Passive Safety Analyses

The evaluation of the consequences of the so-called Envelope Loss-of-Coolant Accident in ITER and in a fusion power plant (SEAFP) has been carried out by the computer package set up in the previous year at Ispra. Envelope conditions correspond to an instantaneous complete and permanent loss of active cooling. The time evolution of the temperature in the various components of the reactor plant has been calculated up to three months after the accident in order to investigate their capability for passive safety.

Neutron Induced Activation Analysis and Activated Waste Management

Activation analyses on various reactor configurations and alternative structural and breeding materials (ITER and SEAFP designs) were performed.
Source terms have been provided as inputs for the transient analysis of loss-of-coolant accidents, and to assess waste management options for activated materials.
Sorting of activated waste according to a new classification of waste categories, has been performed. This classification aims at defining three options for the activated waste, i.e., to declassify to non-active waste the materials subjected to low neutron fluencies, to recycle other irradiated material and to dispose the remaining waste with simple handling and storage procedures.

Human Capital and Mobility

During 1993 several networks set-up in the Human Capital and Mobility programme by national organisations with participation of ISEI-staff have started to operate in the following fields:

- Semi-Autonomous Monitoring and Robotics Technology;
- Diagnostics and Reliability of Composite Materials and Structures for Advanced Transportation Applications;

– Interactive Image Synthesis and Processing on Innovative Computer Architectures;

– Design of Robust Human Machine Interaction;

– Human Factors in Complex Real Systems.

Exploratory Research

Neural Networks for Navigation of a Teleoperated Vehicle

The work concentrated on two complementary aspects of the navigation problem. The first aspect deals with local navigation.

Data from the on-board ultrasonic sensors are used to built perception maps of the free space around the vehicle. Special grids have been designed and used to map the ultrasonic data into a reliable description of the robot's surrounding environment. The mapping problem was solved by means of artificial neural networks which have been trained on a set of real ultrasonic measurements.

The second aspect aims at controlling the robot so that it reaches efficiently a goal location in an unknown indoor environment. A reactive approach was followed. At each moment, the neural controller computes an action which depends on the current situation as described by the on-board sensors. The robot acquires the appropriate navigation strategies in a few trials through reinforcement learning.

Three Dimensional Surface Sensor (coherence radar)

The coherence radar is a hybrid method, combining optical interferometry and time of flight techniques, used for contouring rough surfaces. Its main advantage is the theoretical possibility to combine high resolution and wide dynamic range.

The main achievement of 1993 was the performance of an effective and complete theoretical analysis of the system, never made before, which led to the development of a mathematical model linking the field contrast and the parameters of the system.

This theoretical result is very important because it allowed us to understand the origin of the existing problems and to optimise the parameters of the experimental set-up achieving the desired performances. The implementation of a prototype was consequently started. Its completion is foreseen for the middle of next year.

Propagation of Solitons

Computer modelling techniques have been used to examine the possibility of soliton propagation in the layer silicate mineral muscovite. A demonstration of the existence of lattice solitons in crystals would provide a mechanism explaining the transportation of energy from one region of the crystal to another and increase current knowledge of radiation damage processes and crack propagation.

The work insofar performed led to demonstrate that the conditions necessary for lattice solitons to propagate in the potassium chain directions of muscovite exist. Such conclusions are consistent with experimental observations of decorated linear tracks. Combined together the experimental and computational data provides strong evidence for the propagation of lattice solitons in the non-atomic potassium atom planes of muscovite. Work is now in progress to model the atomic motions and propagation of energy in muscovite using molecular dynamics techniques.

Support to the Community Policies

General Secretariat

Antifraud Database (DAF)

An integrated authoring and end-user system for the antifraud database was further developed. An advanced prototype of the DAF end-user system was developed in Ispra and demonstrated in Brussels. Specifications for a new powerful authoring environment for DAF were completed. In addition, contribution was given to the definition of a charter and a work programme for the proposed Antifraud Policy Support Office . This Office is intended to give longer term and wider scope technical support to the Commission's antifraud policy needs.

Statistical Office

Statistical Applications of Artificial Neural Networks

The neural network model called Kohonen Maps has been used, adapted and enhanced for addressing two applications pertaining to the field of unsupervised clustering tasks. In both cases, the experimental results have shown that the connectionist approach provides a promising alternative to traditional techniques. Related theoretical results have also been obtained.

The first application concerns the topology of European regions. The study was completed early this year. The second application deals with time series of foreign

trade statistics. In this case, the Kohonen Map model is used for estimating missing data and it also acts as a pre-processing device for selecting time-series forecasting methods or hyperparameters.

DG I, Collaboration with IAEA on Safeguards

Optical Surveillance

The main activity concerned the development of techniques for design information verification (DIV). A prototype based on the use of image processing has been developed in laboratory. A second technique based on laser range images has been investigated.

Information, Data Treatment and Evaluation

A computerised system is being developed to process the information expected from the IAEA-Member States on all exports and imports of nuclear material and equipment (Universal Reporting Scheme). During the year the software for the front end processor of the system have been worked-out, tested and implemented.

Sealing and Identification Techniques

An exchange of know how and equipment on seals has started with Canadian AECL has been carried-out. The cooperation aims at the development of a single instrumentation for reading the respective sealing systems, in view of their delivery to IAEA.
Training Courses to IAEA staff on ultrasonic sealing bolts have been organised.

DG III, Industry

High Performance Parallel Computers

The activity has been focused on the CONCERTO type of parallel machines, namely on the implementation of CS-1 and on the evaluation of the extension of its software to CS-2.

Safety Critical Computing Systems

The work has been centred around the collection of information on research activities in the area. A survey of the activities in Europe has been performed with a view to publishing a directory and setting-up an on-line information system.

World Shipbuilding Databank

The personal computer version of a system capable to present statistical tables on world shipbuilding production has been completed.

DG VII, Transport

European Coordination Centre for Aircraft Incident Reporting Systems (ECC-AIRS)

The development of a prototype of ECC-AIRS system has been started. Hardware and basic software environment have been purchased ant the system has been installed. A set of documents that formally define the user requirements, software requirements and the architectural design has been produced. The architectural design of the system has been completed, the main components and their mutual interaction identified and approved.

DG XI, Environment

Major Accidents

The activities related to the implementation of Directive 82/501/EEC on the control of major accident hazards from chemical and petrochemical industries have been strengthened on the coordination of the technical working groups constituted by authorities and industrial representatives for the harmonisation of the national practices. The coordination started by production of guidance notes with respect to safety reports and safety management systems.
The operation of the Major Accident Reporting System (MARS) has been pursued. A book including lessons learnt and a data base implemented according to the newly adopted accident collection forms have been published.
The activity of the Community Documentation Centre on Industrial Risk (CDCIR) has been pursued.

Natural Disasters

A major conference on natural risks and civil protection has been organised organised in October 1993 in cooperation with DGXI and DGXII. The results of the conference are now being exploited for establishing priority actions and for getting indications on the DG XII research programme.

Biotechnology Hazards

Support to the Commission with respect to the regulation on the contained use of genetically modified micro-organisms and of the deliberate release into the environment of genetically engineered organisms has continued according to the permanent mandate, which includes the operation of a Community Documentation Centre on Biotechnology Safety and Regulations (BIOSAFE).

Civil Protection Information and Communication System

The pilot system operation was completed by middle of the year but the standard utilisation has been not yet decided. The JRC received also a mandate to head an evaluation task force which ended its work by the end of the year.

Risk Communication

Two projects have been carried-out, the first one on management of uncertainties in the communication of the Seveso Directive on major hazards and the second one on the response of the Seveso Community to the 1976 accident.

Community Nuclear Safety Policy

Support has been given for monitoring and assessment of results of study contracts awarded by DG XI. Catalogues of data on historical earthquakes for the seismic assessment of nuclear installations will be issued.
A pilot study to assess the uncertainties associated to the parameters of atmospheric dispersion and deposition modules of two probabilistic accident consequence codes has been started.

DG XIII, Innovation Policy

Image Processing and Holographic Processing and Synthesis

Work has been pursued on basic ray tracing and radiosity techniques. Theoretical development has been carried-out for the implementation of holographic synthesis on work stations and for comparison with experimental data.
Numerical tools for hologram synthesis, based on the fast transformation principle, have been set-up, so realising an advanced software package which was applied for image compression and colour holographic synthesis.

Ultra High Sensitivity Interferometric Sensors

Further tests have been performed on two patented interferometric devices . These tests confirmed the extraordinary characteristics of the first of them, used as a sensor for radiation flux measurement (radiation pressures as low as 10^{-8} atm can be detected).
The measurement campaign carried out on the optical switch has shown that an excitation power of 10 microW or less is sufficient to drive the system.
Industrial applications, for which separate patents are being asked, are envisaged.

Key Reading Device for Sccess Control

A key reading device manufactured by the French firm company SPECTEC on the basis of a JRC patent has been installed as an access control system to command the opening of the door in the LaSCO laboratory. The system has been in use satisfactory for one year and the staff has been acquainted with the operational procedures.

DG XVII, EURATOM Safeguards Directorate

Surveillance Techniques

The activity in the field of surveillance and monitoring concerns the development of equipment and software for applications of EURATOM Safeguards Directorate. The main tasks dealt with semi-automatic review of recorded surveillance data, front-end data reduction, analysis of motion detector alarms, feasibility study of the identification of fuel elements, the realisation of five surveillance systems CAVIS- 2S and two review stations CARES.

Sealing and Identification Techniques

Two hundred sealing bolts have been fabricated and delivered to EURATOM and IAEA. A verification of several of these bolts sealed on multi-element-bottles was proved to be successful.

DG XVII, Solar Energy and Rational Use of Energy

THERMIE Programme

In the photovoltaic area work was dealing with technical evaluation of new proposals of demonstration projects, with corresponding updating of the Ispra data bank work on monitoring the utilities interface with real data, on-site measurements and control visits were also accomplished.
In the area of building and transport, in addition to the assessment of the standard proposals, "targeted proposals", which correspond to major European collaborative projects, were also evaluated.
In the area of solar thermal systems, new proposals have been evaluated and a guideline report for telemonitoring active solar projects has been published.

ALTENER Programme

A survey study has been carried-out on European standardisation needs for solar thermal energy components.

SAVE Programme

Support was given in order to introduce in Europe the option in energy planning strategies named Demand Side Management (DSM). The option is that of investing in demand reduction rather than in new generating capacity.

Buildings Identification Parameters

The work has been concentrated on complementing the measurement campaign on occupied buildings by investigation of the variation of heating plant with load. The simulation model TRNSYS, previously used to investigate the thermal behaviour of different zones, was also used to simulate the heating plant. In this way it was possible to carry out detailed investigations of the building envelopment plant system.

Parametr identification activity on passive solar cells was concentrated on methods to promote, application of passive heatingt and cooling techniques.

Informatics Services

Corporate Informatics Services

A multi-annual plan for the modernisation of the information systems in support of the administrative and managerial activities carried out by the JRC Institutes and the Administration has been produced. Such plan is based on a consistent blend of cost-containment, end-user satisfaction and innovation goals.

Most significant achievements were: the downsizing of the mainframe server, the development of the information warehouse, the migration of a number of applications, the revision of major business processes in view of a substantial re-engineering effort. Finally, a new policy as regards the procurement of informatics tools and services has been defined. This will facilitate the adoption of advanced solutions that prove to be effective instruments in support of the change of work processes.

Distributed Informatics and Communications Service

The activities were oriented towards the provision of network services (the JRC wide-area network and the Ispra site network), systems support services (distributed systems management for PCs and Unix systems), applications support services (E-Mail and Xerox support) and communications services (information dissemination and videoconferencing).

The major improvements in terms of networking were the connection of the Geel establishment to the Europanet network at 64kbps, and the connection of Ispra to the SWITCH network at 64kbps for access to the Internet. A domain name server and Interest Protocol Router were installed as part of improving the connection to the Internet.

The reliability of the E-Mail service was improved and a new E-Mail application software on user systems was installed.

The central Computer Aided Design service ceased to be supported as from the end of 1993, as a distributed solution using intelligent workstations had been be put in place.

Other Projects

Euro-Québec Hydro-Hydrogen Pilot Project

Contract activities have progressed in the areas of aviation propulsion, public transport, steel fabrication, cogeneration and storage technology.

An important step was the first successful test with hydrogen gas of a Belgian city bus (1 hour, 10 km and max speed 60 km/h).

The construction of a hydrogen fuel cell driven passenger boat fo inland navigation and other studies have been contracted.

The Ispra ECOCENTRE Project

Contribution to this project was involving the organisation of the international energy retrofit competition for Ispra buildings, an aerial infra-red survey of heat losses from roofs and the district heat network, ventilation measurements and the environmental assessment of a new building.

Work for Third Parties

Work under payment was carried-out for various European and non-European industrial and public organisations. The areas where this type of activity was addressed were:
– Photovoltaics
– Computer-Aided Engineering
– Analysis of Industrial Components
– Human Capability and Dependability
– Reliability and Safety Analysis
– Decision Support Systems
– Insurance Risk
– Nuclear Safeguards and Fuel Cycle.

2 SPECIFIC PROGRAMMES

2 SPECIFIC PROGRAMMES

WORKING ENVIRONMENT

Accident Prevention

The activity in the Working Environment has been focused on 3 main topics of research, namely:

– Cognitive Ergonomics and Organisational factors, for the study of the human element by direct observation of working environments, during normal and critical conditions;
– New Technologies and Safety at Work, for the evaluation of the impact of Information Technology (IT) on the design of control system and accident management procedures and for the assessment of the human factor during abnormal situations;
– Process Diagnostics, for the early fault detection and diagnosis of malfunctions of plants, focusing on components and instrumentation.

The activity of Information and Documentation has been stopped after an initial consultation with DG V.

Cognitive Ergonomics and Organisational Factors

The research performed in Cognitive Ergonomics and Organisational Factors has been centred on experimental and field research in the working environment of Air Traffic Control (ATC). The research has been performed in concurrence with the Human Capital Mobility Research Programme and partly as a collaboration with the Italian National Council of Research (CNR). The methods applied to the research have been: observation of individual and team behaviours in real setting /1/, video and audio recording, application of rating scale of stress. Data have been analysed using Cognitive Task Analysis (CTA) and Verbal Protocol Analysis (VPA) techniques. Two models of stress and of distributed decision making have been developed (collaboration with CNR) and related to previous modelling development.

Analysis and Modelling of the Effects of Stress in ATC
The goal of the research was to analyse the causes and the effects of stress on controllers' cognitive activities in Air Traffic Control. A stress-based analysis was carried out in order to find out causes and effects of stress on the Air Traffic Control Operators (ATCO) cooperative work, distributed cognition, attention and communication. Ultimately the objective of this research is to improve the design of computer-based tools.

The study consisted of collecting data during the execution of the task in presence of external stress conditions, such as high traffic density and bad weather, and of analysing these data in cooperation with the controllers in order to obtain an evaluation of psychological stress. Data were collected by:

– observing controllers when executing their tasks;
– video-recording the controllers on the field;
– audio-recording the communications between controllers and pilots.

A self confrontation of controllers with the video recording was performed and a subjective rating scale of stress was inferred. Video-based analysis and Verbal Protocol Analysis (VPA) were applied to examine these data, focusing in particular on the strategies and actions being performed as well as on verbal and non-verbal interactions and communications. Exploratory Sequential Data Analysis (ESDA) using a specific software tool was applied. Results show that the main causes of stress can be related to the number and kind of communications (information load), the temporal distribution of the task (temporal overlapped and related tasks), the traffic characteristics (complexity, volume and holding), and the appearance of unexpected problems. These causes have been shown to impact on the performance of cooperative work, the distributed cognition, the selection of the focus of attention, the communication, the memory load and the "predictive capacity".

Analysis of cooperative work in ATC
The data obtained from the field study allowed to analyse the cooperative work performed by various controllers and therefore the coordination between different sectors suite: en- route, approach control, and tower of control. The analysis focused on verbal and non-verbal communication using speech- act theory and conversational analysis. The relation between the increase of workload and the form and content of dialogues were analysed. A model of cooperative work was developed and related to the design of Computer Support to Cooperative Work (CSCW) in the area of ATC. In figure 2.1 you can see an overview of Cooperative Work in Air Traffic Control. The arrows illustrates the main interactions between the different agents of the cooperation.
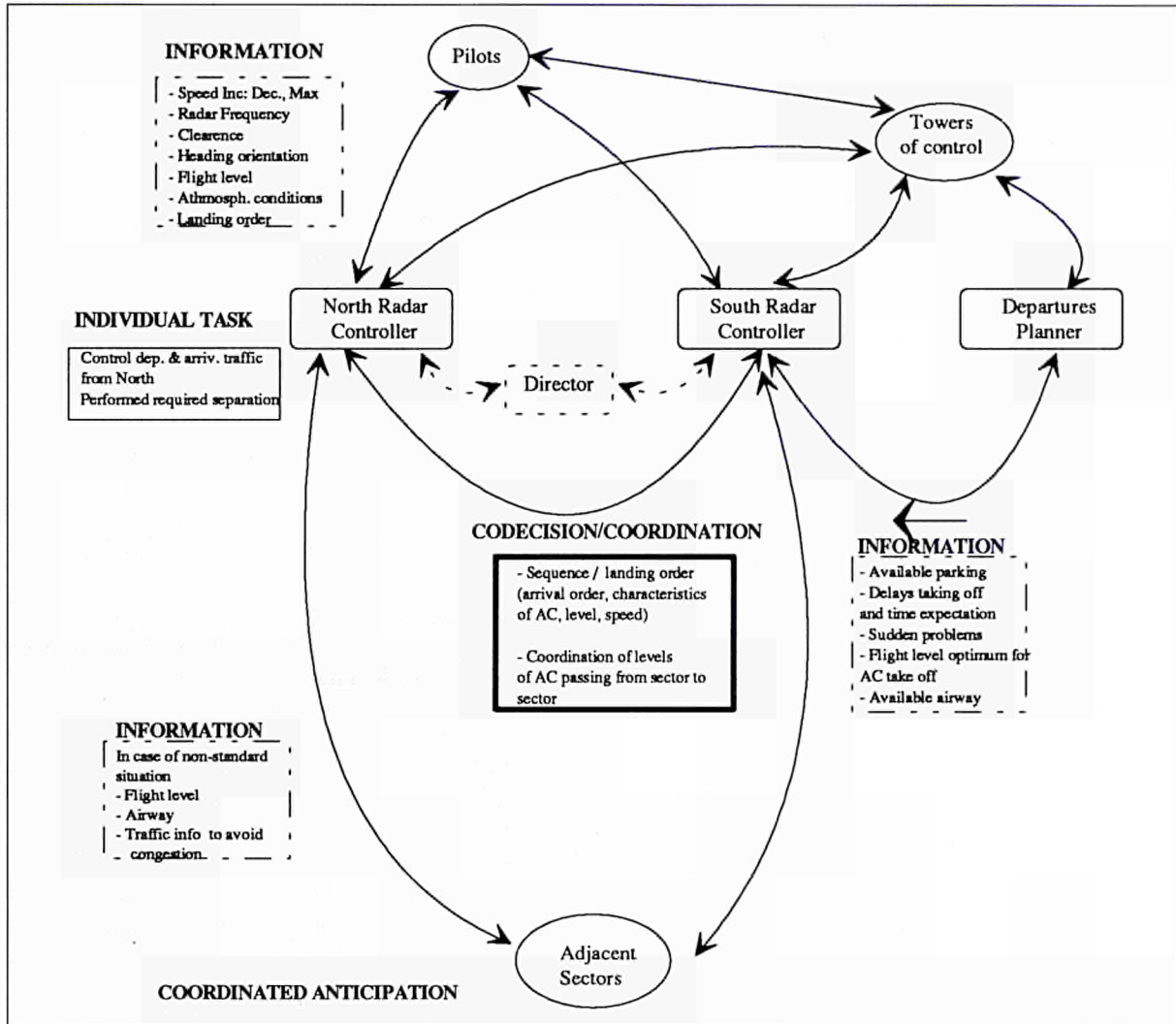
INFORMATION
- Speed Inc: Dec., Max
- Radar Frequency
- Clearence
- Heading orientation
- Flight level
- Athmosph. conditions
- Landing order

INDIVIDUAL TASK

Control dep. & arriv. traffic
from North
Performed required separation

CODECISION/COORDINATION

- Sequence / landing order
(arrival order, characteristics
of AC, level, speed)

- Coordination of levels
of AC passing from sector to
sector

INFORMATION
- Available parking
- Delays taking off
and time expectation
- Sudden problems
- Flight level optimum for
AC take off
- Available airway

INFORMATION
In case of non-standard
situation
- Flight level
- Airway
- Traffic info to avoid
congestion

Pilots

Towers of control

North Radar Controller

South Radar Controller

Departures Planner

Director

Adjacent Sectors

COORDINATED ANTICIPATION

Fig. 2.1. Overview of Coopertive Work in ATC

New Technologies and Safety at Work

System Response Generator

The overall purpose of the System Response Generator (SRG) project (*fig. 2.2*) is to develop and implement a software tool which can be used to analyse the interactions between an operator and a process, in particular the influence of human decision making and action in the way in which incidents in complex systems evolve /2/4/. The SRG project initiated in 91 will finish 1.4.94. The project consortium consists of JRC- ISEI, Computer Resources International (DK), and Aerospatiale Protection Systems (F).

The SRG will serve to:
- identify potential problem areas, i.e., the parts of the task and the man-machine Interaction where problems are likely to occur;
- provide quantitative data as input to a more formal analysis;
- evaluate the effects of specific modifications to the system (e.g., procedures, information presentation, control options, etc.).

The concern of the System Response Generator is the way in which misunderstandings and incorrectly executed human actions can change the evolution of an accident. The fundamental innovation of the System Response Generator project is the consistent method for dynamically combining simulations of both the technical process and the human operator. Most notable activities in 1993 were the development of a model of the
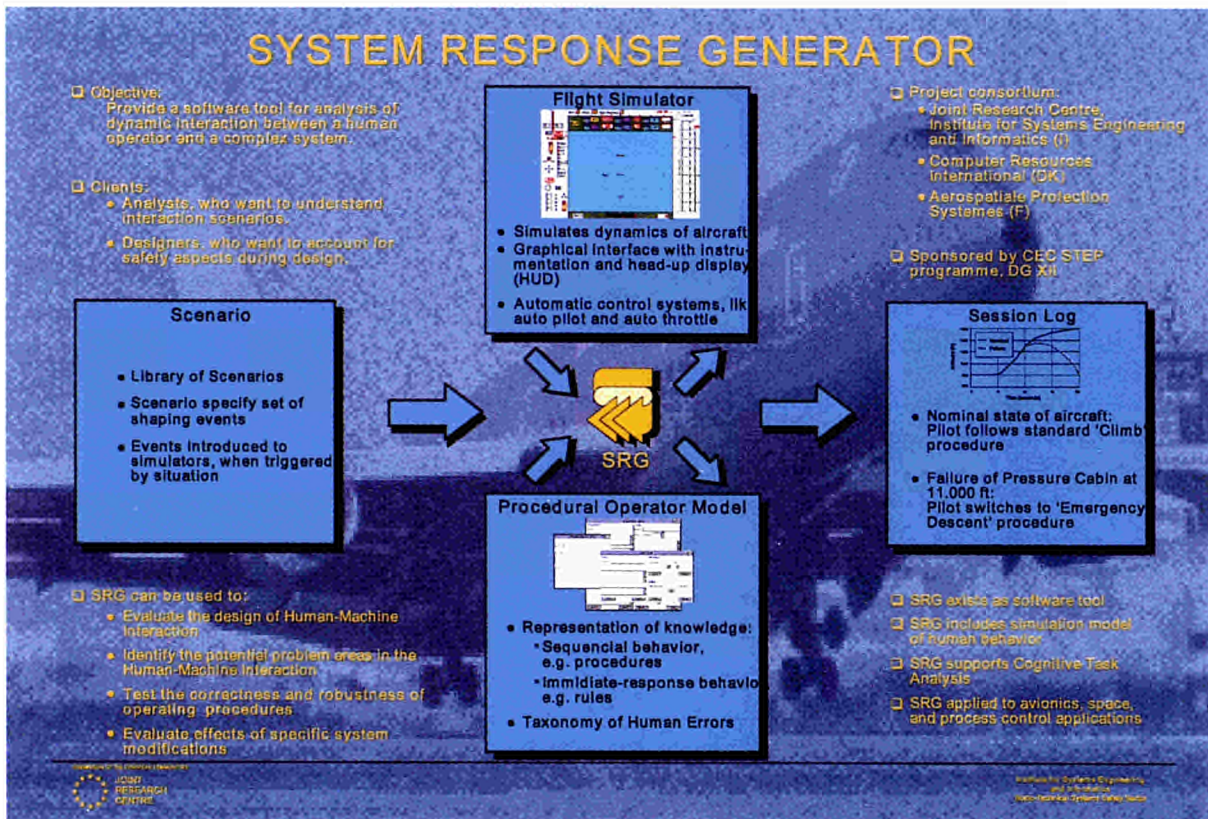
Fig. 2.2. Poster from System Response Generator project

human operator, and the application of the SRG technique and software tool to two domain applications.

The human operator model, Procedural Operator Model, enables the modelling of immediate response actions and procedure based control sequences. On the basis of a taxonomy of human errors, control actions can be attributed with execution errors /3/6/.

Two domain applications have been studied: the control of (1) a flight simulator, and (2) a satellite simulator /5/7/. The Aircraft Demonstrator shows how a correctly executed procedure handles errors in the physical process. This is used to test for the completeness of operator knowledge in terms of correctly applied operator rules. The Satellite Demonstrator shows how the SRG can be used to test and verify satellite flight control procedures to maintain the east-west position of a geostationary satellite, and to evaluate the effects of incorrect operating procedure execution, i.e., human errors. The SRG has been demonstrated at commercial exhibitions at Le Bourget in Paris (June 11-20, 1993), and at the InterAirport exhibition in Frankfurt (September 21-24, 1993).

Methodologies for Analysis of Planning, Control and Supervisory Functions in Complex Technological Systems

The purpose of the project is to study the structure of knowledge in complex dynamic working environments. Specifically, the study of knowledge structures, task allocation and performance of human operators confronting dynamic physical processes, with the objective to develop concepts for the analysis of multilevel control, planning and supervision functions in complex technological systems.

The combination of action descriptions and functional models of a plant has been investigated, and a modelling methodology has been developed which allows automatic or interactive derivation of start-up action sequences. /8/9/10/11/ Based on this, the notion of function has been studied further with special regard to actions. This is an extension of the functional modelling concept, as this usually deals with physical entities, such as plant components. Based on existing action classifications, a simple modelling language has been developed, which has been used to describe

25

existing emergency procedures (from the nuclear domain). From these procedures, sequences of goals involved have been identified, and a first attempt to a graphical representation has been developed to capture the change of operational goals over time, as well as goal conflicts. An example of the use of the graphical notation is seen in *figure 2.3*. A further description can be found in /12/.

Human Factors Studies

The dynamic human reliability methodology HERMES has been developed in conjunction with the work performed in the frame of the Reactor Safety research programme. Both the prospective and retrospective uses of the human error methodology HERMES were covered. The activities developed in this area are focused on the aeronautics and aerospace domains. An overview of the existing taxonomies for human errors has been done and the most promising one has been properly modified in order to study the causes of human

errors. A study case has been performed in the civil aviation domain in order to study the causes of human errors. In particular an application has been made on the study of the accident AZ-404 Milan-Zurich that crashed on November 1990 (*fig. 2.4*) /13/14/.

In this area of research, another project has been carried out in collaboration with other European research institutions and industries, within the STEP programme: the Project HEAT (Human Error Analytical Taxonomy, STEP-Project 89). The aim of this project is to develop a method for data collection and analysis on accidents in the industrial domain, with particular attention to the human factor. The theoretical protocols of HEAT are oriented to the evaluation of the socio-technical aspects of the working environment in which the accident has been generated. A number of accident data have now been collected in different European industrial environment. The JRC contribution to this work has essentially consisted in the development of the
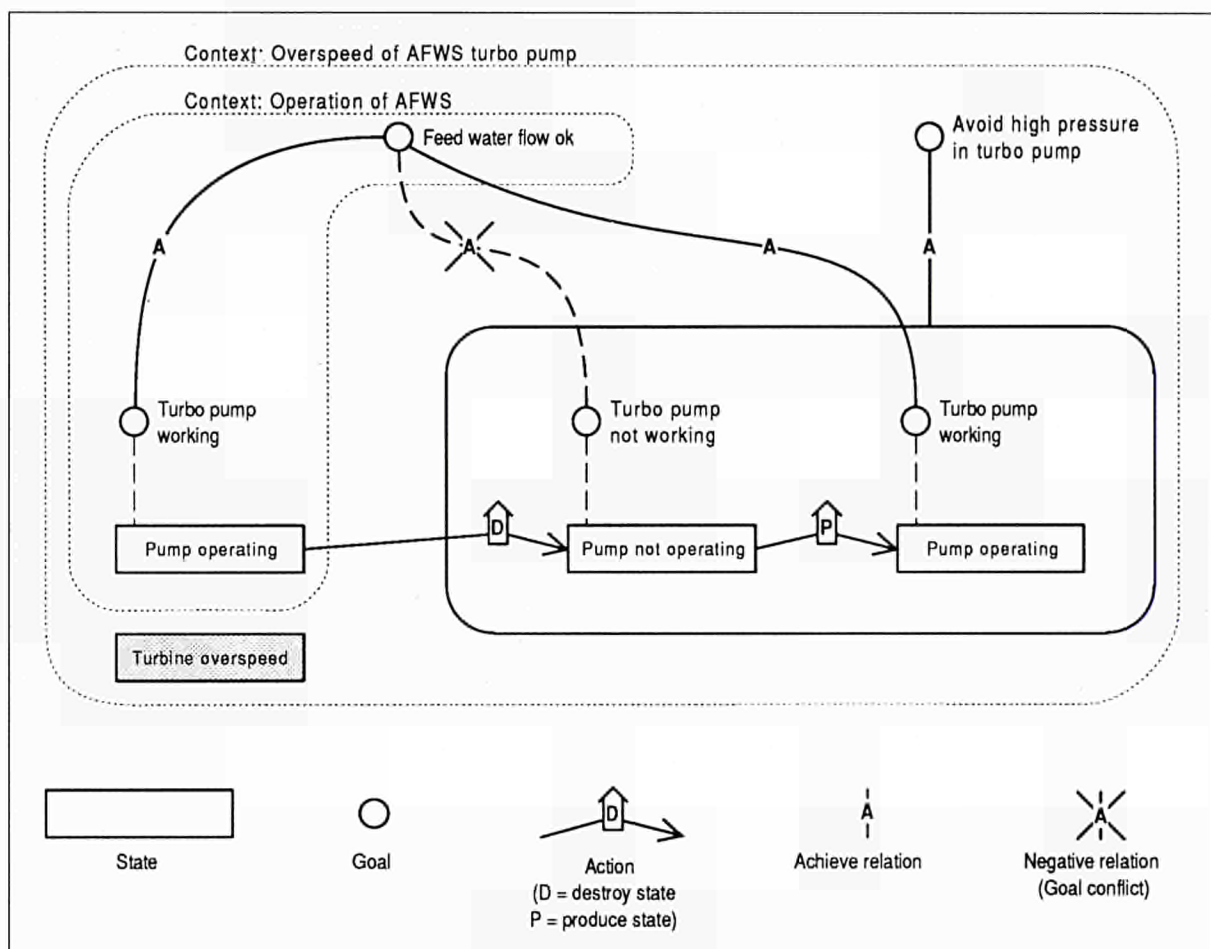

Fig. 2.3. An example of the use of the graphical notation for modelling an emergency procedure
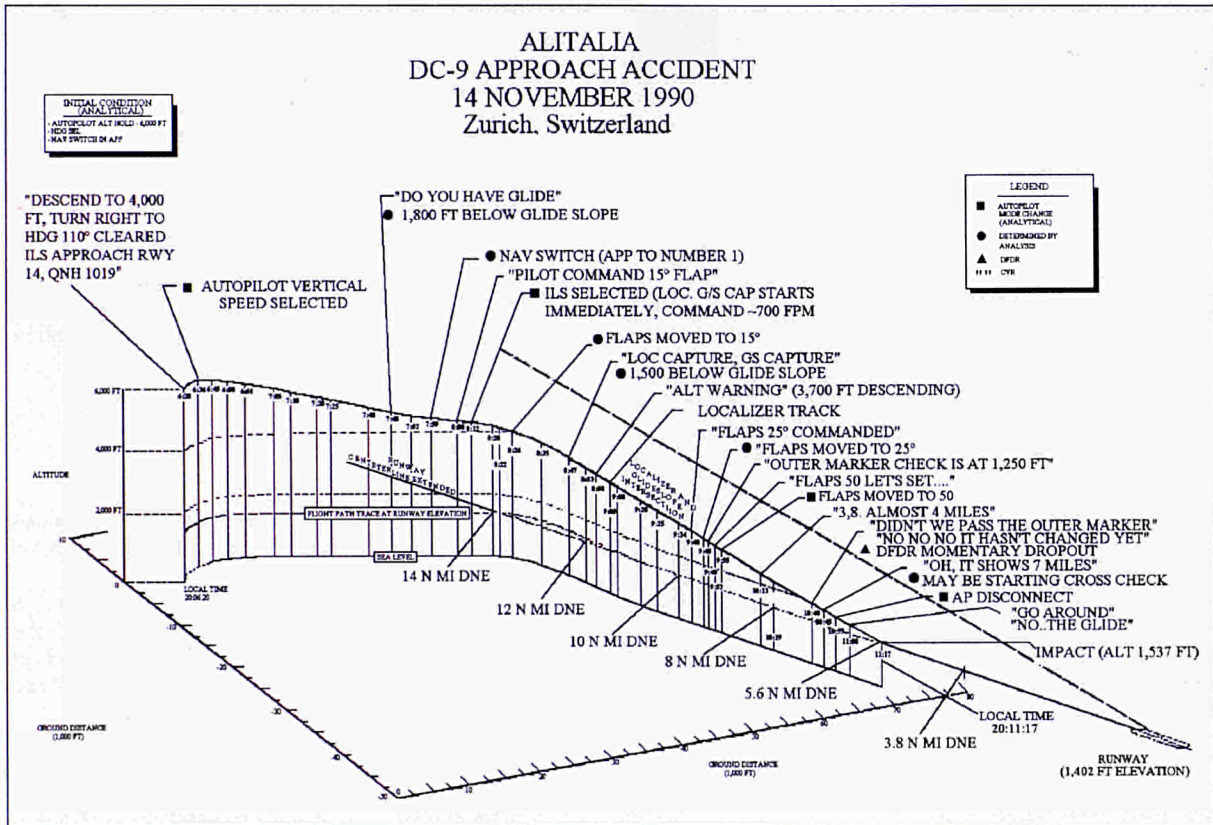
Fig. 2.4. Approach path of the flight AZ 404 to Zurich Airport (Nov. 1990)

software tool dedicated to support the work of the field analyst during the data collection.

Process Diagnostics

The work has been oriented to the formulation of diagnostics tasks in the technology of large scale systems. In particular, a guide to a typical integrated diagnostics design has been proposed and applied to a large scale system of reference. Basically, the methodology refers to physical systems as ruled by a set of differential stochastic equations /15/. In particular, the system is able to interface human operators through its dynamic model which can analyse all the signals emitted, without suffering of human filtering and signal overlapping. The human operator, besides the usual console information from instruments, may profit of graphs and tables on video displays units illustrating on line the diagnostics of the actual state.

A large scale system of dimension N, or else a N-composite system, can be approximately defined as a set of N interconnected subsystems. It is represented by the following system of differential equations:

$$X_i = f_i (X_i (t), t) + B_i g_i (t); \qquad i = 1, N$$

$$g_i (t) = Y_i (t) + U_i (t); \qquad i = 1, N$$

$$Y_i (t) = h_i (X_i (t), \ldots, X_N (t)); \qquad i = 1, N$$

where the outputs X_i (t) are vectors of dimensions n_i, g_i (t) and U_i (t) are vectors of dimensions r_i ; f_i represent the dynamics of each subsystem and g_i (t) are the inputs to each subsystem selected by means of the $r_i x r_i$ matrix B_i. Y_i (t) is the collective contribution to the input of the M interconnections with a dynamics h_i and U_i (t) the external inputs (*fig. 2.5*). A suitable global diagnostics will consider, not only the cooperative contribution of the single insulated subsystems, but also the specificity of the mutual interconnections. Therefore, the conditions for the stability involve feedback interconnections.

The procedure proposed considers two criteria for global diagnostics:

– Analytical criterion: the alarm is activated when at least a diagnostics chart in a subsystem or in a interconnection detects a rupture; this criterion corresponds minimum risk.
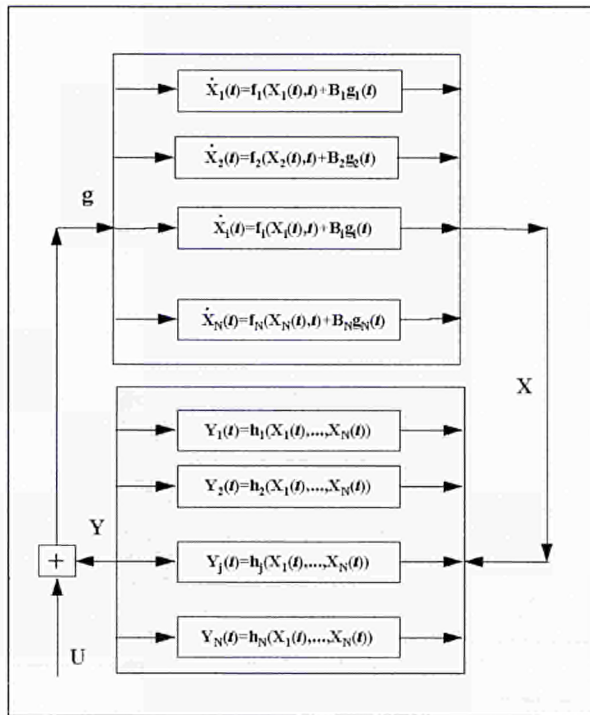
Fig. 2.5. N-composite systems

– Robust criterion: the subsystems and the interconnections are provided with several indicators of the same fault, e.g. a test on the mean, the alarm is activated from a predefined coincidence of fault diagnosis.

The approach exposed above has been applied, by using TREE tool programme /15/ to the thermoelectric power station of an industrial plant, already studied in the past (see Annual Report ISEI, 1992), seen as a N-composite system. The components are the combustion boilers, the heat exchangers, the supply circuit and the general collector. Results lead to the following conclusions:

– Black box approach, which was already tested in simulation environment, is able to capture essential information also in industrial environment, when the technological processes can be identified by linear dynamic models.
– Problems of portability of TREE, as diagnostics interface, are to be expected in every plant. TREE is a very sensitive, but sophisticated tool. It needs to be fitted to actual requirements of the system; e.g. false alarms triggered by spurious, but natural signals, can be avoided after a learning campaign and a suitable set-up.

– Such kind of problems seems to be common to several MMI applications. Integration designs of heterogeneous diagnostics decision supports, with man-machine interfaces, which are flexible to user and application adapted, are still at the stage of methodological development.
– An integrated diagnostics methodology for large scale systems is a reasonable objective to be pursued. Indeed, the difficulties are expected to be drastically reduced, when systems, diagnostics decision supports and man machine interfaces will be designed together in a same global plane.

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MEASUREMENT AND TESTING

Reliability Models of Structures

The two main lines of the 1993 activity were: structural diagnostics by optical techniques and structural diagnostics by volumetric techniques.

Structural Diagnostics By Optical Techniques

This line of activity contains several research actions /1/2/, performed in collaboration with national laboratories and companies (University of Loughborough; University of L'Aquila; Politecnico of Milano; FIAT; etc), co-ordinated and focused towards the development or improvement of optical methods for deformation analysis and surface profilometry. The main achievements are hereafter briefly reported.

Use of Pulse Laser
PULSED HOLOGRAPHIC INTERFEROMETRY FOR BENDING WAVE VISUALISATION

Pulse lasers provide coherent light pulses of extremely high peak power (up to 100 Megawatts) and considerable energy (up to 3J). The short light exposure times related to the high peak power level are needed to record holograms of either moving or vibrating objects. For standard continuous wave holography even vibrations in a submicron scale are extremely harmful, hence, the usage of a pulse laser is appropriate in many kinds of measurements outside an optical laboratory. The relatively high pulse energy is needed to record holograms of larger size. With 3J, surfaces of several square meters can be investigated. Moreover, the usage of pulse lasers is compulsory for the observation of transient, even very fast, non-repetitive phenomena.

A very interesting application, realised in our laboratories, is the visualisation of bending waves in composite material plates (supplied by aeronautical companies) /3/. These bending waves and their propagation behaviour can give valuable information used to characterise the material properties. The optical apparatus for pulse laser holographic interferometry was coupled to an impact pendulum by means of optical light bars and electromagnetic devices. The pendulum, released magnetically, hits the centre of the composite material plate and, before the impact, fires a light bar that actuates the laser trigger flashlamps in a manner that the pendulum impact coincides with a first holographic exposure. A second holographic exposure is taken a

split second later (i.e. 100, 200, 400, or 600 microseconds later) in order to provide a double exposure interferogram that monitors the state of propagation of the bending wave in the composite plate. Varying the time gap between exposures leads to a series of snapshots documenting the different states of evolution of the bending wave. These snapshots reveal precise information on the material anisotropy and fibre orientation. The knowhow for such an experiment is not only hidden in the complex optical setup but also in the extremely critical timing of the laser. To achieve this, individual electronic time devices had to be developed. *Fig. 2.6* shows the bending wave 200 microseconds after the impact.
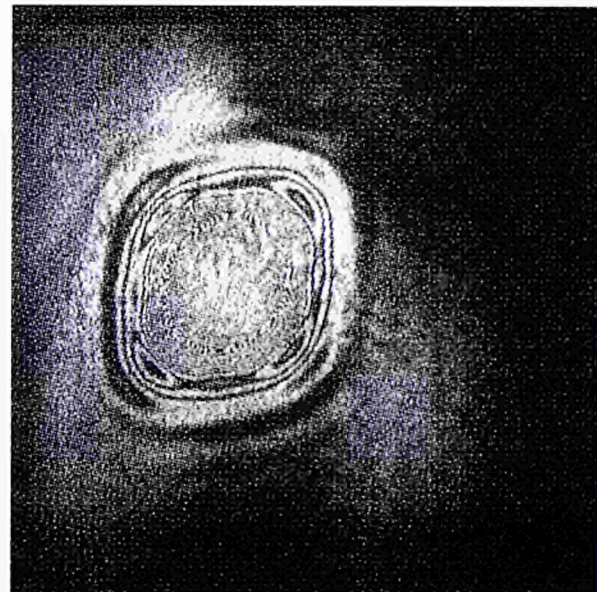
Fig. 2.6. Visualisation, by pulse laser, of a bending wave on a composite material plate 200 microsec after the impact

DEVELOPMENT OF A HIGH SPEED AMBIENT LIGHT REDUCTION DEVICE FOR PULSED HOLOGRAPHIC INTERFEROMETRY AND THERMOPLASTIC PROCESSING SYSTEM

This work has been done in order to enrich the versatility of the existing pulse laser holography system with thermoplastic hologram processors. Most industrial environments do not allow on-line holographic processing because of the high level of ambient light. The usual holographic processors have in fact an open design and require experimental conditions with extremely reduced straylight levels.

We have designed and built a closed camera chamber equipped with two shutters and a high precision electronic timing system. This system, tested both in laboratory and industrial environment, was demonstrated to be very reliable and to allow holographic registration and reproduction work all day long, without depending on light conditions, with a reduction of the process time by a factor 100 /4/5/.

The system was successfully used for the periodic inspections on the nozzle corner of the RPV model of the Pressurised Thermal Shocks Experiment in the Structural Reliability testing laboratory, where no arrangements are foreseen for ambient light reduction and vibration elimination.

Testing and Application of ESPI (Electronic Speckle Pattern Interferometry)

The development, in collaboration with the Department of Energetics of the University of L'Aquila, of a portable ESPI system for micro-deformation analysis, using a small diode laser and fibre optic technology, has been completed. This instrument allows interferometric measurements to be easily done directly in field. Field tests of the system have been performed for the diagnostics of works of art confirming its capability of non-invasive inspection for the detection of hidden defects or unwanted alterations in paintings, sculptures, frescoes /6/ /7/8/9/. Fig. 2.7 and 2.8 shows the application of the portable ESPI to a 15th century mural fresco. More systematic tests are planned for 1994 in two fields: old paintings (in collaboration with the Italian Ministry for Fine Arts) and civil structures under simulated seismic
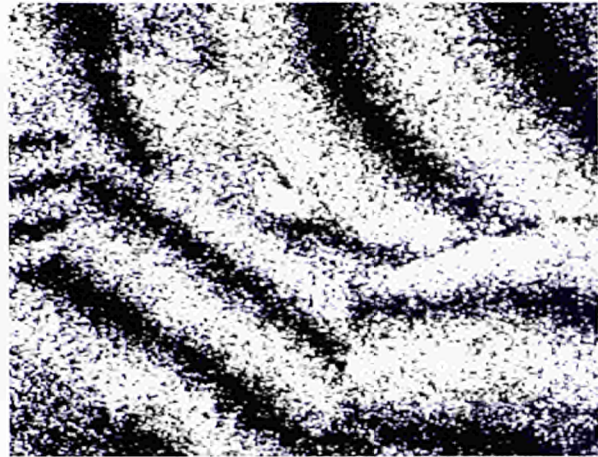

Fig 2.8. Example of an ESPI interferogram obtained on the fresco "Incoronazione dell'Assunta" (15th century). This image clearly indicates the presence of a microcrack where the speckle fringes are disconnected

loads (in collaboration with the Institute for Safety Technology).

Furthermore, an improved fiber-optic interferometer for ESPI (fig. 2.9) has been realised as the result of a graduation thesis work /10/, leading to:
- design, construction and testing of an optoelectronic device for the automatic compensation of unavoidable ambient induced phase fluctuations in the fibres;
- implementation of a fully automatic phase stepping technique for the quantitative evaluation of interferograms.

Fig. 2.7. Microdeformation measurements in the church S. Maria di Collemaggio of L'Aquila (Italy). The mural fresco named "Incoronazione dell'Assunta" (15th century) was successfully investigated. ESPI was applied to determine the location and size of microcracks, detachments and voids. This wok was carried out in collaboration with the Dipartimento di Energetica - Università dell'Aquila, L'Aquila (Italy)
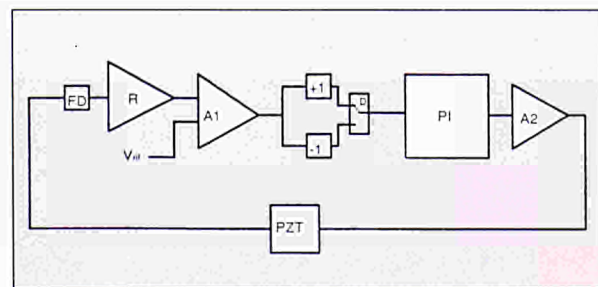
Fig. 2.9. Block diagram of the optoelectronic feedback system for phase fluctuations compensation. (Work done in collaboration with the Dep.s of Electronic Engineering of the Politecnico of Milano and of the University of Pavia).

FD	photodiode detecting phase changes;
R	trans-impedance amplifier;
A1	differential amplifier;
+1/-1	non inverter/inverter device;
D	electronic switch;
PI	proportional-integral stage;
A2	high voltage amplifier;
PZT	piesoelectric device

Applications to out-of-plane and in-plane microdeformation analysis have given successful results. The main results obtained with ESPI are here after reported.

MECHANICAL CHARACTERISATION OF STONE MATERIAL

The application of optical techniques to mechanical stone characterisation is quite new. After loading stone specimens it is possible to obtain a full-field map of deformation and from it to extract some important parameters of the inspected material.

At a first stage, compression and three-point bending experiments have been performed and the resulting distributed in-plane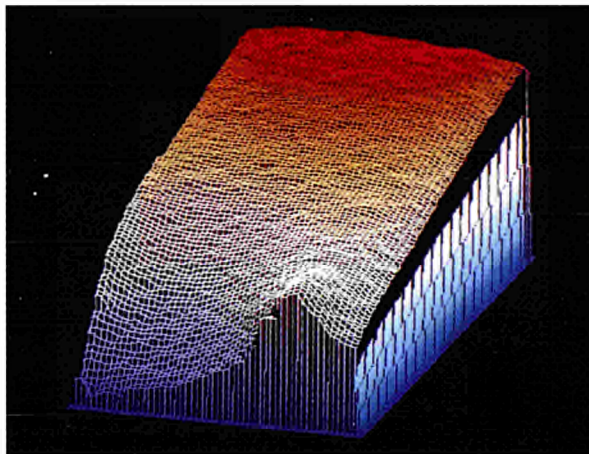 deformations have been observed in real time. *Fig.2.10 and 2.11* show the results obtained with ESPI during the compression test of a sandstone specimen.
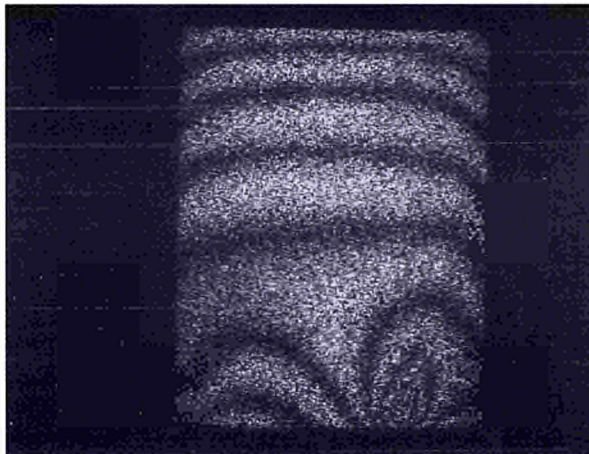
Fig. 2.10. ESPI interferogram depicting the out-of-plane deformation of a sandstone specimen (4 cm height, 3 cm diameter) subjected to a compression load of 1 KNewton

Fig. 2.11. Three-dimensional plot of the stone deformation shown in previous figure. The deformation is not uniform because of the non-homogeneous distribution of the load over the surface of the specimen

ESPI is a very useful tool because micro-deformations are observable: in this way the stone specimen characterisation can be monitored in the elastic zone (where deformations are obviously very small) before the appearance of any crack. Moreover the appearance of cracks could be observed at a very early stage. Optical techniques are very important in this field because of their non-contact properties: the use of contact transducers, especially in small specimens, can modify the real behaviour.

This work will continue in 1994, in collaboration with the Department of Structural Engineering of the Polytechnic of Milan, and is aiming at proposing new procedural standards to UNI.

STATIC DEFORMATION MEASUREMENT

ESPI offers a non-contact and whole field description of object deformation in the sub-micron range. All measurements can be done in real-time. This technique, as seen in the previous paragraph, is particularly useful in studying structures where dishomogeneus mechanical properties are difficult to predict on a pure theoretical basis. An example of application is the study of static deformations in violins.

The study of this static behaviour can be interesting for two main reasons: the first is that the violin maker can receive fundamental information to prevent any eventual structural failure of the instrument; the latter is that, since the structure of the instrument inevitably changes because of aging, the restorer, who knows the expected static behaviour, could infer the original arching. *Fig.2.12 and 2.13* show the map of the out-of-plane deformation of the back of a violin as obtained by ESPI. This work is done in collaboration with the Istituto Professionale Internazionale per l'Artigianato Liutario e del Legno Cremona (Italy).

STATIONARY VIBRATION MEASUREMENT FOR DIAGNOSTIC ANALYSIS OF STRUCTURES

Laser interferometric techniques are widely used for studying relative displacements of surfaces. In the past, holographic interferometry has been used in our laboratories for the visualisation and analysis of micro-vibrations that can take place in structures. Nowadays, the ESPI techniques allow easier and faster measurements of stationary vibrations. With this technique a very simple real-time vibrational inspection of structures can be performed (see for example *fig.2.14*).

FILTERING AND ANALYSIS OF ESPI IMAGES

Electronic Speckle Pattern Interferograms are obtained with an electronic subtraction of speckle images. Sim-
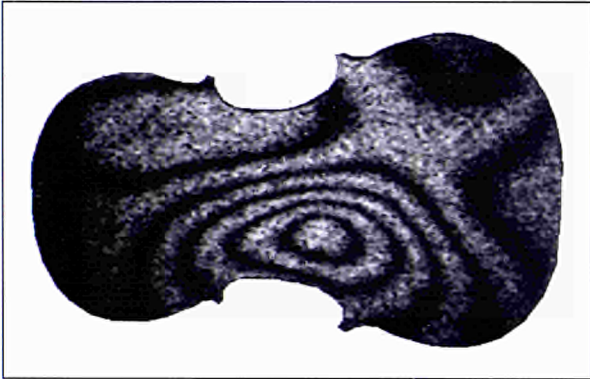
Fig. 2.12. ESPI interferogram depicting the out-of-plane deformation of the back of a violin caused by a slight tension change of the second string
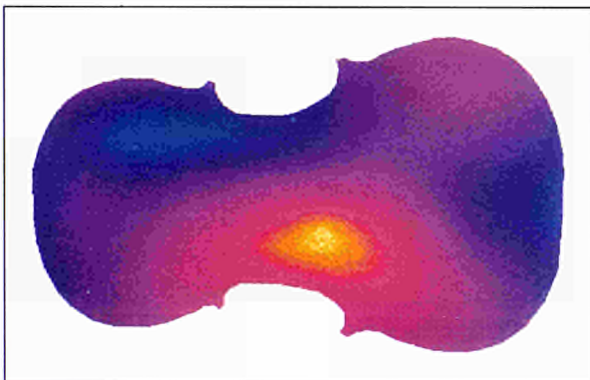

Fig. 2.13. The quantitative evaluation of the violin micro deformation is represented as a colour map. Yellow and blue areas deformed outwards and inwards respectively. Intermediate values of displacement were represented by violet coloured pixels

plicity, portability and real-time inspection make this technique sometimes more practical than holographic interferometry. However the quality of the images is lower. A quantitative evaluation of the interferograms information is difficult when the fringe contrast is low or the speckle noise is very intense. For this reason image processing techniques are very important in order to increase the signal to noise ratio. While in the last years only spatial filtering was possible, nowadays, as the speed of computers is continuously increasing, filtering in the Fourier domain are feasible: the filtering and analysis work done has led to very good results with sufficiently short elaboration time /11/12/13/.

Surface characterisation and profiling

The method of surface contouring based on the Fourier analysis of interferometric fringes projected with optical fibres has been fully implemented/14/15/.
The method (whose development was started in 1992

as an exploratory research), based on digital correlation of speckle images for the diagnosis of stone surface modification, has been improved. Tests have been performed during chemically induced modification of surfaces. Real time monitoring of micro structural changes of stone surfaces during salt crystallisation cycles has been achieved /16/17/. The method constitutes a real progress (i.e. the method is faster, really non destructive and shows higher sensitivity) compared with the classical methods of inspection. It could be effectively applied in the investigation of the decay of buildings and their protection. *Fig.2.15 and 2.16* show two correlation images of the speckles from two different types of stone used in ancient buildings.

Structural Diagnostics By Volumetric Techniques

The technical capabilities of the DAM laboratory have been enhanced with the installation of 200kN hydraulic grips and of a high precision extensometer to our Universal Testing Machine. The corresponding computer programme DITE (Damage Investigation by Thermal Emission) for acquisition and analysis of thermal emission data has been upgraded accordingly, as well as the high frequency digital Transient Recorder and Waveform Analyser.

Quality assessment of aeronautical adhesive joints by Acoustic Emission measurements

The work, conducted within the frame of the EAMA (Acoustic Emission from Aerospace Materials and structures) group activities, is a prenormative research for the development of standards for the application of Acoustic Emission to aeronautical materials. The focus is at
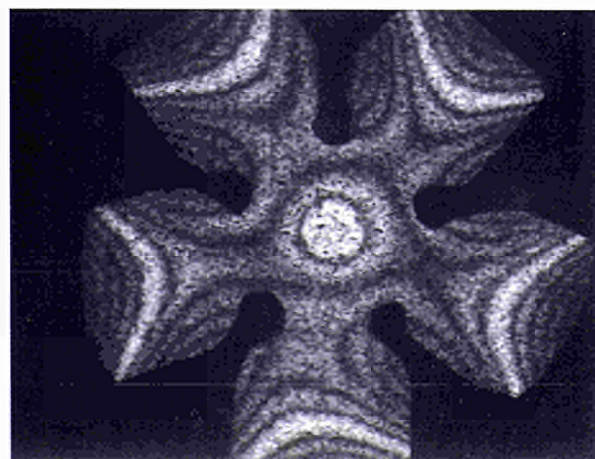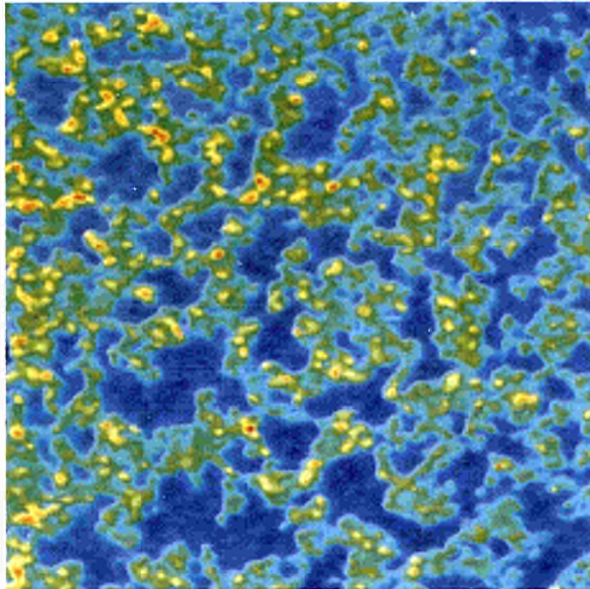

Fig. 2.14. ESPI interferogram depicting the stationary vibration of an impeller model in the presence of an acoustic wave at a frequency of 647 Hz

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Fig. 2.15. Correlation image of a sample of the "Pietra di Angera" stone (mostly composed of carbonates). False colours represent areas of different correlation. The blue pixels have the highest correlation (no surface change detected) and the yellow-red pixels have the lowest. Pixels with intermediate correlation are green
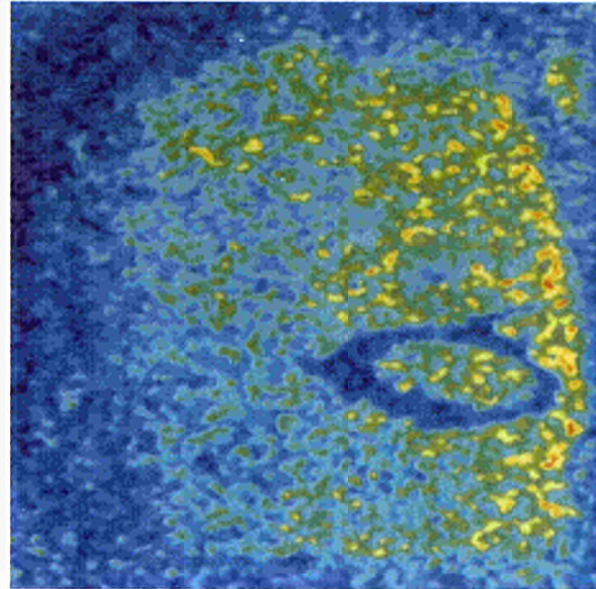
Fig. 2.16. Effects of the presence of a tubulo on the correlation image for a stone specimen of the "Biocalcarenite di Noto". The efflorescence phenomenon is less active along the edge of the tubulo (blue ring in the centre of the image)

present on the quality analysis of aluminum-aluminum bonding with epoxy resin adhesive. Adhesive joints are increasingly entering the construction engineering field, and in particular that of avionics. They offer certain advantages over other connector forms (bolts, rivets), such as reduction of stress concentration across the joint, increased joint stiffness, possibility of joining dissimilar materials etc. It is the objective of this study to investigate the possibility of utilising acoustic emission techniques in real time during the adhesive joint curing process for assessing the bond quality.

The specifications for a joint experimentation on this subject have been defined. The preparatory phases of this project have been completed. A temperature controlling unit and special heated plates/grips have been prepared. The aluminum specimen and the adhesive have been supplied by the aerospace firm ALENIA (Pomigliano d'Arco, Italy).

Preliminary tests have been performed at the Agusta-SIAI Marchetti (also a member of EAMA) because of their know-how in adhesive bonding and the availability of a hot press at their labs. A supported film epoxy adhesive has been used whose polymerisation cycle is approximately 120°C in a hot press for 90 min at a pressure of 2.45 kg/cm². Results obtained from these experiments exhibit some type of dependence on the quality of bonding, and show three different patterns of activity corresponding, respectively, to the heating-up,

the constant temperature and the cooling-down phases of the process (see *fig.2.17*).

The planned AE tests are being performed during 1994 by four laboratories: JRC-ISEI; University of Roma; University of Napoli; CIRA. The aircraft manufacturers will supply the material and the necessary assistance and know-how in avionic structure and materials.

In the last months of 1993, also Centro Ricerche FIAT
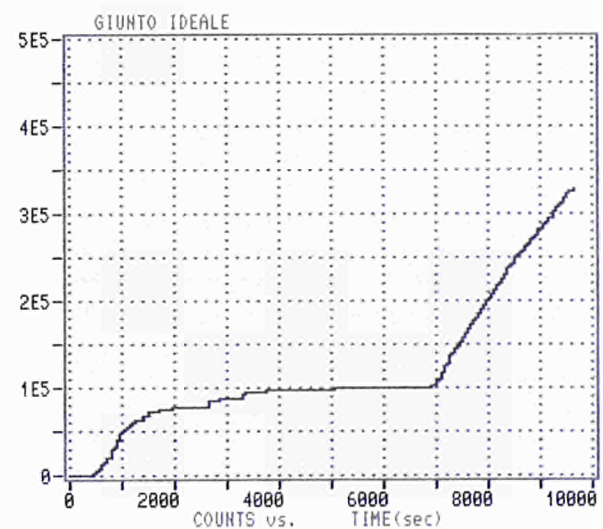
Fig. 2.17. Typical acoustic emission counts vs time graph of a bonding polymerisation cycle. The three phases (heating up, constant temperature, cooling down) of the process are evident

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(CRS, Orbassano) has expressed interest for this problem and is asking for a collaboration agreement.

Damage accumulation estimation

VIBRATION MEASUREMENTS USING LASER INTERFEROMETRIC TECHNIQUES

The activity aims at identifying vibrational modes and at estimating modal damping, which may prove a reliable indicator of damage accumulation. Qualitative and quantitative studies of vibrations have been conducted using holographic interferometry and ESPI methods. Experiments have been performed on aluminum and steel beams and circular plates with clamped boundary conditions. Sinusoidal sound waves of known properties are used for the excitation, and the natural frequencies are identified when a clear visualisation of the corresponding nodal system (see *fig. 2.18*) has been obtained. These experimentally found natural frequencies are compared with the theoretically calculated ones, and estimates of the modal damping are accordingly derived. These values exhibit satisfactorily the proper trends.

Fig. 2.18. Inteferometric fringes corresponding to a nodal vibration system of a circular clamped plate. One nodal diameter and one nodal circle are clearly visible

THERMAL EMISSION MEASUREMENTS

A new methodology for high cycle fatigue damage assessment, based on the microscopic approach, has been developed and tested (for constant amplitude fatigue loading). A preliminary agreement has been reached with the Centro Ricerche Fiat (CRF, Orbassano) for a collaboration in the field of experimental/theoretical approach to metal fatigue limit estimation via thermal emission techniques and stored energy concepts /18/19/20/.

Stricly related to the problem of damage accumulation and its measurement is the problem of plant maintenance and inspection. A reliability and life-time prediction based approach to maintenance planning is being developed in collaboration with ENICHEM /21/.

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Photovoltaic Systems

Sampling Flash Radiometer

Spectral radiometers measure the spectral irradiance of a light source, that is, the light intensity in a particular wavelength interval throughout the whole wavelength range the light source can emit. ESTI has need for this type of instrument for the purpose of calibration of photovoltaic devices. All data measured have to refer to a particular, standardised spectral irradiance distribution (Air Mass 1.5 global, IEC 904-2), which cannot be reproduced well enough by artificial light sources and only occasionally under natural sunlight conditions. By measuring the actual spectral irradiance during the calibration, one can correct for Air Mass 1.5 conditions as long as the spectral response of the device under test and its reference is known. During outdoor calibrations at ESTI, a commercial spectroradiometer is used to determine this correction. However, no instrument is available to measure the spectral irradiance of the laboratory large area pulsed simulators at ESTI at the time of a calibration measurement, as the duration of the light pulse (2 ms) is by far to short for commercial instruments. ESTI is developing a fast radiometer for this purpose.

The principle is as follows: as high wavelength resolution is not necessary, the concept does not utilise usual monochromators. Instead, an array of 64 optical bandpass filters (bandwidth about 10nm) is used, to cover the range of interest (300nm.1200nm, silicon absorption range). Each filter has its own detector system and is housed in its separate aperture system. The detectors are to be optimised for the wavelength of the bandpass filter, but are for the majority of the 64 wavelength normal silicon photodiodes. The mechanical construction [see *fig. 2.19*] allows the exchange of any of the selective detector systems (including apertures and filters), so as to adopt other wavelength ranges of interest. The photodiodes are operated in current mode. In contrast to the voltage operating mode, the signal is much smaller, but almost linear over wide range of photon flux. The electrical signals of the 64 detectors is fed to a multiplexed amplifier systems, with a subsequent digitiser to allow processing by a computer. The multiplexer samples each detector for 64 microseconds before switching to the next detector of the array. After whole scan, which takes 409.6 microseconds, the multiplexer starts at the first array element again, and the sequence number of each sample can be related to the wavelength. The data rate for the digitiser is 156250 samples per second, a speed which can be handled by a few plug-in boards for a normal personal computer.

During the light pulse of one of ESTI's solar simulators, 4 or 5 spectral irradiance curves can be stored. This allows the on-line correction of the device data to the non-perfection of the simulator light. In addition, a permanent control of the flash-bulb degradation is possible, which enhances the time of usage of the flash bulb. Other application of the instruments in remote sensing or environmental research are possible.

(during bad weather, or at night), recording was suspended.

The measurements were taken from September 1992 until August 1993, totalling in about 23000 data sets.

To analyse the data, a three-dimensional matrix was created, with the ambient temperature in columns and the solar irradiance in rows. The average of power values found at a certain ambient temperature and irradiance constitutes the value of a matrix element. *Fig. 2.20* demonstrates the graphical output of this analysis.

The colour coding is related to the measured average power. The maximum power as measured in the laboratory for Standard Test Conditions (STC) for this module is 48.W.
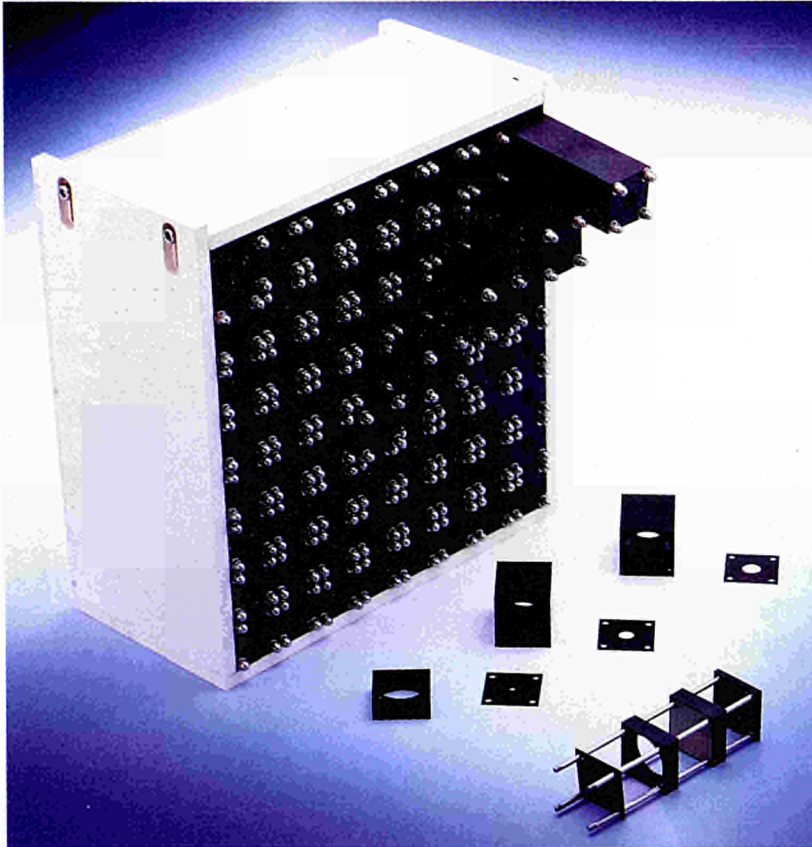
This plot allows to draw some conclusions:

Fig. 2.19. Mechanical construction of the fast spectral radiometer

Standard Procedures

Power Output of Photovoltaic Modules under Real Operating Conditions

With the increasing commercialisation of Photovoltaic (PV) Solar Electricity, a stronger competition between manufacturers is observable. In this context the question was risen by some Standards committees, to which extent declared performance values as published by the manufacturer on data sheets are of use for the end user, and how they compare to reference measurements as provided by ESTI.

To give input to this discussion, ESTI measured the outdoor performance of a single module for 12 months. This experiment required to trace the current-voltage characteristics of the module every 10 minutes. In addition, environmental data such as ambient temperature and solar irradiance were recorded. Module temperature was measured by a PT 100 temperature sensor attached to the rear. The mounting of the module corresponded to the requirements of IEC 1215, test "Determination of the Nominal Operating Cell Temperature". Whenever the solar irradiance as measured by a silicon reference cell was below 100 W/sq.m

- The STC power output can only be found on cold days (ambient temperature below 0 deg. C) with high irradiance. This fact is certainly not new but not usually sufficiently known

- The graph allows the determination of the power at nominal operating conditions (ambient temperature 20 deg. C, irradiance 800 W/sq.m), which results to be 35 W

- Data presented in this way allow to forecast the actual performance under any conditions at different locations of Ispra. It requires only the knowledge of ambient temperature and irradiance for a particular geographical location, which can be found in meteorological reports

- An interesting effect can be revealed at irradiances around and below 500 W/sq.m: The power of the module is almost independent of the ambient temperature, differently from decreasing with higher ambient temperatures, as can be seen at higher irradiance values. Apparently other cooling effects, such as wind, play a role at the relatively low irradiance. It might also well be the case, that at low currents the positive temperature coefficient of current compensates the negative of the voltage.

As a conclusion one can say that manufacturers could use this type of data representation to show the expected performance of their product under real operating conditions. ESTI will propose this method to the Standards organisations (*fig. 2.20*).

Basic Research on Physics of Photovoltaic Devices

In the context of the scientific collaboration with the Photovoltaic research group at the university of Ferrara the possibility of producing very thin (70 um) solar cells of an efficiency suitable for large scale applications was investigated. This study was triggered by the recent growing of dislocation-free, 3-grain ingots that allow thinner slicing than single -crystalline ones.

A numerical 2-D code for the simulation of silicon cells was developed, based on finite difference discretisation and the uses of Newton's method for the solution of the resulting set of non-linear algebraic equations. The very large sparse system is solved with a SOR (Successive Over Relaxation) procedure.
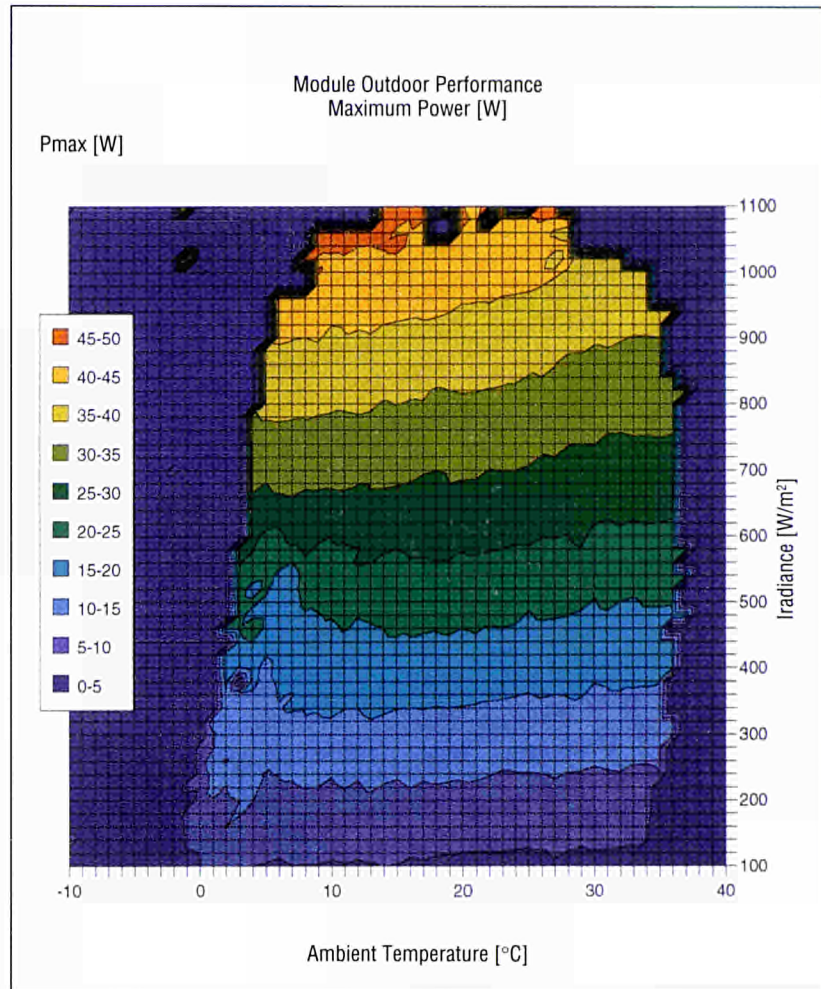

Fig. 2.20. Outdoor performance of a Photovoltaic module during 12 months. The graphs allows to predict the power output by selecting a particular ambient temperature and irradiance and then looking up the corresponding colour code for Pmax

ENVIRONMENT/REMOTE SENSING

Centre for Earth Observation (CEO)

The JRC is participating with ESA and other national organisations in the creation of the European Earth Observation System, an end to end service which will provide the users with satellite data on Earth Observation. In particular, the JRC is developing as part of EEOS the CEO - Centre for Earth Observation - a coordinated, decentralised European network which will deal with these data and their use. It will address scientific users, policy makers, as well as socioeconomic and commercial operators.

CEO Feasibility Phase

In 1993 the Feasibility Phase of the project has been successfully terminated and the following phase, the Pathfinder Phase, initiated.

The Feasibility Phase consisted in a Feasibility Study accompanied by two Feasibility Demonstrators which were developed by the IRSA and EI institutes to illustrate some basic concepts of the proposed functional architecture.

The Feasibility Study, which was the main achievement during this Phase, has been carried out by an International Consortium led by the National Remote Sensing Centre, UK /1/; the study brought to numerous useful information (e.g.: horizontal and vertical definition of the system, Collaborating Institutes, etc.); the main result was the development of a conceptual model of CEO built around the definition of a series of "User Communities" which, by addressing particular applications (e.g. environment monitoring, global change, agriculture, regional and urban development, etc.) try to partition and organise the overall Earth Observation user population.

Each "User Community" is a collection of logically or physically connected Collaborating Institutes and users. Typical functions of Data Brokers and Data Pools inside the User Communities have also been defined. The various "User Communities" will be monitored and tied together by a CEO Coordinating Facility which will thus assure the users with interoperability and interdisciplinarity of the system /2/.

The results of the Feasibility Phase have been reviewed and accepted by an ad hoc Steering Committee with representatives from Member Countries.

CEO Pathfinder Phase

The JRC Board of Governors agreed also on the start of the following CEO Phase, i.e.: the Pathfinder Phase. A detailed planning of this phase has been prepared and the Pathfinder Phase Steering Committee has reviewed it.

The aim of this phase is basically the definition of the following phase of the project, i.e.: the Design and Implementation Phase as far as its content, organisation and funding aspects are concerned. This will be achieved through

– a careful assessment of the Earth Observation Data networks and projects already existing

– a detailed analysis of the user requirements of the User Communities, Collaborating Institutes, existing projects in terms of data, services, infrastructure, expertise and, eventually,

– a definition of the CEO conceptual model to be implemented in the follow up of the project (including a cost estimate).

CEO Technology Support Laboratories

In parallel to the main management and coordinating activities of the CEO Project, the activities of two laboratories have been started with the aim of supporting the project studies with tests and pilot implementations:

– Laboratory for the Analysis of Remote Sensing Applications

– Laboratory for Computer Aided Cooperative Activities

LABORATORY FOR THE ANALYSIS OF REMOTE SENSING APPLICATIONS

In order to test new informatic solutions and new remote sensing application domains, HW/SW facilities for image processing have been acquired and implemented.

Particular attention has been given to the preparation of a CEO Pathfinder Phase Study on the set up of a Urban Development User Community. To this aim, a Feasibility Study on the use of remote sensing techniques in urban environment applications has been performed with the help also of a contract given to APSYS (F): two cities - Seville and Strasbourg - have been in particular addressed by remote sensing image analysis /3/.

Following the positive results of this Feasibility Study a major project on the Urban Development User Community has been subcontracted to a consortium led by

Telespazio (I) with the participation of GAF (D), Da Vinci (B) and ATC (GR).

Another application field of remote sensing techniques has been also approached: Marine Coastal Zones; the launch of a project on this particular CEO User Community has been prepared.

LABORATORY FOR COMPUTER AIDED COOPERATIVE ACTIVITIES

The Information Technology - IT - architecture of CEO will be composed of different layers: the two basic IT levels of 'communication facilities' (e.g.: distributed data) and 'data access and management' (e.g.: shared meta data) will be complemented by a 'coordination and collaboration' layer (e.g.: designing applications) and eventually by a 'business process' upper layer allowing the shared (re)design of processes. Adding these two last layers to the Information Technology architecture will allow the CEO to be flexible and responsive to the end-users and to market needs.

In this context various methodologies have been reviewed and examined which will help in the analysis of the CEO organisation structure, and in particular of the CEO 'User Communities'.

A 'Workflow' technology, focused on human behaviour which particularly tracks the interaction of people, has been retained and tested on an ongoing JRC remote sensing project: its use has provided valuable insights for a possible re-engineering of the project and also for the assessment of the capabilities of this technology in analysing and supporting organisational set ups.

The process being analysed is the action 'Rapid Estimates of Changes in Crop Acreages and Potential Yield' of the MARS project (Monitoring Agriculture with Remote Sensing) /4/; the Workflow technologies used is the Action Workflow Analyst tool derived from the speech act theory by Winograd /5/.

A CEO Pathfinder project has also been prepared and launched in order to identify the technological and organisational solutions which will enhance communication and cooperation between users, Collaborating Institutes, data suppliers, in a typical User Community and will allow (re)design of the related processes.

The project called ICSA - Information Cooperative for Sharing and Analysing Remote Sensing Data - has been subcontracted to a consortium led by UMIST (UK), other participants being Siemens (D), the University of Siena (I), QMW (UK).

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Data Visualisation and Animation

In the area of data management and data visualisation the following projects have been successfully carried out in support of Remote Sensing programme.

Digital Video Animation

A hardware and software system for producing video animations of geographic and ocean modelling data has been developed. This work has been performed as part of the JRC contribution to the Eureka Project VISIMAR. Two demonstration videos were produced and shown at various external meetings. A system is
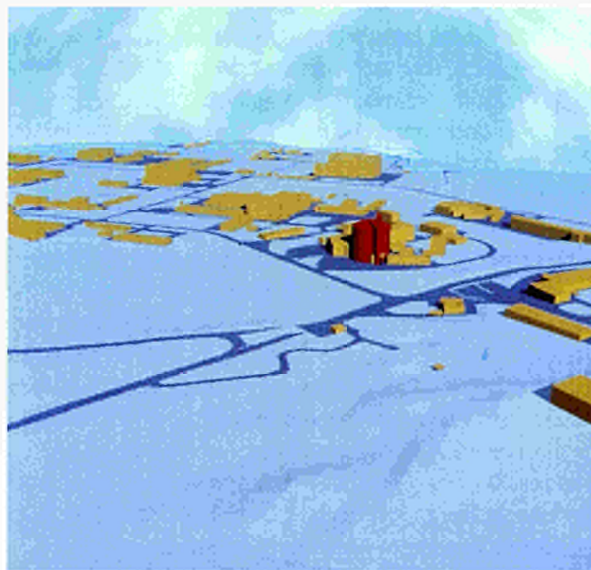

Fig. 2.21. A Ray traced image of a GIS data base of Ispra site - ECOCENTRE project, and a 5 min resolution elevation model rendered from a height of 300 km.

currently under development to allow editing of video clips and incorporation of special effects.

In order to produce high quality animations, new visualisation techniques have been investigated. Ray tracing has been found to be particularly effective at rendering 3 dimensional scenes. *Figure 2.21* gives some examples of our results using this method.

10 year Archive of Global Meteorological Data

An on-line data base of ten years of daily meteorological data has been installed on the optical storage device of the Institute for Remote Sensing. This work has been carried out under an inter-institute contract. The data originate from the European Centre for Medium Range Weather Forecasting (ECMWF). Special access software has been written to allow a user to specify a time and space selection in order to extract sub-sets of data. This access software is now integrated into a Mosaic WEB server set up by the Marine Environment unit of IRSA.

A graphics interface to the ECMWF archive has been written. This software - meteo' displays the weather for any region and any day within the last 10 years. The

software can also overlay weather information onto satellite images, such as CZCS ocean colour images. Animations of the development of weather within any time period may also be produced. *Figure 2.22a/b* shows a computer generated image of cloud and wind data for 1st July 1986.
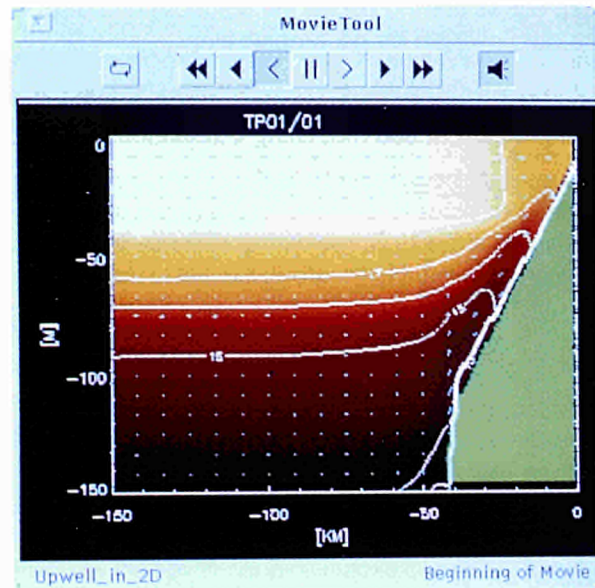
Fig. 2.23. A 2-d vertical profile of ocean temperature calculated by ISPRAMIX and visualised by Hydra. This shows the development of an upwelling of cold water off West Africa coast
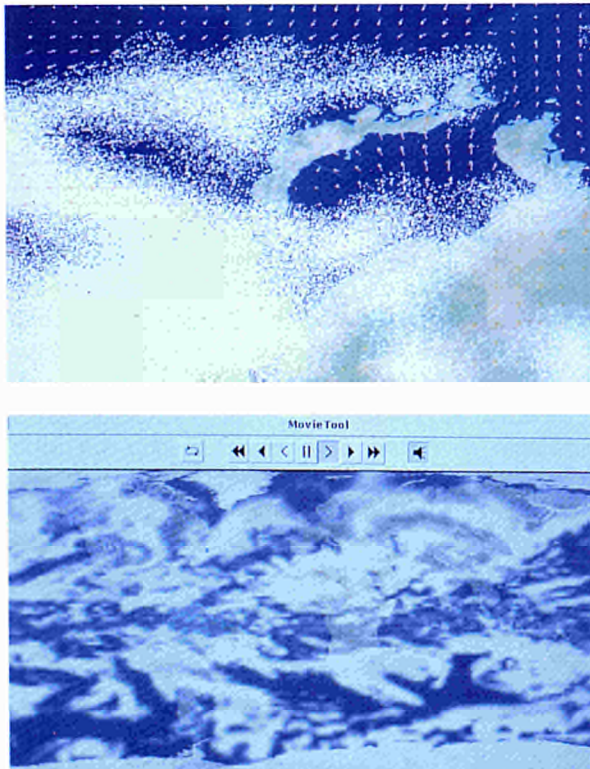

Fig. 2.22 a/b. Artificially generated cloud and wind images. A) Japan B) The world for 1 July 1986. (Data from ECMWF archive)
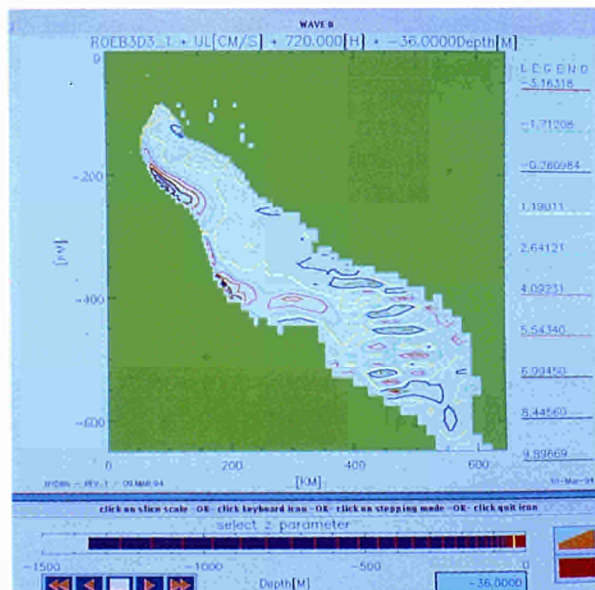
Fig. 2.24. A 3-d visualisation of Ocean temperature profiles for Northern Adriatic calculated by ISPRAMIX and visualised by Hydra

Geophysical Database

A database of reference geophysical data has been set up based on the EDF software /1/. This database runs on a server machine and is accessed by client Unix workstations. The database includes a 5 min global topography, monthly 3-d world oceanographic data for salinity and temperature, and selected meteorological data. The Xmap programme /2/, developed by ISEI, allows users to access the database and display the data overlaid on geographic maps.

Visualisation of Sea Modelling Calculations

The results of the Ispramix code (IST/IRSA) for modelling ocean processes in 2-d and 3-d are stored and visualised using software written during 1993 by ISEI /3/. A new programme - Hydra allows the user to define slices in any projection within a volume of ocean. The sea bed is derived from the data and displayed on contour plots of any hydrodynamic variable. *Figure 2.23* shows a vertical cross-section of ocean off the West African coast during a development of an upwelling of deep cold water. *Figure 2.24* shows a 3-d representation of sea temperatures for the northern Adriatic.

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ENVIRONMENT/INDUSTRIAL HAZARDS

Industrial System Environment Management

Industrial System Environment Management

The focus of this activity emerged from the evolution of environmental management, in which complex decision problems arise, towards the use of formal multicriteria methods (MCDA) and informaton systems aimed at helping decision-making (DSS). Current society requires from different scientific disciplines aids in the assessment and management of these kind of problems. This research is in line with the interest of the Institute for Systems Engineering and Informatics which is now entrused with many tasks concerning protection of the environment. At the same time the Commisssion's Institutional responsibilities have been extended to an intense regulatory and promotional activity on matters at the interface between science, technology and society, leading the Institute to use its technical and scientific expertise to a greater extent in support to these.

As a result of this evolution the ISEI interest is confirmed in developing and implementing several novel approaches and the most advanced formal techniques for providing the best scientific inputs to complex decision problems, such as: the limitation of the impact on the environment of potentially dangerous industrial plants, and the best management of water or energy resources. An important common theme of the tasks undertaken, could be easily identified in the focus of all activities on the management of environmental risks /1/. The activities show deep uncertainty in the systems being studied and legitimate diversity of users in the relevant environmental issues.

Our approach explicitly recognises and copes with uncertainties, diversity and qualitative considerations. It does not accept to eliminate them with algebraic formalisms or computer simulations. Rather it tries to design a synthesis of the subjective and objective aspects of a problem, achieving a system harmony within these methods. By our activity the energetic methodology of DSS has been enhanced by the integration of MCDA techniques. Because of the global and complex nature of environment management applications, more than one MCDA method can fit within a multicriteria DSS methodology /1/3/. Moreover we defined a set of requirements, satisfying both the user's as well as the Commission contextual concern. The scientific relevance of the activity was reflected in publications in international journals, in scientific collaborations, in papers presented to conferences and in the participation in many training and education activities (for example, the European Master Degree Programme (EAEME, 1992-1993) /2/3/4/.

An important activity undertaken during this year was the organisation at Ispra of the Annual Meeting of the European Working Group on MultiCriteria Aid for Decision, in which, for the first time, specific application of MCDA to environmental management was the focus of discussions. The proceedings of the Conference are going to be published by Kluwer.

Applying Multicriteria Aid for Decision to Environmental Management

This activity is centred around complex decision problems. These have emerged as the key issues of environmental management, together with the use of multicriteria aid for decision methods. Current problems in this area cannot be solved on the basis of one criterion of choice, that is by the optimisation of just one criterion /12/9/8/ /7/. Therefore, multi-criteria methods have been developed to reflect a plurality of perspectives also in the area of waste management /2/5/6/10/.

The NAIADE Method

In this framework a new multicriteria method, based on some aspects of the partial comparability axiom, called NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) is developed /4/. It is a discrete multicriteria method whose impact (or evaluation) matrix may include either crisp, stochastic or fuzzy measurements of the performance of an alternative with respect to a judgement criterion, thus it is very flexible for real-world applications. From an empirical point of view, this model is particularly suitable for economic-ecological modelling incorporating various degrees of precision of the variables taken into consideration. From a methodological point of view, two main issues are then faced namely.

– The equivalence of the procedures used in order to standardise the various evaluations (of a mixed type) of the performance of alternatives according to different criteria;

– The comparison of fuzzy numbers typical of all fuzzy multicriteria methods.

The NAIADE method presents different theoretical properties which are not shared by traditional multicriteria methods in a fuzzy environment. Since in environmental and resource management and policy aiming at an ecologically sustainable development many conflicting issues and interests emerge, particular attention has to be given to the problem of different values and goals of different groups in society. In NAIADE we propose the use of conflict analysis procedures to be integrated with multicriteria evaluation in order to allow policy-makers to seek for "defensible" decisions that could reduce the degree of conflict (in order to reach a certain degree of consensus) or that could have a higher degree of equity on different income groups. The planning balance sheet method aims at providing a broader framework for the assessment of gains and losses of a plan by constructing detailed socio-economic accounts of all project effects and by taking into account different groups in society which are affected in their well-being by the plan. A weak point of this method is that it is primarily meant to present in a systematic way a description of all the distributive impacts, but no elaboration with normative purposes is generally made. As a possible way to overcome this drawback of the planning balance sheet method we propose a fuzzy conflict resolution procedure. Starting with a matrix showing the impacts of different courses of action on each different interest/income group, a fuzzy clustering procedure indicating the groups whose interests are closer in comparison with the other ones is used. Therefore, finally a compromise solution taking into account all the three conflictual values of economics (efficiency, equity and sustainability) can in principle be identified.

The Water Management Case Study

The empirical relevance of the developed mathematical procedures is tested by means of a real-world environmental management problem (in the area of the Delta of the Po river in Italy). From an ecological point of view, one of the most important areas in the whole Po river basin is the Delta region; in this region it has been decided to establish a natural park. The Mesola wood is a part of exceptional environmental value of the Po Delta natural park. In this wood, a sharp conflict between environmental and economic aspects seems to exist. Moreover, different interest/income groups are present.

From this case study the following main conclusions can be drawn:

- multicriteria evaluation can help in finding a compromise solution between conflictual ecological and economic objectives;

- the use of fuzzy sets can be a very useful tool in modelling environmental management problems characterised by deep uncertainties and approximate evaluations;

- the mathematical procedures developed in this study, can be an efficient tool to deal with efficiency aspects, equity aspects and economy-environment interactions of an environmental problem (*fig. 2.25*).

Group Decision and Negotiation (PRODEST System)

During the year PRODEST /14/ a prototype of a Group Decision Support System aimed at giving a detailed documentation of the history, the formal representation and conflict resolution of a given decisional process was developed. PRODEST is based on knowledge bases with hypertext characteristics, aimed at facilitating a versatile interaction with the user. The negotiation of conflicts is assisted by communication, voting and pricing (premium) tools, which are based on the hypertext structure and on other information captured (resident) by the system. One of the basic assumptions during the design of PRODEST is that in a group decision process various important tools may facilitate the decision making process. These may be reasoning and communication tools. The PRODEST prototype is aimed for representing, structuring and documenting a group decision process; the whole system is conceived to be integrated with a collection of multicriteria decision analysis tools. The structuring phase is assisted by tools which enhance each decision-maker's ability of "dominating" the problem, trying to reduce the global complexity and making the decision-makers cooperate.

To reach an agreement, the decision-makers can use two ways of representation and communication:

- a formal one, allowing to organise their choices and to give them a rational base;

- an informal one, that allows information that cannot be easily reconducted to the given formal notation to be shared, or that can be used for dealing with other aspects of negotiation, in particular the socio-emotional ones. PRODEST is implemented in the Microsoft Windows graphic environment, using the graphic and hyper-textual application development tool ToolBook from Asymetrix Corp.

The PRODEST package is structured on three levels:

- representation and documentation

- analysis and ranking tools;
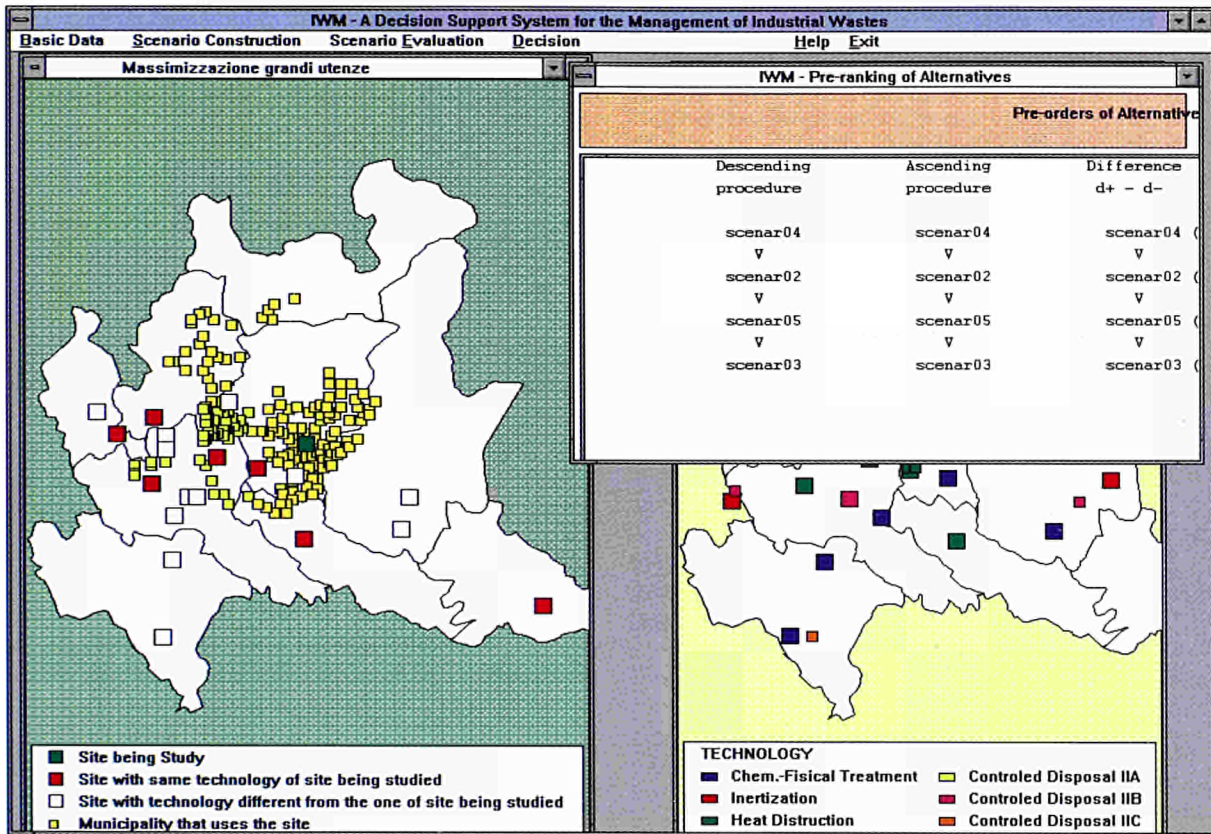
- informal communication tools.

Fig. 2.25. User interface of a DSS for the management of Industrial Wastes

Implementation of this prototype privileged the above level 1, because it is the main support for the "explicitation phase" of the decision model we are dealing with. The level 2 consists only of a classical multicriteria analysis tool (weighted average) and of other more specific tools working on the structure of the PRODEST environment. Level 3 consists of a simple personal and public annotation system.

Analogical Use of MCDA Theory

MCDA theory can provide the analytical tool for the suitable solution of aggregation problems /15/; when one is thus cumulating different parameters linked to the same phenomenon in just one indicator. An attempt to base the formulation of a systematic approach on MCDA theory has been developed, particularly for water quality indicators. In practice various water quality parameters have been formulated in relation to their different uses, taking account of the quality thresholds considered necessary for each use.

The following problems have been tackled:

– Evaluation of the importance of the various water quality indicators. On the basis of the opinion of various experts, and using quality standards established by national and international legislative organisations, the method can give a sliding scale of the importance of the various indicators (not only ordinal but also cardinal) as a function of the water body studied and the water use planned.

– aggregation in a single indicator. The method makes clear the meaning of the aggregation and the importance of each component. In fact it formulates standards, generally given implicitly without clarifying the meaning and avoids naively and mistakes in adopting the aggregation function. In the applications up to now we have used various techniques such as, dealing with discrete problems, ELECTRE, REGIME, PROMCALC and PRAGMA /11/. Despite some differences they have all indicated a substantial convergence of results.

Which technique is most suitable for the specific application must be established in the context of each real case.

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Applications of Geographical Information Systems

In order to set up any decision support system for environmental management a base of information on the terrain involved is required together with the means for accessing, manipulating and displaying it /1/2/. Spatial analysis applied to geo-referenced data is also frequently required to derive criteria on which to base decisions. For this reason an activity started in the fields of Geographical Information Systems (GIS) and Spatial analysis, and their application to Environmental Management. The last year saw several enhancements to the hardware and software resources in this area including Personal Computers and a workstation equipped with Intergraph GIS products, the Oracle database, the MAP- INFO system for personal computers and the Digital Chart of the World data set on CD-ROM. Existing competences were further developed by attendances to appropriate training workshops, conferences and specialised training courses.The following subsections describe projects in which these resources and competences were applied. A GIS has also been set up for the Ispra ECOCENTRE project.

A Prototype GIS for Environmental Management in the Attert Natural Park

The commune of Attert, in the south east corner of Belgium, bordering with Luxembourg, has recently applied for, and been granted, the status of Natural Park, within the framework of the Ardennes-Eifel Interreg Programme. This presents those concerned with the management of the territory, including the inhabitants, with an opportunity to move towards policies of more sustainable environmental management. The management practices of recent decades should be changed in order to optimise the benefits for the whole community in the long term, and to adapt for the disorientation that has occurred in the past due to changing agricultural policies. To this end it has been proposed that a GIS should be implemented as a first practical step in designing plans for more rational management. As part of a thesis project in the European Masters Programme a prototype GIS was implemented, including digitised maps of the existing sector plan, the forest areas, soil types, geology, landscape characteristics, and river and road networks. This prototype was used to illustrate how the GIS can be used not only for spatial analysis related to management options, but also as an effective means for communication of ideas and proposals to interested parties. Spatial analysis was used to find areas where tree planting has occurred outside the existing sector plan, and to highlight areas which are appropriate or inappropriate for certain types of agricul-

tural activity. This has allowed a new plan for land use allocation to be proposed which aims to achieve sustainability. The prototype GIS has proved useful in helping to convince local and regional authorities of the need for a more comprehensive installation for use in on-going planning and management of the natural park, and a consortium is now being assembled to build on this work and develop a fully operational system for use in the management of the Natural Park (*fig. 2.26*).

Spatial Analysis and Earthquake Risk

The project has three main objectives:

- to demonstrate the potential and possibilities of using a Geographical Information System for storing and interrogating the European Earthquake Cata-logue.
- to explore and demonstrate the application of Spatial Analysis techniques to analyse the relation-ship between earthquake events, population and locations of industrial/nuclear facilities.
- to prepare a draft report entitled "Spatial Analysis and Earthquake Risk Assessment".

A preliminary test of the feasibility was carried out by installing some of the European Earthquake Catalogue data on the SPANS Geographical Information System and testing the facilities for data interrogation and selection. Collection of further data required for the study in digital form, including European Regional Boundaries, locations of nuclear facilities and cities continued until the end of 1993.

The three phases now foreseen are:

- Loading of basic maps and tabular data to SPANS GIS.
- Application of Spatial Analysis to explore the rela-tionship between earthquake events, population and locations of industrial/nuclear facilities, and to derive example risk maps for one selected country or region.
- Preparation of draft report.

Phase one will begin in early 1994.

Risk and Environmental Management of Transport of Dangerous Goods

The Risk Analysis Programme XTRIM

The XTRIM programme, which has been developed in the previous years, was refined during 1993, and a new version, version 2.3, was produced. XTRIM is used for the evaluation of the risks to humans of transport of dangerous goods by road and rail. The results are presented in a frequency-fatality diagram, in terms of travel-time, travel-distance, number of transports, the expected cost, and the expected number of fatali-ties. An example of the results from XTRIM is shown in *figure 2.27*. For version 2.3 a number of changes have been made. First of all, a general clean-up of the code has been performed. Secondly a thor-ough testing has been done, and all the bugs found have been fixed. The programme interface has been changed to become more user friendly and a set of control variables, assuring the cor-rect use, has been implemented. Several new tank containers databases have been constructed, and the databases for Denmark have been upgraded. After these changes, the programme has been used by two students, to evaluate the overall risk from the transport of dangerous wastes to a waste treat-ment plant in Denmark.
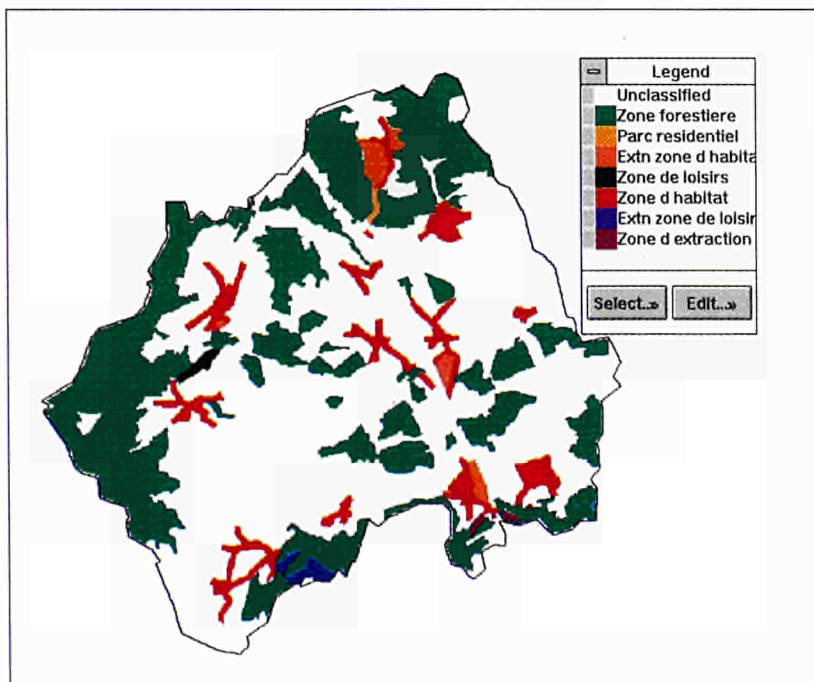

Fig. 2.26. The sector plan for the Attert natural park, viewed using the Geographical Information System
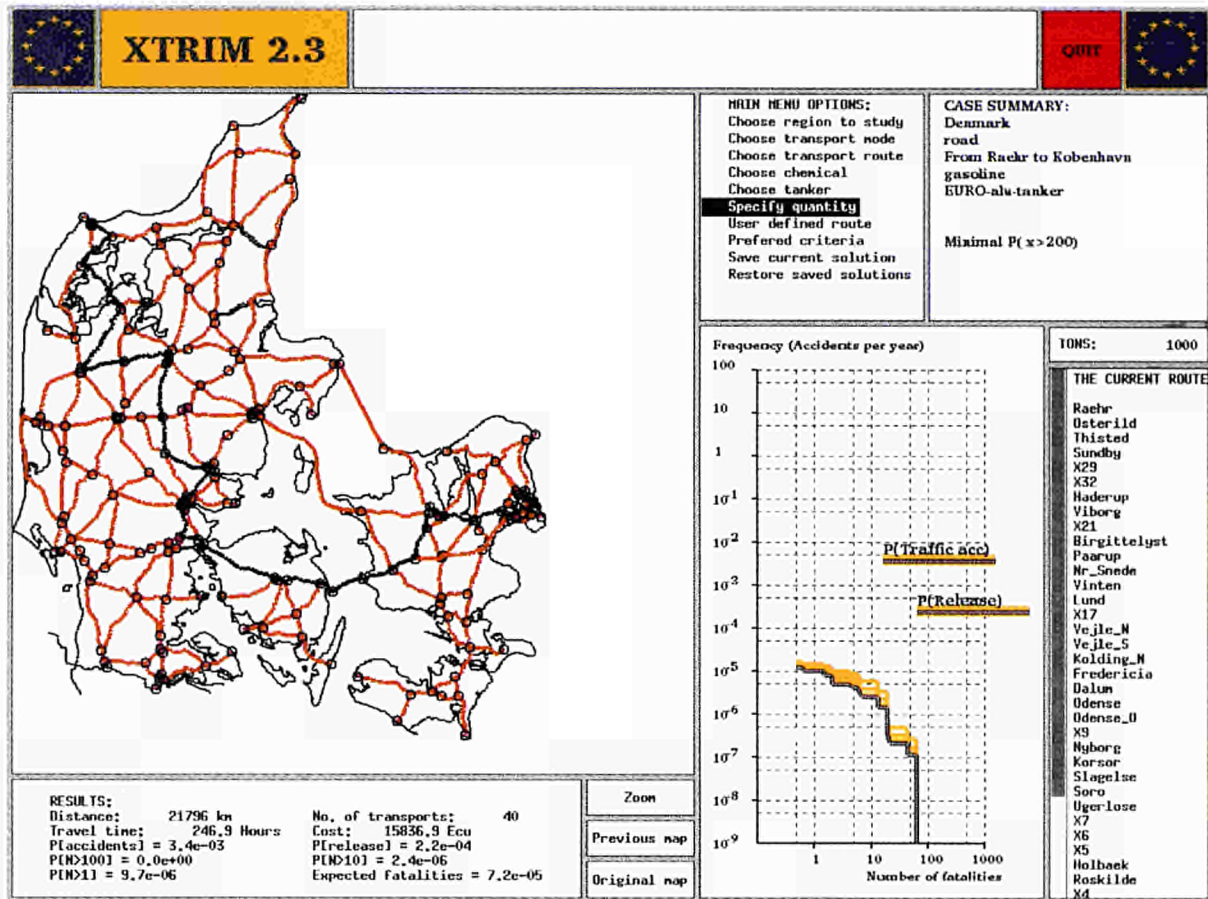
Fig. 2.27. Risk Assessment of the Transport of Dangerous Materials

Marine Transport of Dangerous Goods

A study on the risks of transporting dangerous goods on inland waterways, restricted waters and coastal waters has been initiated. An accident database comprising 1720 accidents which happened during 1945-1993 has been established using 15 different sources from the open literature. Each accident record contains 33 information fields. The database is operated under Oracle. Detailed quantities and routes of dangerous goods transportation in Danish waters have been estimated mainly based on information from 1991-1993. The total estimated quantity of crude and refined petroleum products is approximately 45 mio. tonnes/year, and for chemicals the estimate is approximately 4 mio. tonnes/year, a quarter of the latter being liquefied ammonia. The plan for 1994 is to develop frequency and consequence models suitable for the XTRIM model enabling this to make risk estimates for road, rail, marine and combined transport of dangerous goods within Europe.

Generation of Alternatives for Location Problems

Following the implementation of an algorithm within a Geographic Information System (GRASS) to generate alternatives for siting of facilities (GENET) , activity was divided into two issues:
- the merging of aspects of Multi-Criteria Decision Aid (MCDA) and the algorithms fitness function.
- the extension of the method to the siting of route facilities.

The software GENET MCDA aspects applied to problems of siting give rise to complex combinatorial problems. Genetic Algorithms (GA's) have already proved to be useful in solving many combinatorial problems returning robust solutions. Several characteristics of GA's make them quite appropriate for the generation of alternatives process, viewed as an exercise of exploration of a territory for different settings of the problem. GENET aims at generating alternatives for siting of facilities, though it does not address the problem of conflictuous criteria reflecting different aspects of the

problem and so different possible settings of the problem. In practice, according to multi-criteria theory, the fitness function characteristic of GA's will be the aggregation procedure of the criteria values. Each alternative is assigned to a certain category of fitness, i. e. to a certain category of suitability.

Generation of alternative routes has been another main topic of this project. Extension of the methodology to facilities represented by routes has been studied, namely concerning the use of Evolution Strategies and messy GA's which can deal with incompletely defined problems. Different codification of routes and different operators are the main issues being currently explored. The integration of these algorithms together with a more robust fitness function, as described earlier, is being implemented.

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Quality Science for Environmental Management (NUSAP system)

During 1993 work has continued in the research and further development of methods for the assessment and communication of quality of scientific information, with special reference to the problems of environmental management /4/. "NUSAP" is a tool which assists the analysis of quality of scientific information, by distinguishing among those different sorts of uncertainty and quality /6/. It operates by clarifying the critical distinctions used in each field of competent practice. It is an extension of standard scientific notation and can be easily mastered by anyone with a concern for quality of information. The NUSAP approach is not merely a notational system; it is a sensitivity to the quality of scientific information, and a commitment to solve its problems. As an example, there is the Assessment diagram. To use the Assessment Diagram, one simply plots all the key parameters, by their strength and their relative contribution to spread. The quality of the output can then be estimated by the location of the resulting distribution. Also, if there is one parameter that brings down the quality assessment, further research can be most efficiently focused on improving it. The regions on

the two-dimensional diagram have been shaped so as to express the principle that even a weak parameter does not affect the quality of the calculated model output, so long as its contribution to the Spread is small (fig. 2.28).

Post-Normal Science and Emergent Complexity

Science for the management of the environment deals with systems that are at higher level of complexity than those of traditional laboratory science /2/3/4/5/. Not only are the natural systems themselves complex, but the environment is always influenced by human activities.
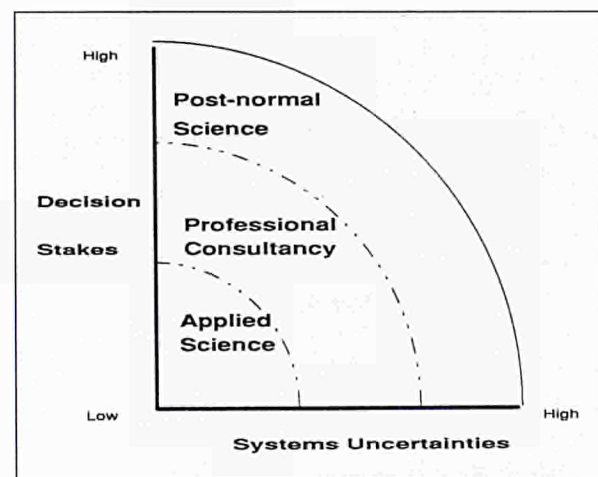
Fig. 2.28. The Post-normal Science

We have described such systems as having "emergent complexity" /7/; which can be studied in terms of a set of dimensions, ranging from the mechanical to those involving culture and consciousness. In these terms, some special properties of these systems can be explained, including "ancient regime syndrome" and "autolysis".

This work forms a part of the new systemic sciences studying self-organisation and hierarchy. Together these provide a methodological justification for post-normal science, with its recognition of ineradicable uncertainties and a variety of legitimate perspectives, and a new role for scientific expertise in environmental management.

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Environmental Impact Assessment

The Environmental Impact Assessment (EIA) activity has been concentrated on the following aspects:

- transformation function and uncertainty analysis of environmental indicators;
- environmental quality of a city;
- informatic tools for EIA.

Transformation Function Indicator/Index and Uncertainty Analysis

To facilitate the interpretation of its meaning, an environmental indicator is frequently transformed into an environmental (simple) index by an adimensional and normalised function usually ranging from 0 to 1 and defined subjectively.

The fact that the transformation function is not defined analytically causes significant problems: (i) in the calculation of an aggregate index (combination of two or more simple indices), (ii) in the uncertainty analysis, both at the level of a simple index and at the level of an aggregate index.

In fact, the uncertainty analysis of aggregate indices is never performed. Analytical functions have been suggested to approximate subjectively defined indicator/index transformation functions /1/. In particular, a double exponential function is proposed to approximate the transformation function used for the Biological Oxygen Demand Indicator in the Chemical Index (a major index of water quality assessment). The use of convenient analytical transformation functions allows a strength calculation of an aggregate index and makes uncertainty analysis feasible.

A Study on the Environmental Quality of a City

Some main aspects of the environmental quality of a city have been investigated /2/. First, the notion of environmental indicator as a stochastic process was discussed and the choice of the shape and dimension of the cells of a thematic map was argued.

Then, considerations about the use of collected and estimated environmental data were given. Some environmental features of the city of Bolzano (Northern Italy) were discussed on the basis of the maps of 55 descriptive and synthesis indicators of the city.

Three zones having very individual characteristics have been identified: the historical centre, a new residential zone in the eastern part of the periphery of the city and an industrial zone, not very far from the city.

One squared kilometre has been considered as a reference area of each zone, and each reference area includes 16 squared cells having a side of 250 metres (See fig. 2.29). The analysis made concerns "residential population", "urban green" and "atmospheric pollution". To investigate the atmospheric pollution, the following indicators have been suggested: a traffic indicator, the power of the large thermal installations supplied by gas oil, the population served by gas oil heating and the population served by methane gas heating.
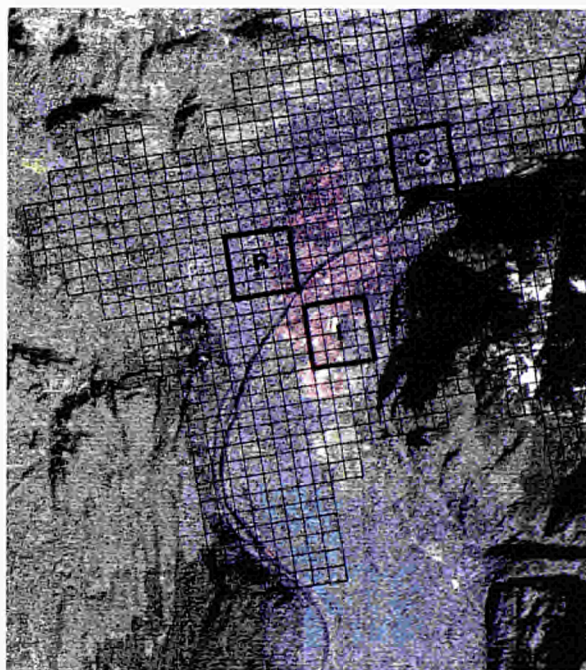

Fig. 2.29. Cellular map of the city of Bolzano and reference areas (one squared kilometre each).
(C= Historical Ventre; R= Residential Area; I= Industrial Area)

Informatic Tool

INES (a system for INtegrated Environmental Studies) is being implemented as a tool for EIA on a Personal Computer (PC, IBM compatible). An incinerator for toxic and dangerous wastes has been taken as a reference installation for such an implementation. The report on flora, fauna and vegetation indicators and the report on water quality indicators have been completed /3/4/.

A paper on the implementation of the EIA directive, based on the report from the Commission of the implementation of directive 85/337/EEC (COM(93) 28 final), has been produced /5/.

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Industrial System Plant Safety

Knowledge Based Systems for Safety and Reliability Assessment: the STARS Project

STARS was started in 1989 as a collaborative project with the objective of developing a methodology and a software structure that provides knowledge based support to different phases in safety and reliability assessment. The collaboration was formally closed in 1992 /1/.

The project has produced a set of methods and software tools that help safety and reliability analysts to /2/3/:
-   collect the information needed for the analysis and structure this information in an object oriented model of the plant;
-   identify potential hazardous events and event scenarios making use of precompiled knowledge about typical process plant units, chemical substances and chemical reactions;
-   model and analyse courses of undesired events making use of precompiled knowledge about typical components and their behaviour.

The STARS methodology and tools have been designed to offer:
-   a structured approach improving consistency and traceability;
-   a full integration with knowledge and data bases that can be used for capturing the general domain expertise of safety and reliability analysis;
-   the possibility to incorporate plant experience as well as knowledge and experience deriving from analyses and other plants;
-   a computer-based explicit documentation of the analysis, its underlying models and assumptions;
-   a user friendly and flexible environment for rapid updating in case of modifications to the plant description, new evidence from the plant changes in the assumptions underlying the process.

A STARS toolkit was developed that consists of :
-   a kernel with the Knowledge Bases (KB's) and the KB related tools that are used to build the plant model;
-   a set of safety and reliability analysis tool that use the plant model to derive RAMS (Reliability, Availability, Maintainability and Safety) results.

Generic knowledge bases in STARS are designed to contain general domain knowledge and expertise:
-   the plant/unit KB contains characteristics, failure events and hazards associated with process units and typical plant systems;
-   the component KB has information on component characteristics, failure modes, generic reliability parameters and contains rules on the behaviour of components;
-   the substance KB contains physical and chemical properties of substances and related hazards;
-   the chemical reactions KB has knowledge about characteristics and hazards of typical chemical reactions, and some conservative estimates of potential hazards involved with unintended reactions.

A graphics based environment has been developed to access the knowledge bases and to create hierarchical object oriented representations of the plant under analysis (see *fig 2.30*). The user can create, modify and
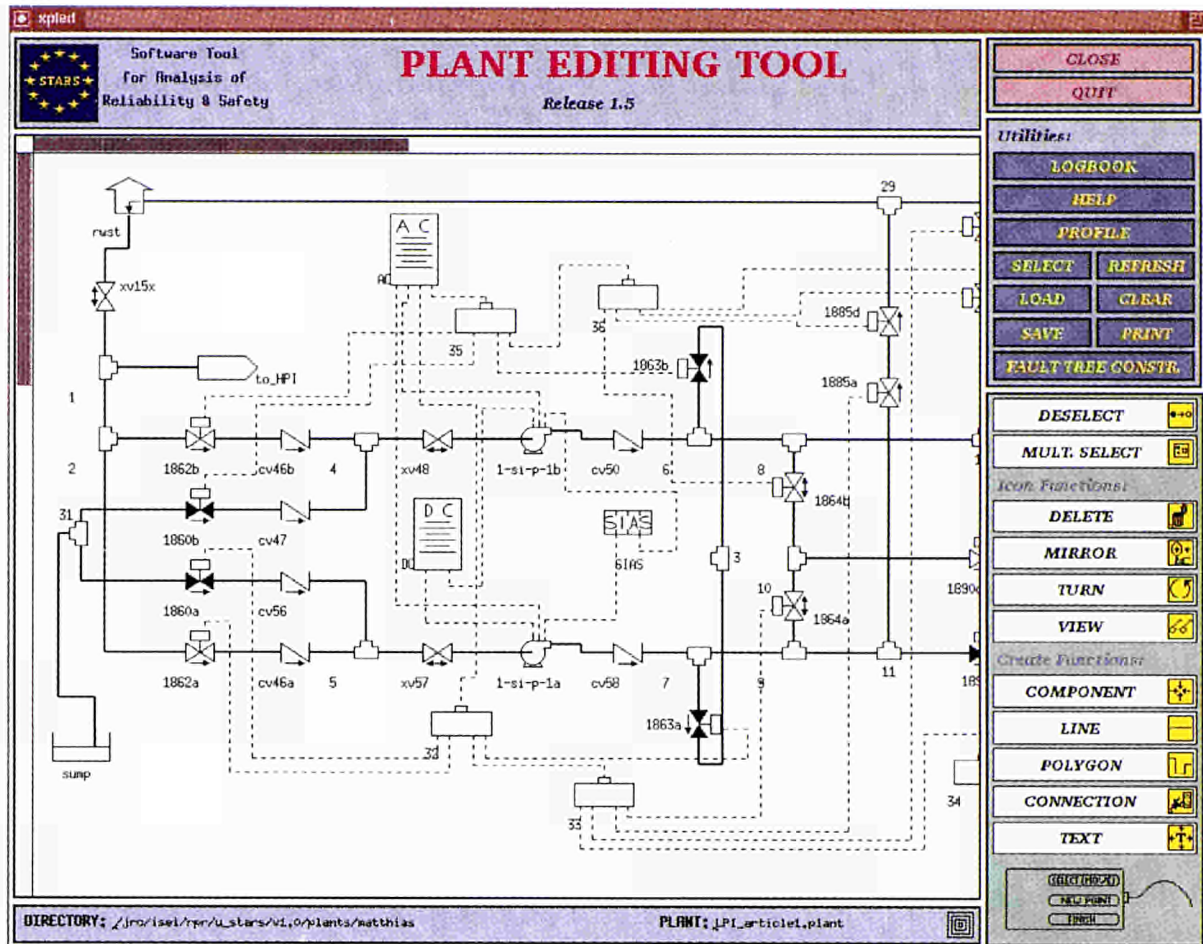
Fig. 2.30. Stars Plant Editing Tool

access this object oriented plant description by drawing diagrams and interacting with those on a CAD-like interface /4/.

ISEI developed a set of tool for supporting computer aided analysis at system level: a fault tree construction expert system, a fault tree editor and a module for determining the cut sets and performing a time dependent quantitative analysis have been developed. These tools support reasoning on a detailed plant representation (Piping and Instrumentation Diagram) and use the generic knowledge of the component KB.

The fault tree construction expert system (*fig. 2.31*) and the modelling techniques have been validated by applications on offshore systems and on nuclear safety systems /5/. It has shown to have an interesting potential for formal certification purposes.

A study was performed on the use of physical models and simulation during system modelling. A prototype was developed of a tool that is able to use simulation as a support for automatic fault tree construction.

The other partners in the project focused on:

– development of a prototype tool for qualitative hazard identification /1/ and analysis based on reasoning on a process flow diagram and using the plant/unit substance and reaction KB's (RISOE, DK and VTT, SF in collaboration with NESTE);

– a specification of an interface to include consequence tools within the STARS toolkit (TECSA, I) and vulnerability tools (TNO, NL).

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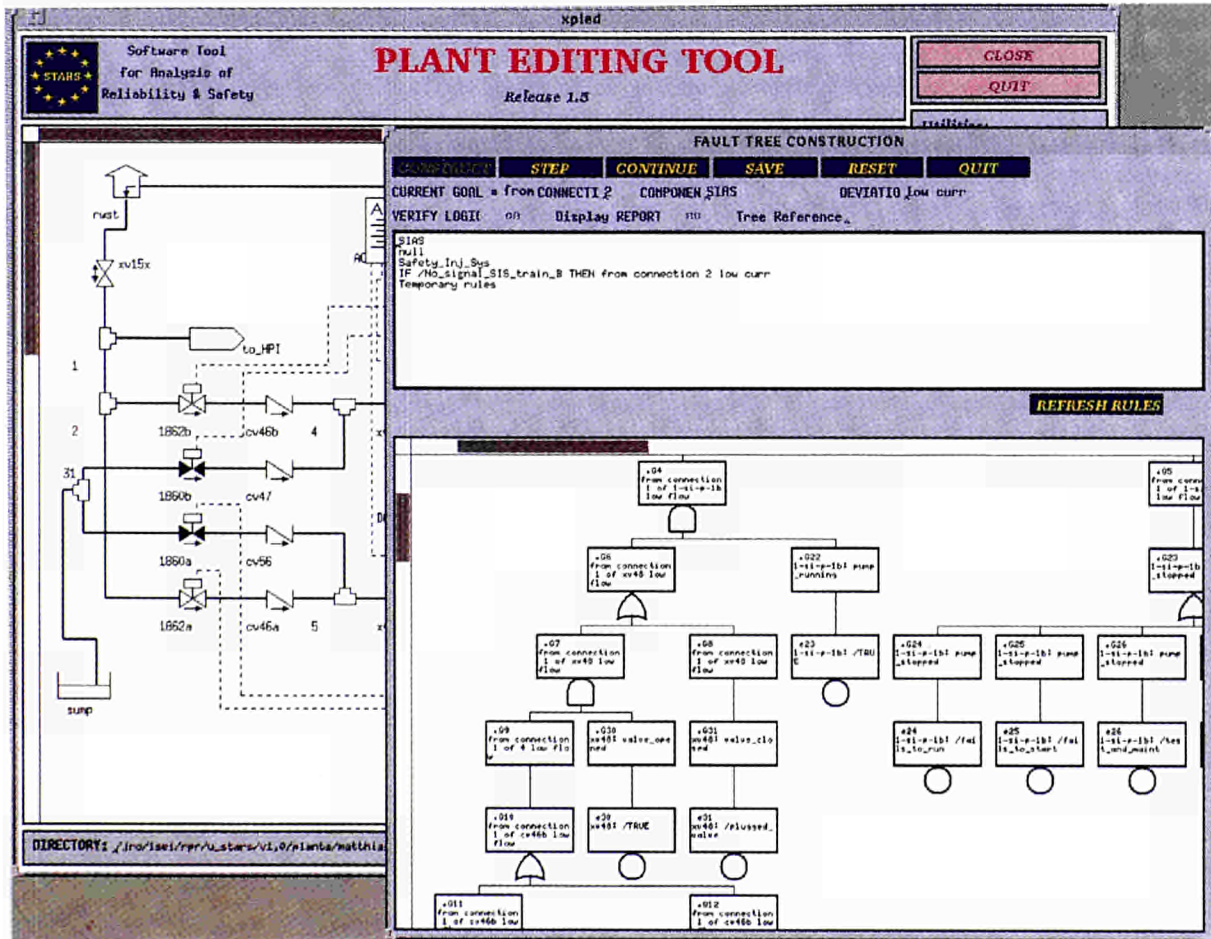
Fig. 2.31. STARS Fault Tree Editing Constructor

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Risk Analysis

The computer code for Fault tree Analyses, ISPRA-FTA, /1/ has been successfully distributed to about 40 organisations and is one of the first example at JRC of a software tool developed for a scientific purpose and then commercialised. An improved version of the software has been developed recently in C to deal with large Fault tree structures. The software runs on personal computers under normal DOS. A version under PC-Windows is planned beginning 1994.

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TOMHID - an Overall Knowledge-Based Methodology for Hazard Identification

An important part of a safety analysis of a chemical plant is the identification of hazards. This task can be carried out at either the unit or plant level. Methods exist for hazard identification at unit level, e.g. hazard and operability study (HAZOP) and failure mode and effect analysis (FMEA). For large chemical process plants the effort required by these methods can be very extensive and it can be very difficult to establish a total risk survey for the plant. Furthermore, the emphasis of these meth-

ods is on identification of hazards closely related to the technical aspects of the plant and less on hazards related to the interaction between the plant equipment, the organisational structure and the management factors.

The objective of the TOMHID project is to develop an overall methodology which can provide assistance and guidance to the user for high level hazard identification of different kind of chemical process plants (batch reactor plants, continuous plants, mixed reactor plants). The TOMHID project, sponsored by the CEC STEP research programme, was initiated in 1991 for a duration of three years. The project is carried out by an international consortium: VTT (Technical Research Centre of Finland), The University of Sheffield (United Kingdom), SRD Division of AEA Consulting (United Kingdom), TRI-Tecsa (Italy), CIEMAT (Spain), Risoe National Laboratory (Denmark) and ISEI.
The project is to provide a comprehensive framework to represent a process plant as a socio-technical system. The methodology is to include technical, human and organisational aspects and is intended to be used as a first stage in the hazard identification process so as to identify critical areas and the need for further analysis using existing methods.

The final methodology will consist of the following main elements:

- a functional description of the plant as a socio-technical system;
- high level hazard identification based on the Concept Hazard Analysis method (CHA);
- plant documentation comprising the functional plant models and the plant level hazard identification;
- evaluation of the safety impact of management factors on the identified hazard;
- software specification and implementation of the methods developed in TOMHID.

A specific analysis, called MIMIX, has been developed to investigate the impact of management factors on plant safety. The MIMIX analysis is performed on selected incident scenarios with the intention to identify critical areas and deficiencies in plant safety management. The general philosophy of MIMIX is to employ an inductive or "bottom-up" approach starting from the events constituting the identified scenarios, assessing the managerial factors that might contribute to the occurrence of these events, and from there proceed to more general managerial practices and principles assessing the overall safety management system /1/.

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ESReDA - European Safety, Reliability and Data Association

ESReDA is a relatively new European Association established to promote research, application and training in Reliability, Availability, Maintainability and Safety (RAMS). The Association provides a forum for the exchange of information, data and current research in Safety and Reliability and a focus for specialist expertise. ESReDa was formed by combining the forces of EuReDatA (European Data Bank Association) and ESRRDA (European Safety and Reliability Research and Development Association), the integration of the two providing a stronger basis for furthering the understanding, development and dissemination of RAMS research and methods throughout Europe.
Membership of ESReDA is open to organisations, private or governmental institutes, industry researchers and consultants who are active in the field of safety and reliability. Membership fees are currently 1000 ECU for organisations and 500 ECU for universities and individual members.

ESReDA seminars provide a forum for presentation and discussions on selected topics. They are held 6 monthly in conjunction with the Assembly meetings. Recent topics have included:

- The Use of Expert Systems in Safety Assessment and Management, London (UK), Oct. 1991
- Safety of Systems Relying on Computers, Amsterdam (NL), April 1992
- Equipment Aging and Maintenance, Chamonix (F), October 1992
- Safety in Transport Systems, Huddersfield (UK), April 1993
- Organisational and Operational Safety, Lyon (F), October 1993.

The next two seminars will deal with:

- Maintenance and System Effectiveness, Chamonix (F), April 1994
- Accident Analysis, JRC Ispra (I), October 1994.

Safety Critical Computer Systems

There is an increasing number of situations where we depend on computer-based technology to control and manage the functions of complex and safety critical systems. The term dependability encompasses more specific notions like 1. safety - where we protect human life, property and the environment; 2. reliability, availability - where we need to ensure the continuity of valuable system functions.

As a result, there is a growing need for theoretically sound but practical methods and tools to aid in the successful deployment of highly dependable systems with embedded computer-based components.

The Safety Critical Computer Systems (SCCS) work initiated in 1993 will be focused on building a coherent set of methods and tools for the development and assessment of such systems, to achieve transfer of this technology to industry and the scientific community, to integrate European activities in this field and to provide services (advice & support) related to this subject matter to customer Directorates General of the EC.

Since safety-critical uses of computer systems are embedded in multi-disciplinary engineering systems, it is essential to take a broad 'systems approach' to the analysis of specific SCCS issues. In particular, we will consider unified conceptual frameworks which also treat the links between a particular system and its embedded software components, to enable us to model and analyse the complete system for particular properties. The work to be performed will build on the Institute's existing strengths in systems and safety engineering and combine this expertise with software engineering aspects. 1993 has been mainly a competence building and analysis phase related to the state of the art in SCCS.

In particular, a study performed during 1993 /1/, addressed following issues:

- State of the art in licensing.
- Quantitative and qualitative assessment techniques.
- Guidelines and standards for the development of safety- critical software.
- Identification of key technical and organisational issues to be addressed.

One of the main conclusions drawn from this study was that there is a general lack of data on reliability of software, in particular used in safety critical systems. Although it is generally assumed that some software development methods give rise to higher dependability than others, there is almost no experimental evidence to support this view. Such evidence is desperately needed to put the licensing of safety critical systems on a firmer basis.

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FORMENTOR (EUREKA Programme)

The FORMENTOR project aims at developing real-time expert system software that offers on-line decision support to operators of complex plant who are faced with unusual and potentially hazardous situations. The ultimate objective is to avoid major disturbances in a plant that could lead to any type of loss: loss of production, startup costs related to shutdowns and in particular accident losses. As such, the scope can be categorised as "Total Loss Control" bearing in mind safety objectives as well as particular process objectives.

FORMENTOR is a project in the EUREKA programme of cooperative international R&D projects (Eureka #19). The partners in the FORMENTOR Consortium are: the Institute for Systems Engineering and Informatics, Aérospatiale Protection Systèmes (F), Cap Gemini Innovation (F), Det Norske Veritas (N). In addition to these partners, British Petroleum acted as application provider.

The pilot development phase of the project, which the partners have been carrying out over the last four years ended during 1993 and the main technical achievements are:

- the experience gained with the development of two pilot industrial applications, one dealing with the ground-based manipulations of a cryostat to be installed in the ISO- satellite (Infra-red Space Observatory), and the other, the BP application dealing with the supervision of an extractive distillation plant operated by British Petroleum.

- a case study application, developing FORMENTOR concepts and methodology on a target plant at design stage. The plant chosen was the emergency cooling system of a nuclear power station /1/8/.

- a methodological workstream, resulting in the final version of the methodological handbook containing different techniques necessary for building a FORMENTOR system /3/.

– a generic workstream resulting in a FORMENTOR toolkit that, supported by the methodology, consists of various computer supported modelling tools and CASE tools necessary for the development of FORMENTOR systems.

At the end of the pilot phase, the next phase, the industrial development phase has been started and is being undertaken now. As such, FORMENTOR is at a point where clients are sought for the development of full-scale industrial applications. The first such application will be developed for TOTAL France under the leadership of Cap Gemini.

The Industrial phase is expected to finish in december 1994. Discussions are under way within the consortium in order to determine the most appropriate framework for exploiting the results afterwards.

A major milestone achieved during 1993 was the completion of the Petrochemical Pilot Application which has been carried out under leadership of ISEI staff in cooperation with BP International and the Cap Gemini Group /5/7/. The developed FORMENTOR system has been installed on an extractive distillation plant operated by BP-Chemicals Ltd. and its performance in responding to real plant upsets has been evaluated. The FORMENTOR system was rated by BP as a qualified success. The majority of initially defined success factors were reasonably well reached. BP's overall feeling was that FORMENTOR shows enough promise of providing commercially- useful capabilities in the near future (*Fig. 2.32*).

Parallel to the methodological and applications development, the generic workstream resulted in 1993 in the realisation of three FORMENTOR tools namely the Safety oriented Functional Model tool (GTST editor), the Data Communication Model tool, and the Statechart editor. These tools are part of the off- line toolkit and intended to facilitate the task of developing an Industrial FORMENTOR application (*fig. 2.33*). Other reports concerning the FORMENTOR activity com be found in /2/4/6/.
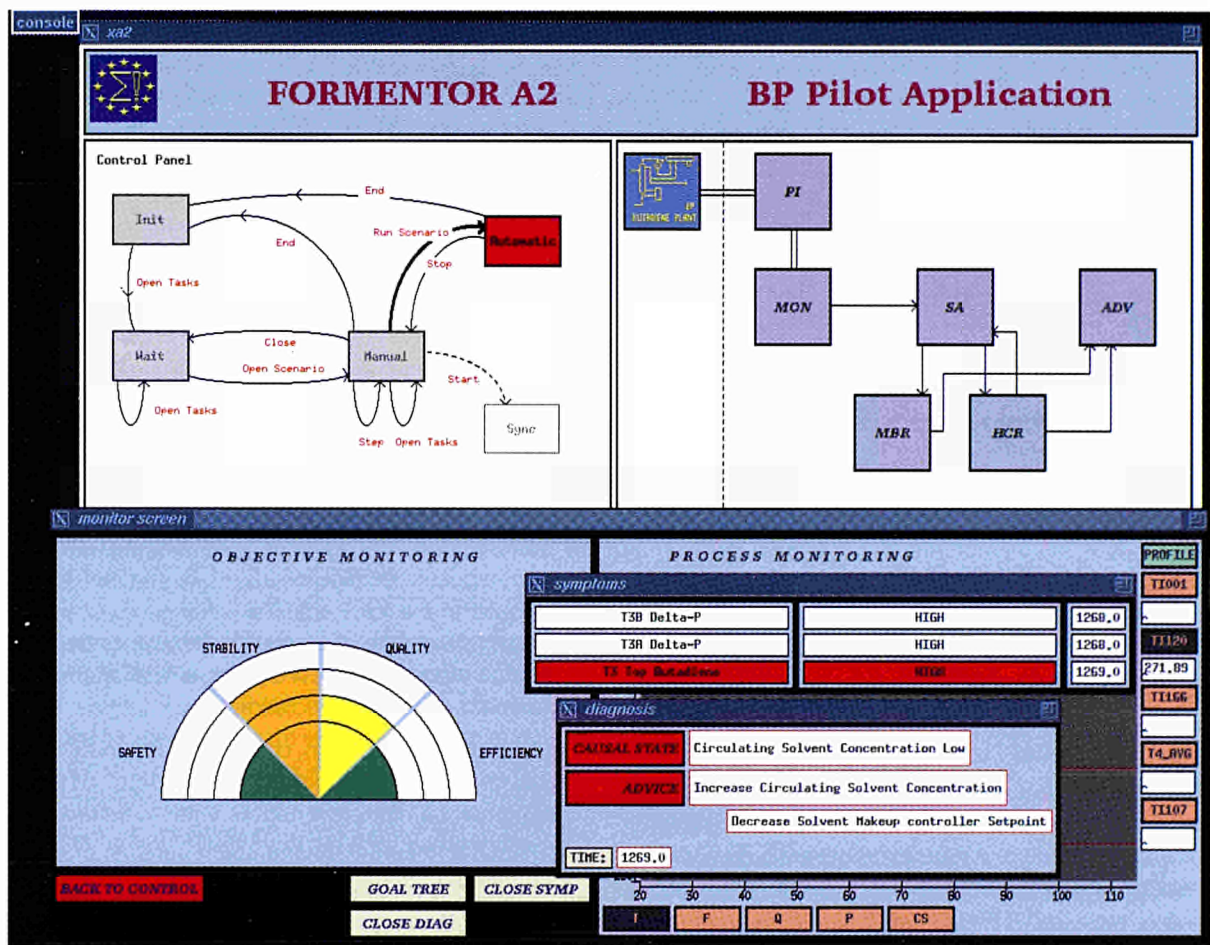

Fig. 2.32. FORMENTOR applied to Petrochemical Application

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Data Visualisation and Storage

Further progress has been made in developing data management and data visualisation software. Expertise in this area has been developed by a small group within ISEI. Application software is written under an inter-institute contract with IST. These applications are in wide spread use.
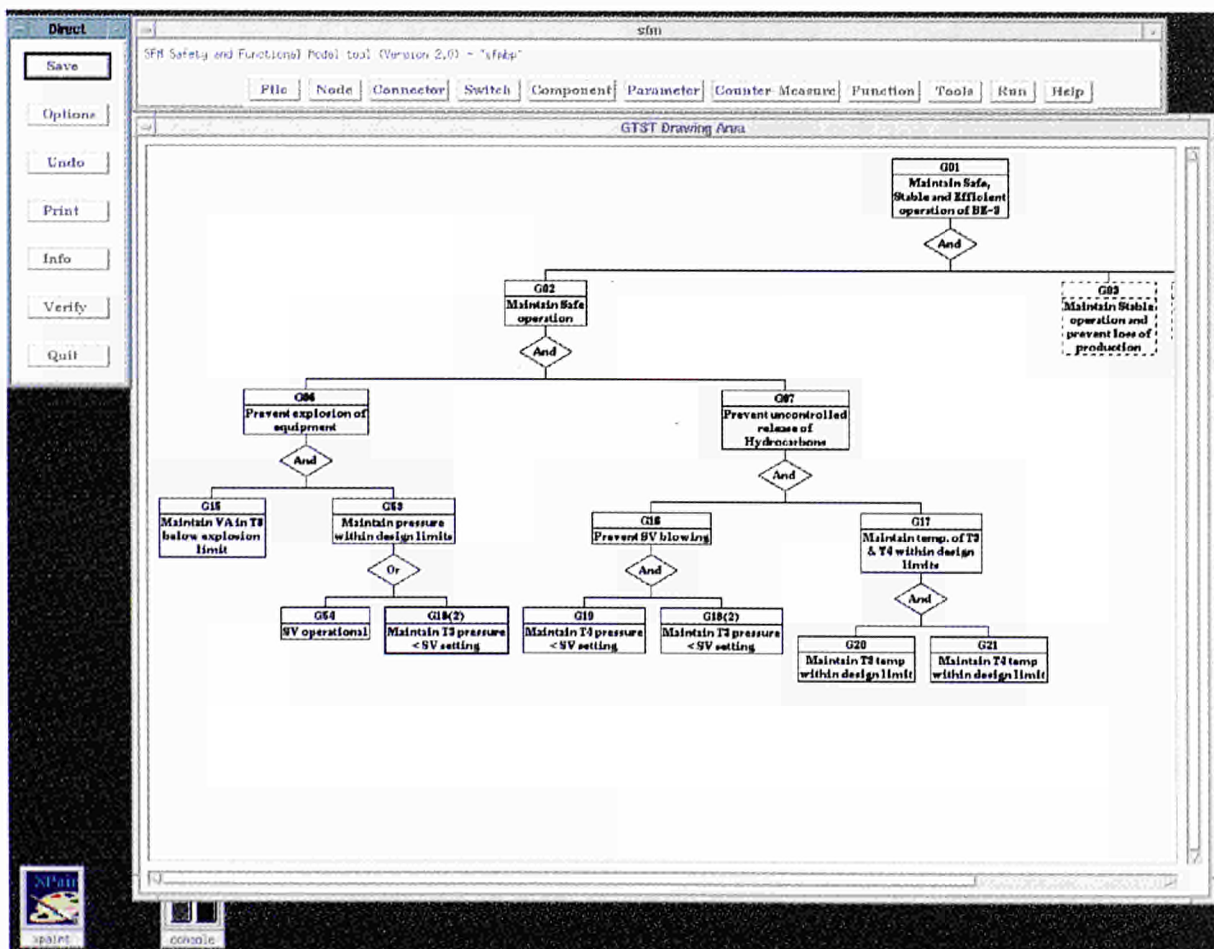

Fig. 2.33. SFM tool with part of the Goal Tree of the Petrochemical Application
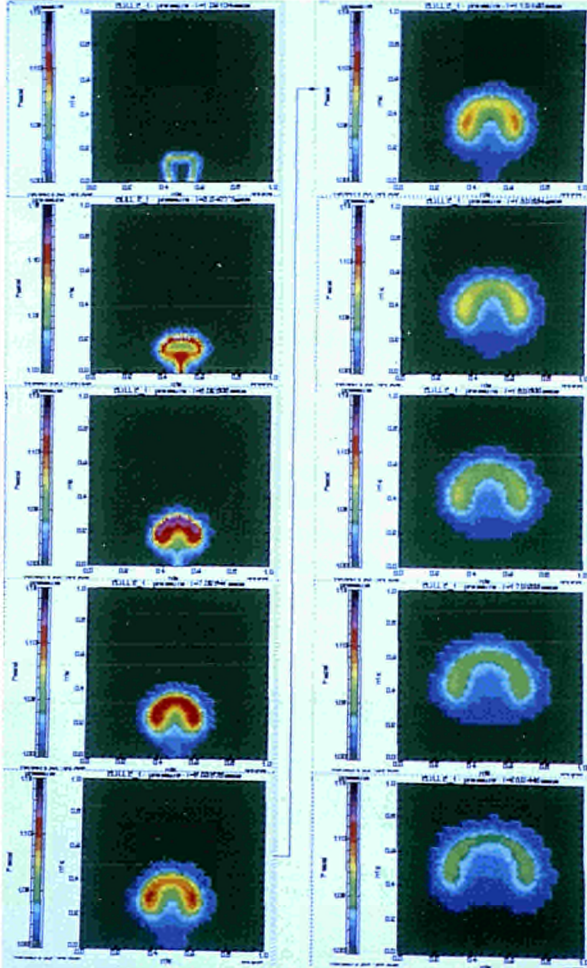
Fig. 2.34. Several frames from an animation of combustion visualised with TURCOM

Data Visualisation of Reacting Gas Flows

The software package TURCOM which is used to visualise the results of 2-d fluid dynamics modelling on non-structured grids, has been further extended during 1993 /1/. The main developments are the addition of a record and play back facility, and a time animation facility. *Figure 2.34* shows some frames from such a time animation. An interface to the digital video system described later allows such animations to be recorded to standard VHS video tape.

Data Visualisation of Gas Transport

TURCOM has now also been installed for use by the TRAFLU project of IST. This new area of application allows to visualise the results of pollutant gas transport in buildings. The EDF database /2/ is used for storing all results.

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FISSION REACTOR SAFETY

Reactor Safety

The general objective of the work is the development and/or assessment of methods to control the level of safety of a Nuclear Power Plant (NPP) over its life or to support the designer in the process of designing a new plant taking into account the safety constraints. The work is based on the use of probabilistic approaches. It aims at extending and strengthening the so-called "Living PSA" approach.

Three aspects of plant safety are considered: the engineering systems, the structures, the control and management by the operator. The grounds for this are the growing importance of the PSA approach for NPP design and optimisation of plant operation, of human and organisational factors in safety management, of the impact of aging of components and structures on plant safety margins. The final target of the research is the development of an integrated set of software tools, capable of dealing with the three mentioned contributors to plant safety.

Research activities related to reactor safety are as follows:

- Knowledge Based Systems (KBS) oriented to living PSA, to support safety and reliability management
- Feedback from operating experience: data analysis
- Man-machine interaction and dynamic reliability studies
- Development/maintenance of databases related to safety and reliability evaluations
- Structural reliability

These research activities are performed in collaboration with national research centres, Safety Bodies and industry.

Knowledge Based Systems oriented to living PSA

The objective of this activity is the development of a software tool for performing a PSA level 1 of a Nuclear Power Plant (NPP) following the Living PSA (LPSA) approach. Due to the adoption of the LPSA concept, the system will be capable of assisting the designer in the process of design of a new plant or the operator in monitoring and controlling the level of safety of his plant over time.

This tool adopts, as a starting point, the concept and the software framework of STARS (Software Tools for the Analysis of Reliability and Safety). STARS is a project based on the use of Knowledge-Based Systems (KBS), which, in its first version, was carried out by the JRC within a consortium of European research organisations for the safety assessment of conventional process industry systems and technical installations.

The guidelines for the adaptation of the STARS structure for the development of a LPSA are defined in /1/. In this paper, the advantages offered by the use of KBSs and the adoption of object-oriented programming are highlighted: advantages such as the declarative nature of all the information stored in the Knowledge Bases (KB), the knowledge of general validity distinct from the plant-specific knowledge, the flexibility in incorporating new knowledge as it becomes available.

The study of a plant functional model, necessary for the future development of a KBS for the (possibly automated) construction of event trees and execution of Failure Mode and Effect Analysis (FMEA), was started. The application of FMEA as a support to the application of Reliability-Centred Maintenance techniques for maintenance optimisation has, as target plant, a conventional power plant of ENEL.

The use of the software tool for RAMS (Reliability, Availability, Maintainability, Safety) Analyses at large and as a support to the operator is dealt with in /2/. Some case studies are being or will be carried on to demonstrate the advantages offered by the STARS approach and to validate the tool itself. A study case which involved the verification by STARS of a Fault Tree (FT) related to the low pressure injection system (LPIS) of the Surry NPP, as recorded by NUREG CR-4550, was performed /3/. It has been ascertained that the results of the analysis of the FT obtained in an automated way from the P&I diagram are more accurate and complete than the results of the analysis of the NUREG FT (which was developed by an analyst). The exercise has shown the potential advantages for system analysis offered by the STARS informatic tool, in particular by the automated FT builder. It is envisaged that, once the laborious task of system representation in the STARS environment has been accomplished, the automated generation of a number of FT's is a very quick and easy operation, and reliable qualitative and quantitative system analysis results can be obtained by applying the FT Analyser. An explorative study on the possible incorporation in this PSA software tool of some advanced techniques presently under study of ISEI, such as those related to the

analysis of the dynamic reliability of systems and human errors (see below), has been started.

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Feedback from Operating Experience: Data Analysis

Methodological and applied work has addressed the estimation of failure rates of individual components under the model of population variability and when detailed data on the failure times of components are stored in a database for use in a living PSA.

A new nonparametric empirical Bayes (NPEB) estimator for individual component failure rates has been derived /1/2/. The posterior expectation of components' failure rates is seen to factor into component specific data and a ratio of marginal probabilities estimated from the database. The estimator is applicable for components with different observation periods and with no failures observed as is most frequently the case because of the high reliability of components. It is optimal in that it is asymptotically unbiased for the posterior mean failure rate and robust in that it is not based on specific parametric forms of the population variability curve.

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Man-Machine Interaction and Dynamic Reliability Studies

The two main issues of the research performed in the domain of dynamic reliability methodologies refer to a) the analysis of systems, and b) the analysis of operational procedures in normal and abnormal conditions and human errors. Both analysis types are based on the use of the code DYLAM (Dynamic Logical Analytical Methodology), developed by ISEI for dynamic reliability analysis. DYLAM permits the dynamic reliability analysis of a system by coupling its reliability assessment with the study of its physical evolution in nominal and failed states.

In the course of 1993, the final documentation of the new version of the code, DYLAM-3, was accomplished /1/. The validation of the DYLAM code continued. In particular, a comparison between DYLAM-3 results and the analytical results of a literature case study was performed /2/. This study confirmed DYLAM-3's capability to assess properly the time-dependent availability of a dynamic system whose component states are subject to stochastic transitions /3/.

The DYLAM-TRETA software package has been further developed in the framework of an existing cooperation with the Consejo de Seguridad Nuclear, the Spanish Safety Authority. The integration of the TRETA (Transient REsponse and Test Analysis) code with DYLAM permits to conduct dynamic reliability analysis taking benefit of TRETA simulation capabilities. A complete model of a real PWR plant has been developed by the TRETA simulator /4/. The model considers the main features and systems of a PWR including the steam dump control system, the safety injection system, the control rod system, the reactor protection system, the chemical and volume control system, the auxiliary feed water system, etc. *Figure 2.35* represents the block diagram of the TRETA model of a PWR plant.

Concerning the modelling of the intervention of plant operator, new components have been added to the library of TRETA to properly cover normal and abnormal operating procedures. The overall model is being applied for dynamic reliability analysis in the case of a Steam Generator Tube Rupture (SGTR) as initiating event (IE). This case represents a necessary step towards the feasibility study of a PSA level 1 by means of dynamic approaches.

The human reliability technique DREAMS/HERMES (Dynamic Reliability methodology for Error Assessment in Man-machine Systems/Human Error Reliability Methodology for Event Sequences) has been further developed /5/6/. The model of the AFWS (Auxiliary Feed-Water System) previously coupled with DYLAM-2 has been updated to the DYLAM-3 version. A simple diagnosis model based on fuzzy logic principles has
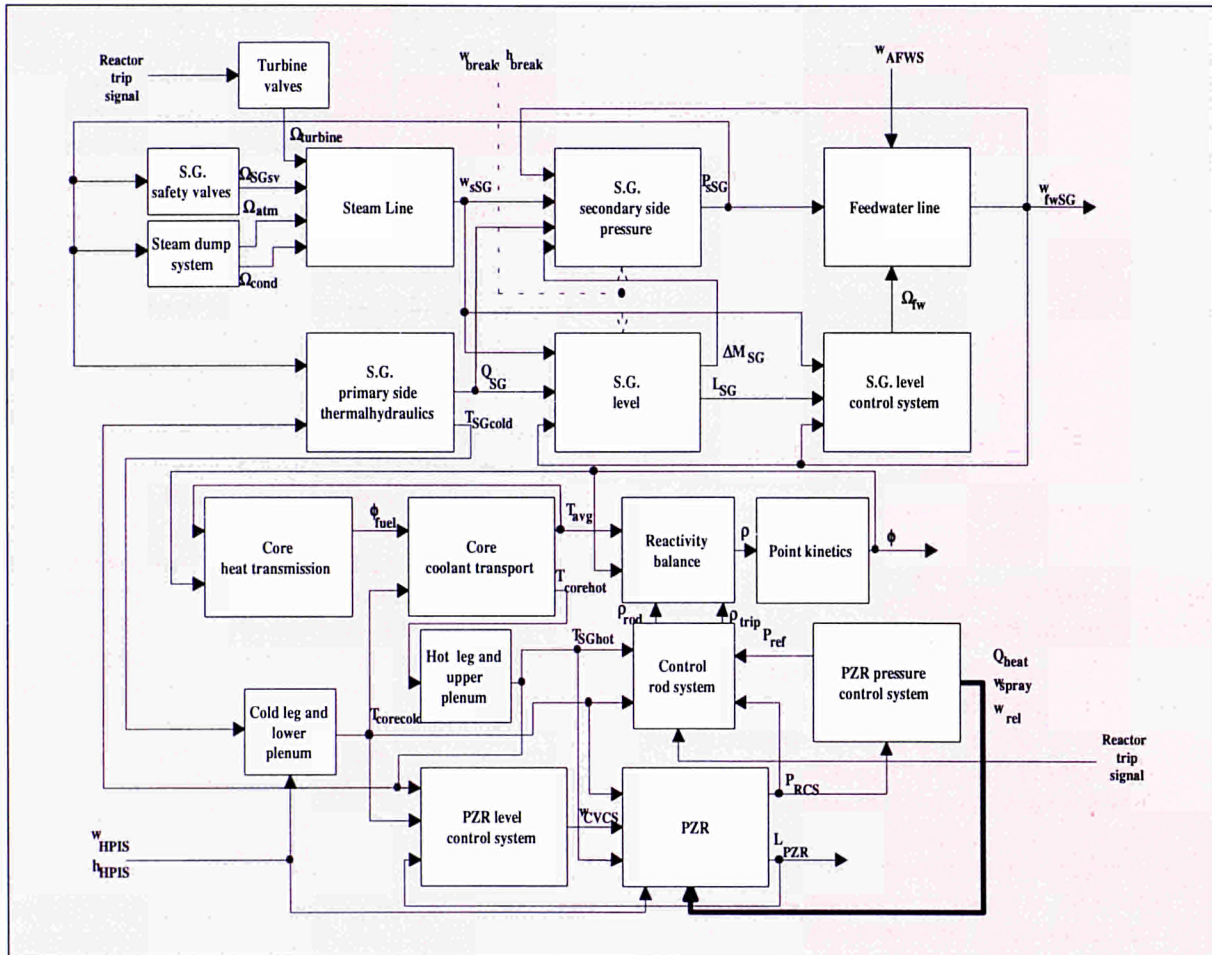
Fig. 2.35. Simplified block diagram of the TRETA model of a PWR plant

been developed to simulate the behaviour of the control room operator facing one of three different situations, namely a loss of offsite power, a loss of feed-water and a loss on a steam line. The DYLAM package permitted to generate a great number of accidental scenarios and

Fig. 2.36. Trend of SG1 physical parameters in the case of a feed line tube rupture

to assess the effectiveness of "ideal" operational procedures, i.e. of procedures assumed as perfectly executed by the operator. In *figure 2.36* the trends of the inlet mass flow (kg/s), of the water level (m) and pressure (MPa) of the steam generator are represented for the case of a feed line tube rupture on the same steam generator where the failure is located.

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Development/Maintenance of Databases related to Plant Safety and Reliability Evaluation

Improved Version of Component Event Data Bank (CEDB) for Personal Computer

In the framework of a collaboration contract with ENEL-CRAM (formerly ENEL-CRTN), support is being given to CISE/ENEL in the development of a version of CEDB for PC. The CEDB is a Component Event Data Bank developed for the main frame and operated by the JRC until end 1991. ISEI made available all the programmes related to CEDB operated on Amdahl and is giving assistance to ENEL-CRAM. The latter takes care of the design and implementation. This first version, developed in DBIII/CLIPPER, will have the same features of the CEDB operated on Amdahl. It should be completed by the first half of 1994. The following step will be a revision of all the CEDB structure, to include some advancements, e.g. making it capable of storing information related to preventive maintenance.

Maintenance of Various Databases related to NPP Safety and Reliability

Copy of the following databases is made available to the members of JRC staff:
- Incident Reporting System (IRS by OECD)
- Power Reactor Information System (MicroPRIS by IAEA)
- Significant Event Compilation Tree (SECT by OECD)
- Nuclear Power Plant Data Collection Scheme (NPPDCS by OECD)

Information to Public on Risk

A research activity on the information to be given to public on risk according to the European Communities Legislation and on how this can influence the acceptance of risk related to new technologies has been started. As a first step, a study contract has been given to ISIG, the Institute of International Sociology of Gorizia (Italy), having as subject "Technological Development, Safety and Environment: Information to the Citizens in the European Communities Legislation". Two main areas were selected for investigation, where information to citizens constitutes a major concern and interest from the part of the legislator. These are nuclear safety and environmental management. The latter includes topics such as: major accident hazards, environmental impact assessment, biotechnology, eco-labelling and eco-management.

The aims of the critical review of the content and the structure of the legislative norms referring to public information are:
- to identify the basic concerns underpinning the requirements of information to the citizens in the EC legislation. These concerns may refer to prevention of risks, mitigation of negative consequences of accidents and the achievement of social consensus on valuable technological innovation;
- to identify the types of scientific knowledge necessary to meet these basic concerns and the sorts of uncertainty present in such knowledge. This in order to design effective information policies.

The critical review identifies and revises the relevant pieces of legislation, including the pertinent parts of the Treaties and of the Community Action Programmes on the environment. The latter define principles and objectives of the Community policy on a wide range of issues, including nuclear safety.

Structural Reliability

Pressurised Thermal Shock Experimentation

In 1992, at the end of the thermal shock campaign, non destructive techniques of inspection gave experimental confirmation of the theoretical prediction on structural behaviour, i.e. that no significant propagation of the artificial crack had occurred, mainly because:
- the sharpness of the front of the artificial crack was not as high as that of real fatigue cracks, and consequently the Stress Intensity Factor was not high enough;
- the material of our test piece did not undergo any irradiation embrittlement; consequently its fracture toughness remained higher than the applied Stress Intensity Factor (resulting from the combined actions of thermal shock and internal pressure).

Phase 3 of experimentation was designed to obtain a more critical situation for structural integrity in two ways:
– raising the crack tip sharpness by a mechanical fatigue propagation;
– lowering the material fracture toughness by simulating the neutron embrittlement by low temperature operation.

In order to obtain the first of the two above mentioned effects, a specially designed and built actuator has been placed inside the vessel in a position orthogonal to the nozzle. With the help of this actuator, some 250000 cycles of mechanical loading have been applied on the vessel. The range of the force developed by the actuator during every cycle has been from 0 to 2000kN. The test has been monitored online by 24 strain gauges and by acoustic emission sensors. The aim of propagating the artificial crack (obtained by electroerosion at the nozzle corner) to a fatigue crack of suitable dimensions and front sharpness has been apparently reached at 250000 loading cycles (the indication of ultrasonic inspection and acoustic emission monitoring as well were, as usual, largely uncertain).

Neutron embrittlement simulation was obtained by realizing a temperature jump (to produce the thermal shock) from 100 °C to approximately −197 °C (i.e. the temperature of liquid nitrogen). The thermal shock performed under these conditions provided at some extent a simulation of the irradiation embrittlement of the material of a real PWR vessel. The theoretical scheme of the simulation of the irradiation embrittlement of the material provided by the shift of the thermal shock temperature range towards negative values is explained in *Figure 2.37*. Initial heating at 100 °C of the nozzle has been obtained by resistance heaters placed at the external surface of the vessel. At the interior of the vessel and in front of the nozzle a metallic box has been placed, which has been welded on the inner face of the vessel. The nozzle with this box formed a container which has been filled up by liquid nitrogen during the thermal shock. In this way the temperature at the inner surface of the nozzle, being in direct contact with the liquid nitrogen, reached the value of −197 °C, whereas

the wall temperature reached approximately −70 °C at 15mm depth. A slight critical growth of the existing fatigue crack has been observed, followed by an immediate arrest event.

Phase 3 of the PTS test concluded the experimentation programme on pressure vessels. Future work will involve fractographic analysis (at Scanning Electron Microscope) of the nozzle and comparison between theoretical calculations of crack growth and experimentally observed crack fronts as will be revealed by fractography.

The Knowledge Based System BOSS (Backtracking and Overviewing for Structural Safety)

The knowledge based system BOSS tackles the problem of supplying the plant supervisor with a fast, intelligent tool for the surveillance of critical regions of the structure. Most of the work has been focused on the coupling of symbolic and numerical programmes and on the implementation of a qualitative reasoning module which has to cope with situations requiring fast, although approximate, answers.

The numerical codes COVASTOL (based on probabilistic linear elastic fracture mechanics and a phenomenological approach to fatigue modelling) and RELIEF (based on a semi-Markovian model of damage accumulation and a purely statistical approach to damage modelling), see *fig.2.38*, have been reshaped for an easier and more effective graphical presentation of results and a more user-friendly use.

More details about BOSS and the mentioned codes can be found in /1/2/.

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/1/ LUCIA, A.C. , BARBARO, P. (1993). Knowledge Engineering Application for the Management of Aging Plants. SMiRT 12, Stuttgart, 1993, K. Kussmaul (Edit), Elsevier Science Publishers B. V

/2/ LUCIA, A.C. (1993). "Knowledge-Based Systems Development for Structural Engineering at ISEI-JRC Ispra. SMiRT 12 post Conf. Seminar on "Expert Systems Applications in Power Plant and Structural Engineering", Constance, 1993

PRESSURISED THERMAL SHOCK EXPERIMENT
SIMULATION OF IRRADIATION EMBRITTLEMENT

Fracture Toughness

$$K_{IC}=28+27 \cdot exp[0.04025 \cdot (T-RT_{NDT})]$$
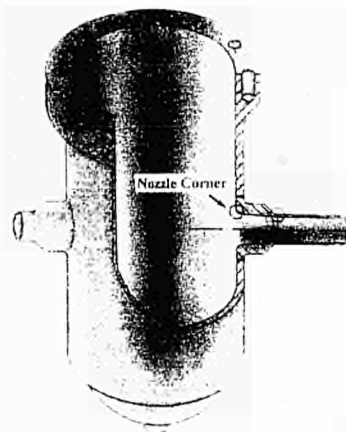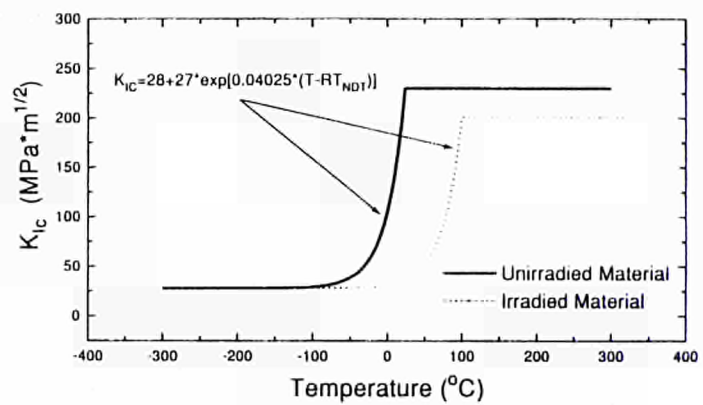
Fracture Toughness - SA508

Irradiated Material
$RT_{NDT} = 68 °C$
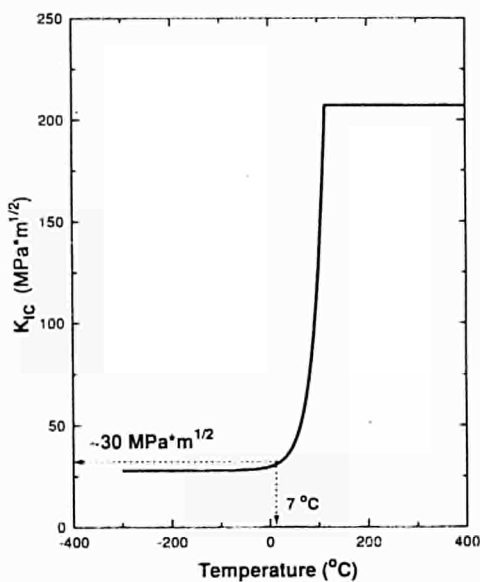
REAL THERMAL SHOCK CONDITIONS

$$T_{INITIAL} = 300°C \rightarrow T_{FINAL} = 7°C$$

Fracture Toughness - SA508

Unirradiated Material
$RT_{NDT} = -25.8 (°C)$

THERMAL SHOCK CONDITIONS FOR SIMULATION OF IRRADIATION EMBRITTLEMENT

$$T_{INITIAL} = 100°C \rightarrow T_{FINAL} = -197°C$$

Fig. 2.37. Theoretical scheme of the simulation of the irradiation embrittlement of the material provided by the shift of the thermal shock temperature range towards negative values

COVASTOL

Probabilistic Code for Fatigue Crack Propagation

Code features:

* Is based on Linear Elastic Fracture Mechanics

* Employs a randomized form of PARIS law:

$$\frac{da}{dN} = C(\Delta K)^n$$

a =crack size, N =number of loading cycles, ΔK =stress intensity factor range

n : mean value,   C : five-class distribution

* Considers elliptical defects (described by distributions); adapts easily to other type of defect geometries

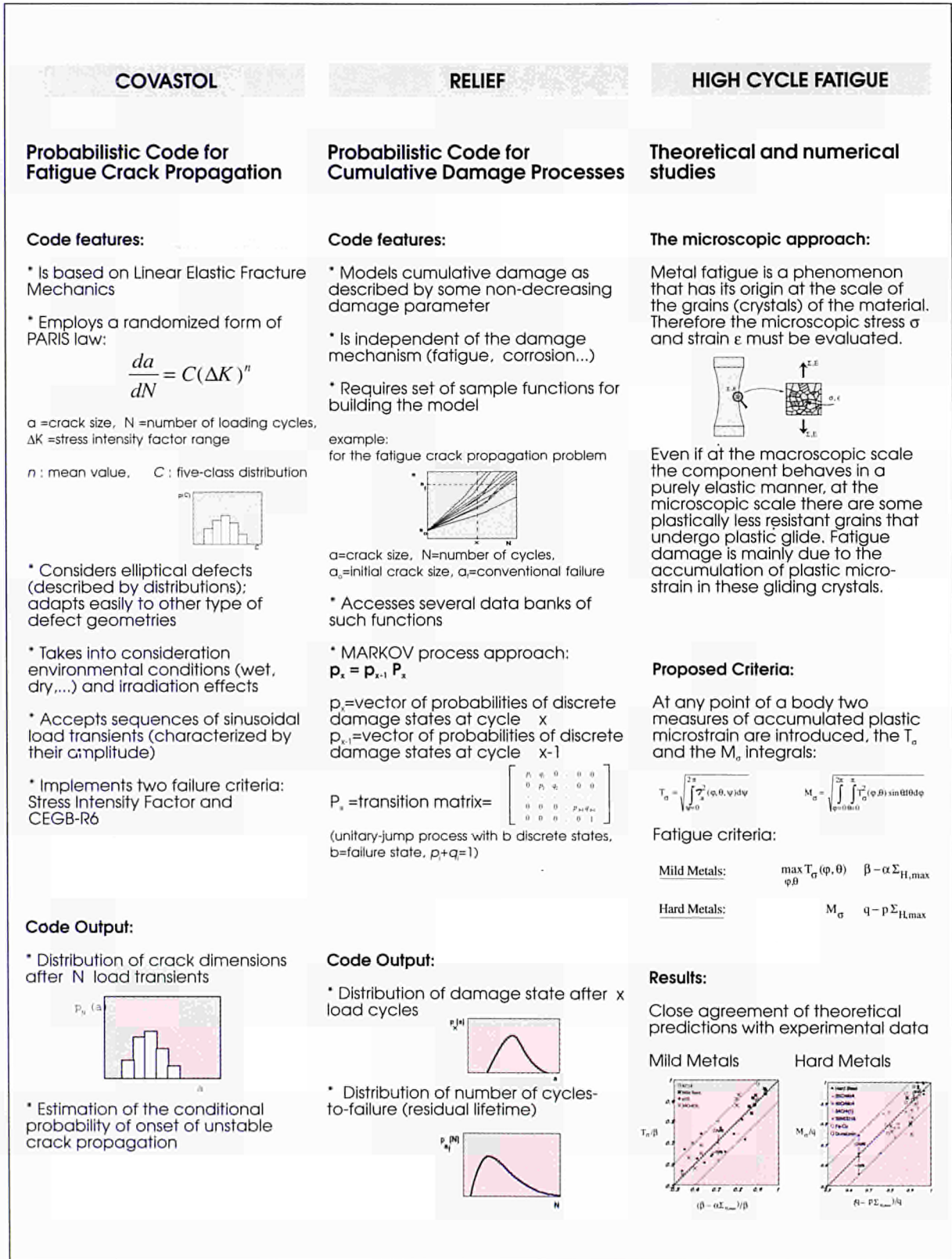* Takes into consideration environmental conditions (wet, dry,...) and irradiation effects

* Accepts sequences of sinusoidal load transients (characterized by their amplitude)

* Implements two failure criteria: Stress Intensity Factor and CEGB-R6

Code Output:

* Distribution of crack dimensions after N load transients

* Estimation of the conditional probability of onset of unstable crack propagation

RELIEF

Probabilistic Code for Cumulative Damage Processes

Code features:

* Models cumulative damage as described by some non-decreasing damage parameter

* Is independent of the damage mechanism (fatigue, corrosion...)

* Requires set of sample functions for building the model

example:
for the fatigue crack propagation problem

a=crack size, N=number of cycles, a_o=initial crack size, a_f=conventional failure

* Accesses several data banks of such functions

* MARKOV process approach:
$$p_x = p_{x-1} P_x$$

p_x=vector of probabilities of discrete damage states at cycle   x
p_{x-1}=vector of probabilities of discrete damage states at cycle   x-1

P$_x$ =transition matrix= $\begin{bmatrix} p_1 & q_1 & 0 & \cdots & 0 & 0 \\ 0 & p_2 & q_2 & \cdots & 0 & 0 \\ 0 & 0 & 0 & \cdots & p_{b-1} q_{b-1} \\ 0 & 0 & 0 & \cdots & 0 & 1 \end{bmatrix}$

(unitary-jump process with b discrete states, b=failure state, $p_i+q_i=1$)

Code Output:

* Distribution of damage state after x load cycles

* Distribution of number of cycles-to-failure (residual lifetime)

HIGH CYCLE FATIGUE

Theoretical and numerical studies

The microscopic approach:

Metal fatigue is a phenomenon that has its origin at the scale of the grains (crystals) of the material. Therefore the microscopic stress σ and strain ε must be evaluated.

Even if at the macroscopic scale the component behaves in a purely elastic manner, at the microscopic scale there are some plastically less resistant grains that undergo plastic glide. Fatigue damage is mainly due to the accumulation of plastic micro-strain in these gliding crystals.

Proposed Criteria:

At any point of a body two measures of accumulated plastic microstrain are introduced, the T_σ and the M_σ integrals:

$$T_\sigma = \sqrt{\int_{\psi=0}^{2\pi} \overline{\tau}_\sigma^2(\varphi,\theta,\psi)d\psi} \qquad M_\sigma = \sqrt{\int_{\varphi=0}^{2\pi}\int_{\theta=0}^{\pi} \overline{\tau}_\sigma^2(\varphi,\theta)\sin\theta\, d\theta\, d\varphi}$$

Fatigue criteria:

| Mild Metals: | $\displaystyle\max_{\varphi,\theta} T_\sigma(\varphi,\theta)$ | $\beta - \alpha \Sigma_{H,max}$ |
| Hard Metals: | M_σ | $q - p\Sigma_{H,max}$ |

Results:

Close agreement of theoretical predictions with experimental data

Mild Metals   Hard Metals

Fig. 2.38. Analytical tools for lifetime prediction of structures subject to fatigue damage

FISSION SAFEGUARDS

Surveillance and Remote Verification

Mobile Robotics for the Remote Verification of Fissile Materials

The objective of this project is to explore and demonstrate the use of mobile robotics technologies for the remote verification of fissile materials storage areas, i.e., remote inspection and inventory. The system consists of two main components: a vehicle carrying on board a manipulator arm and sensors (TV cameras, laser range finder and ultrasonic sensors) and the system's operator console. Considering the application area and the demonstrative character of the project, particular emphasis has been given to nuclear Safeguards considerations as well as to the ergonomy and functionality of the system's operator interface.

Software Architecture

System's hardware architecture has been thoroughly tested, and apart from minor changes can be considered stable and definitive at this stage /1/2/. Software architecture has evolved and is now being tested in terms of its flexibility, and efficiency.

In terms of software the system is divided into two main blocks:
an application oriented block running in the system's operator workstation, and a sensor oriented block running in the remote computers aboard the vehicle.

This distribution of the software into two main blocks has proved to be flexible, and an efficient way for remote control using a standard serial line. Three criteria have been considered for the allocation of a particular task to the existing processors (basically, the workstation and the remote computer).

The combination of these, often contradictory, criteria reduces the number of available options, and conditions the allocation of a computer to a particular task:

- to have all application oriented tasks running in the host computer, and all hardware (sensor) oriented tasks running on the remote computers;

- to minimise the amount of data through the serial line (ideally, only high level commands and measurements);

- to minimise the time delay introduced by a task in an interactive control loop, i.e., a control loop in which the operator is involved.

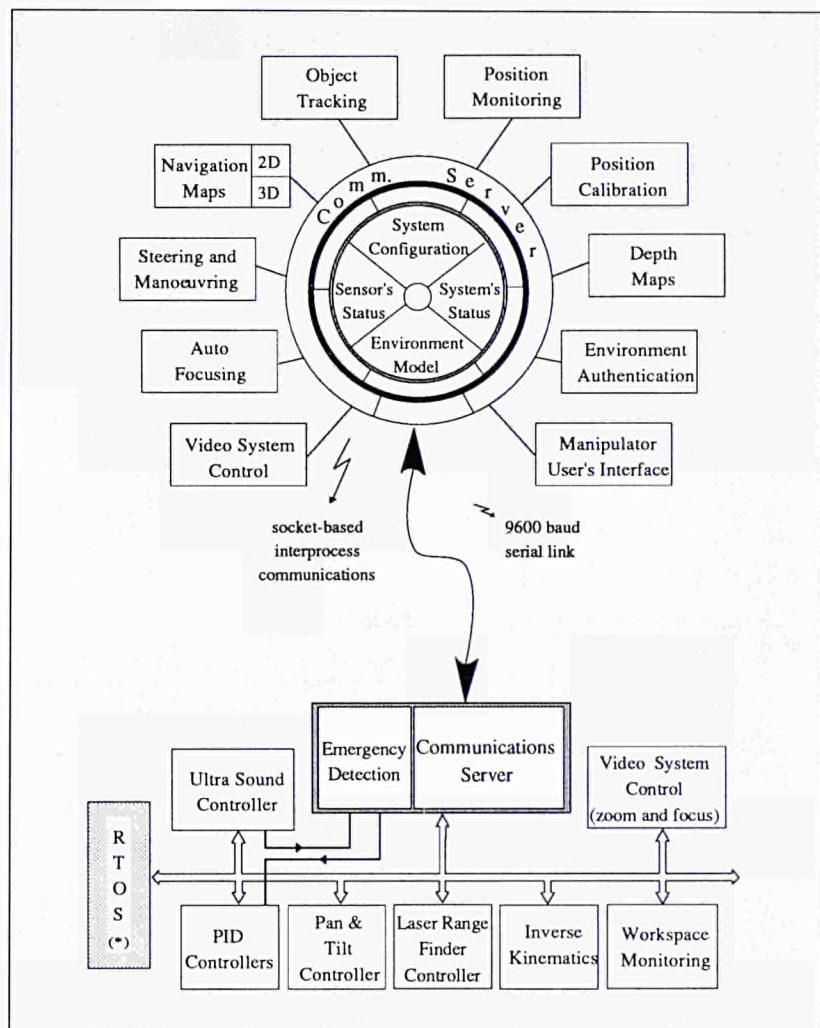A key element in the software (*figure 2.39*) is the communications server module /3/.

Fig. 2.39. Functional Modules and Software Architecture

The scope of this server is threefold:

- provide modularity at the system level, by creating a "standard" for inter-process communications, and by storing system's intrinsic data (*figure 2.40*);

- rationalise the traffic in the serial line, by coding, interpreting and filtering commands to and from the mobile robot;

- provide embedded security and safety.

Vehicle Navigation

Several graphical tools were developed for steering and manoeuvring the mobile robot, and to provide the necessary feedback (navigation) maps. Each tool has its own human-computer interface to let the operator choose at any moment the set of tools more adapted to his/her current job. The following navigation tools have been developed /4/.

Fig. 2.40. Inter-Process Communications provided by the Communications Server

- Steering and Manoeuvring: a graphical interface to steer the vehicle in one of three possible modes - Arrow Mode, Mosaic Mode and Spaceball mode.

- Navigation Maps: 2D and 3D real-time animated interfaces representing the mobile robot within its own environment.

- Ultrasound Perception: real-time display of ultrasonic sensors data. Environment maps can be overlaid to data representation, providing a position monitoring capability.

- Position Monitoring: checks the consistency between the position of the mobile robot as read from the odometers with the a priori known environment model.

- Trajectory Generation: generates (and checks for collisions) a smooth clothoidal trajectory path joining a set of target points input by the operator (*figure 2.41*).

- Position Localisation: calibrates the exact position of the vehicle, based on a set of distance measurements made by the on-board laser range finder /5/.
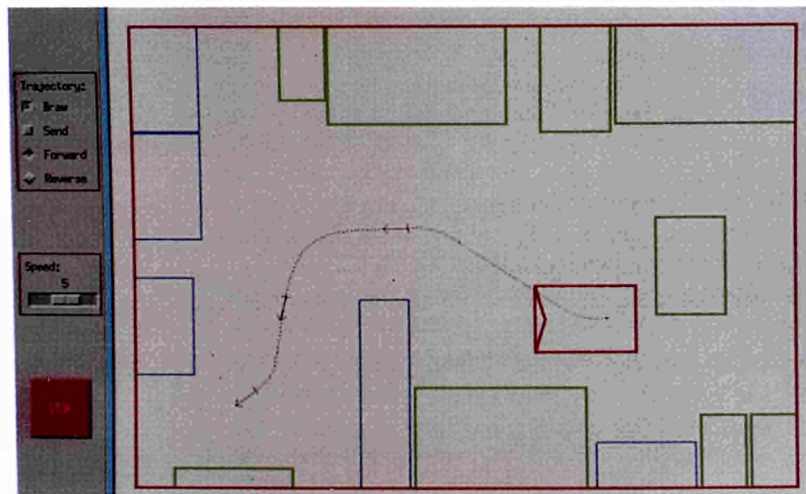

Fig. 2.41. Trajectory Generation and Simulation for Obstacle Avoidance
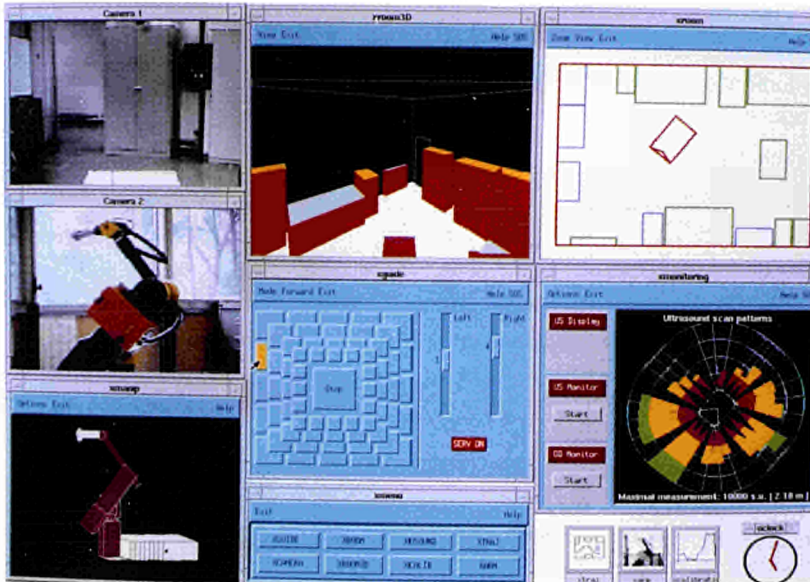
Fig. 2.42. Human Computer Interface, integrating Visual and Graphical Information in a Single Screen

Visual Perception System

The vision system includes two TV cameras equipped with computer controlled motorised zoom and focus lenses. The cameras are installed on top of two computer controlled pan- and-tilt units. The operator can interactively change the orientation of the two cameras and observe the quasi-live images on the workstation screen. *Fig. 2.42* shows the human- computer interface displaying the integration of different tools: two video images, vision system control panel, vehicle's steering, 2D and 3D navigation maps, and ultrasonic data representation.

Control of the Manipulator Arm

The operator controls the manipulator arm by means of the Spaceball input device. Operator commands are filtered, sent via the serial line to the remote computer, and translated into motion commands by the real-time inverse kinematics module. At the same time the manipulator arm joints coordinates are sent to the operator's workstation and a 3D animated view of the motion is displayed /6/. A workspace monitoring task, running concurrently, extrapolates existing motion and determines whether there is a danger of collision with surrounding equipment. *Fig. 2.43* represents the architecture and data flow diagram of the manipulator arm control /7/.

Position Authentication

Security measures foreseen in a nuclear Safeguards

environment require to have sensors based on different physical principles. The environment authentication tool must be able to provide an answer to the following question: "Considering that the mobile robot is supposedly located at position (x,y) how does the environment information measured by the sensors match the a priori known environment model?"

It was decided to use range data (i.e., distance measurements) to provide the extra information needed for the authentication of the environment. Distance information is difficult to reproduce and to tamper with, unless exact geometric conditions are known. Furthermore, distance information as measured by the laser range finder does not depend on a predisposition of the environment, e.g., illumination conditions.
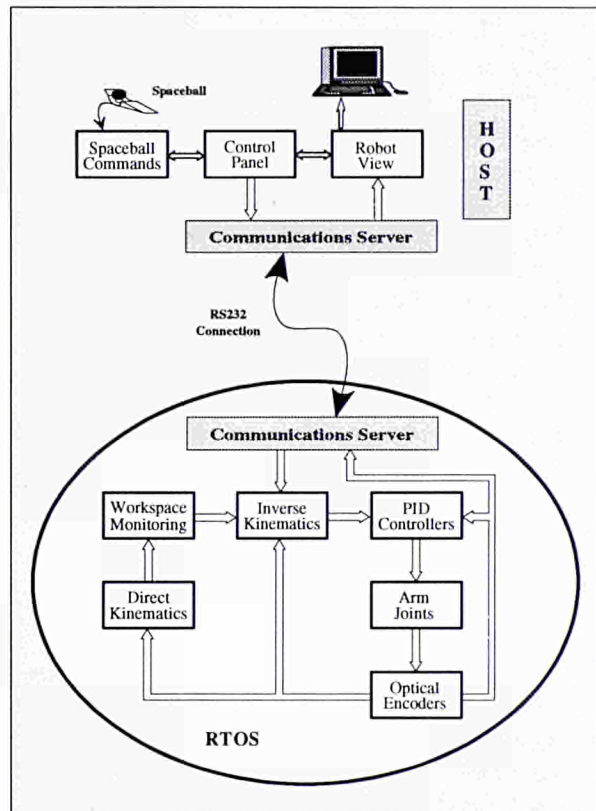

Fig. 2.43. Manipulator Arm Control: Software Architecture and Data Flow Diagram

Different approaches, all working upon range images, have been pursued /8/. A successful approach uses the concept of range occupancy grids /9/ and is based on matching real range data with a 3-dimensional grid of occupancy cells based on a priori model of the environ-
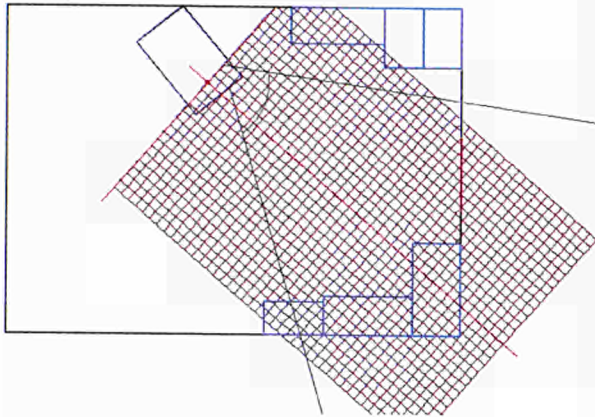

Fig. 2.44. Range Occupancy Grid

Fig. 2.45. 3D Representation of a Range Image of an Office Scene

ment. *Fig.2.44* represents a 2D illustration of the method. It was found that the method works well for displacement errors smaller than about 5 cm and orientation errors smaller than 2 degrees. These values are within the precision margin achieved by the existing position localisation tool.

Environment Modelling using Range Images

The fact that all the project assumes an a priori known environment is realistic, though it may lead to operational deadlocks whenever there are undocumented changes, or when the plant design databases are incomplete.

It was decided to start investigating the possibility of building a 3D model of the environment based on sensors data, namely on the on-board laser range finder. By scanning the environment in both the horizontal and vertical directions, the range finder produces a range image, i.e., a rectangular array of numbers, each one representing the distance between the range finder and the nearnest obstacle along a particular orientation. The applications for this technology are varied, namely in the field of the verification of building or plant design.

Fig. 2.45 shows the 3D representation of the range image of an office scene.

Some details in the office are easily noticeable: a cupboard, a piece of furniture with five drawers, the drawers handles, a thermostat on the wall, the office door (on the left) and its handle. This picture illustrates the
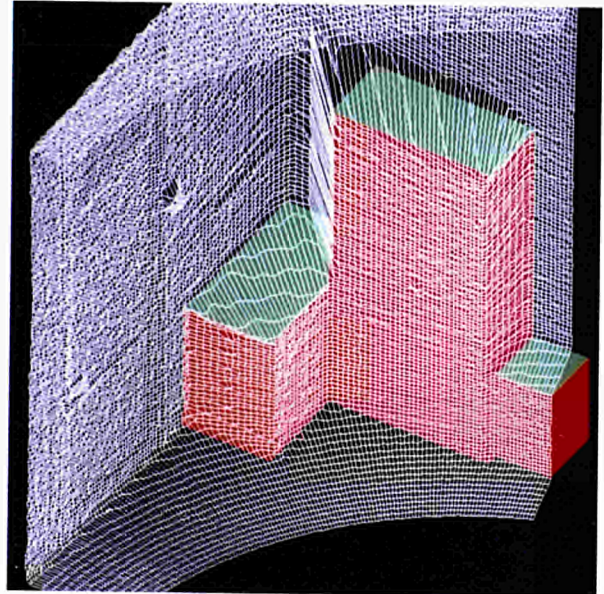
potentialities of this technology for environment modelling.

Active Vision Surveillance

One drawback of front-end video surveillance data reduction systems stems from the fact that once data are reduced, it is no longer possible to get more detail than the one provided by the data reduction system. A combination of a scene change detection algorithm with gaze control was set up in order to complement alarm data with details of the causes that generated the alarm /10/.

The gaze control system that was implemented is composed of two TV cameras, one with conventional wide angle lens and the second with a motorised lens with computer controlled zoom and focus, installed on a pan-and-tilt unit. During operation, the scene change detection system /11/12/ analyses the images from the first camera at full frame speed to detect scene changes. Once an alarm is detected, the image from the first camera is archived. At the same time, the pan and tilt system aims the second camera at the point of the scene where changes have occurred. The zoom of the second camera is then activated to get a more detailed image of a specific scene region and an auto-focusing procedure is initiated /13/.

A second scene image is then acquired and archived, complementing the first scene image with the necessary details in the area of interest. *Figure 2.46* shows the architecture of the gaze control system.
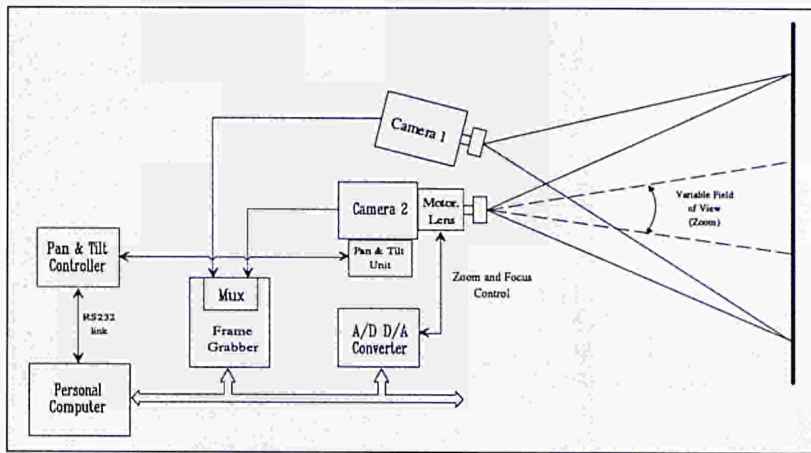
Fig. 2.46. Architecture of the Active Surveillance System

References

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/11/ MOL M.J. - "Programme REVIEW for Real-Time Scene Change Detection in Video Images on a PC Based Vision System", Report EUR. 11677EN, June 1988

/12/ MOL M. J. - "Image Processing Methods for Scene Change and Motion Detection", ESARDA Bulletin No.19, pp.9-13, May 1991

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Sealing and Identification Techniques

Based on experience acquired on site and in laboratory in 1992, an effort of rationalisation of the software used for the identification of ultrasonic seals has been conducted leading to simplified and easier inspection procedures. In parallel, much work was devoted to the installation of such procedures on portable equipment using commercially available, newly developed ultrasonic/electronic boards. This has required the acquisition, testing and approach of the new boards prior to come to the creation of other software and source codes.

A study has been launched as for the use of a sealing-bolt system for the sealing of concrete or cast iron nuclear containers used for the transport of spent fuel elements and/or for their storage in intermediate or permanent repositories. A preliminary visit to GNS German installations and production plant has indicated the feasibility of such systems provided that the storage procedure and casks handling and accessibility be well known. Information about South American open air permanent storages shows the system could also apply to the sealing of the lids of fixed concrete containers.

Containment and Surveillance (C/S) Performance Evaluation

The main objectives of the Laboratory for Surveillance and Containment (LaSCo) are summarised as follows:

- Performance assessment of C/S devices and systems
- Demonstration and development of effective procedures for proper use of C/S in specific applications
- Training of users for the application of different C/S techniques.

Performance Assessment of Containment and Surveillance Devices and Systems

In general terms, performance tests may be defined as those which are performed to determine if C/S devices and systems, or other components, can be stored, transported and operated under various conditions without experiencing physical damage or deterioration in performance.

This definition includes three distinct conditions:

– Storage
– Transportation
– Operation

Systems may be transported and stored under very severe environmental conditions, which do not correspond to the operation conditions, which are normally much less stringent. For instance seals and cameras may be shipped by air with important temperature transients (thermal shock) and handling shocks, while they are packed. The same seals and cameras may however operate under nearly constant temperatures and submitted to very limited vibrations and shocks.

The conditions of transport, storage and operation are to be analysed in terms of environmental characteristics which include mainly temperature, humidity, vibrations and shocks. Other characteristics not considered yet in the Laboratory for Surveillance and Containment (LaSCo) are electromagnetic perturbations, radiations test....

The US standard "MIL-std-810 E", gives a good overview of the various conditions which may occur during the life of a hardware component and is described in Table 1.

In order to qualify newly developed components (from JRC, other R/D laboratories and industry) or existing ones, to establish performance profiles and the fitness for the purpose, LaSCo has been equipped with several test facilities.

These equipments are divided in two zones: a Thermal Test Area, which was described in details in the last Annual Report and presented in figure 2.47, and a Mechanical Test Area which was extended during 1993 as described below.

The Mechanical Test Area was originally equipped with a small vibration unit which permits to test small components up to 2 Kg under sinus vibrations up to 19 g's. In order to test larger components and systems, LaSCo was equipped with a second vibration unit composed of two coupled vibration pots which gives a load capacity of about 30 Kg (fig. 2.48).

This new installation is driven by a special general calculator which permits the generation of complex random vibration profiles (fig. 2.49) in order to simulate the real vibration conditions which could appear in the life time of an equipment (i.e. during transportation, handling..).

The various vibrations profiles which are applied on the components which are tested on this equipment are generally picked from the international standards.

The general calculator, which is connected to both the small vibration unit and the new one, also permits the generation of classic sinus vibration profiles and also shock waves of different shapes, amplitudes and durations.

It is now possible to study the C/S equipments and

	Truck Transport	Train Transport	Plane Transport	Ship Transport	Closed Storage	Open Storage
Environmental stress generation mechanism (Induced)	.Road Shocks .Road Vibrations .Handling Shocks	.Rail Shocks .Rail Vibrations .Handling Shocks	.In Flight Vibrations .Landing Shocks .Handling Shocks	.Wave Induced Vibrations .Wave Shocks .Handling Shocks	None	None
Environmental stress generation mechanism (natural)	.High Temperature (Dry/Humid) .Low Temperature .Rain/Sand .Dust	.High Temperature (Dry/Humid) .Low Temperature .Rain/Sand .Dust	.Reduce Pressure .Thermal Shock	.High Temperature (Humid) .Low Temperature .Rain/Salt Fog .Temporary Immersion	.High and low Temperature .Salt Fog .Fungus .Chemical Attack	.High and low Temperature .Rain/Sand/Dust .Solar Radiation .Chemical Attack, Fungus

Table 1: Generalised life cycle histories for hardware (from MIL-std-810 E).

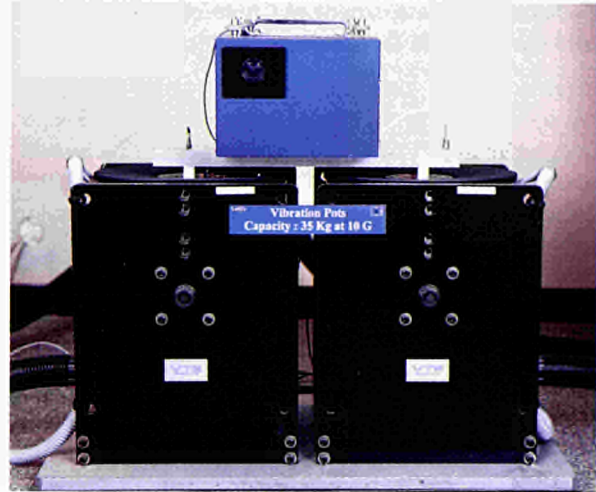**Fig. 2.47.** View of the Thermal Test Area in LaSCo

Fig. 2.48. View of the Vibration Test Unit in LaSCo

systems under a very wide range of mechanical stresses they could encounter during their life time.

With both tests zones, we are now able to run the tests in LaSCo following various international standards or as requested by the customer.

During 1993, tests protocols have been defined and specific tests on items have been performed on:

– An inclinometer used on trucks, produced by a French company. This inclinometer was tested under sinus vibrations up to 6 g's in a frequency range of 20 to 1000 Hz;

– A video camera used for surveillance. This camera was tested under thermal and mechanical stresses, under storage and operation conditions. The test procedure was taken from standard MIL-std-810 E;

– The Titus ultrasonic seal. A complete test procedure was applied on this seal in order to study its performances under thermal and mechanical stresses;

– Compact surveillance system (COSMOS), developed by JAERI (Japan), for which the first reference tests at room temperature were done.

LaSCo's test programme foreseen for 1994 is the following:

– Continuation of thermal and mechanical tests on Compact Surveillance System;

– Study of the performances of the Logitec Fotoman camera used in the Gemini surveillance system for which a detailed protocol was prepared and submitted to Euratom Safeguards Directorate in Luxembourg;

– Environmental tests on the ultrasonic seal reading system called IRUSS, developed in the framework of a cooperation contract between AECL (Canada) and JRC;

– Thermal and mechanical tests on the Authenticated Item Monitoring System (AIMS) for which a detailed protocol was prepared and submitted to Sandia National Laboratories.(U.S.);
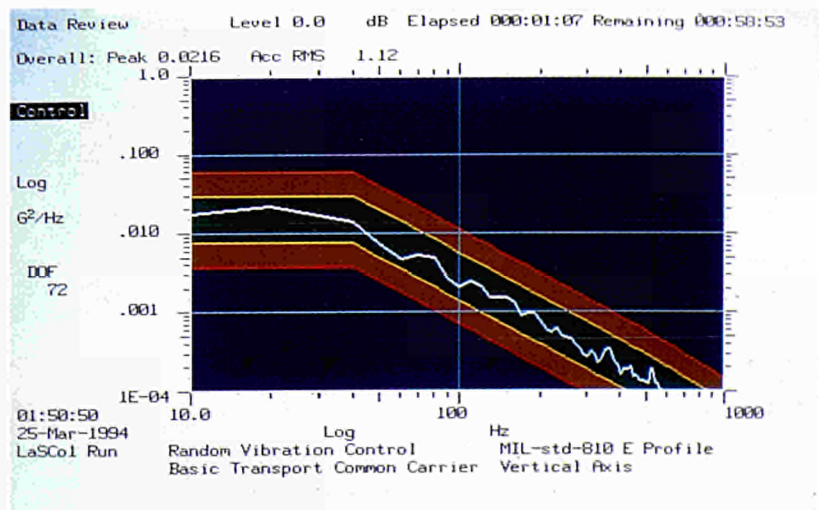

Fig. 2.49. Typical random vibration profile used for basic transportation test (from MIL-std-810E)

– Study of the performances under thermal and mechanical stresses of a Multi Channel Acquisition system Nos- National Instruments for which a detailed protocol was prepared and submitted to both companies;

– Study of the reliability under thermal and mechanical stresses of TIRIS transponders and portable reading unit used for animal tagging.

Demonstration and Development of Effect Procedures for Proper Use of C/S in Specific Applications

Containment and surveillance devices and systems are widely used by inspectors in various parts of the fuel cycle. The LaSCo laboratory is studying in a systematic manner the performance characteristics of these devices and systems. One has to define the tasks or functions each C/S device is supposed to perform in a particular situation and select a device or a combination of devices which have the appropriate performance profile. In order to perform these studies, experimental facilities were set-up.

Mock-ups have been assembled, one with real size horizontal units and the other one with vertical storage pits. These mock- ups are equipped with different C/S devices.

A multi-sensor system has been assembled within the LaSCo hall for the surveillance of areas defined as "strategic". This system comprises an optical surveillance unit called CAVIS-IIs (Computer Aided Video System) developed at JRC and which is now being used by EURATOM Safeguards Inspectors in several bulk handling facilities.

A model of the Advanced Storage Area (ASA) has been assembled and has been described in the 1992 progress report of ISEI. It consists in eight real size storage units (typically used for PuO2 storage). Each unit comprises four cavities, which may include two cans each. Every operation to open the cells and to handle the cans is remotely controlled.

The activities carried out in the Advanced Storage Area are aimed to study different scenarios of using C/S systems (see *fig. 2.50*). The scenarios will vary according to the type of storage (e.g. short / long term ; type of material).

The sensors and systems presently under study are mainly commercial products.

Three kinds of monitoring are envisaged:

– at the level of the storage area (building, room);

– at the level of the storage unit (cell, pit,.);

– at the level of the individual nuclear material container (can, assembly, .).

Each sensor will be tested for its reliability and its specific, technical and operational, characteristics and functions will be described. The final system will be a combination of the appropriate sensors.

Monitoring of the Storage Area

The LaSCo's storage area is equipped presently with three cameras connected to the optical surveillance unit (CAVIS). For the monitoring of the entrance, this area will be equipped with a heat flow detector, to detect the human presence . For the darkness surveillance, an I R. camera is being tested.

The entrance of nuclear material in a storage area is normally detected by a neutron-gamma detector (not installed in LaSCo).

To detect the introduction of material or persons other than through the authorised entrance an accelerometer has been installed on the wall. This detector is intended to identify, for instance, if a hole is being made in a wall.

Monitoring of the Storage Unit

At this stage, two types of monitoring are carried out:

– monitoring of the entrance to the unit,

– monitoring of the internal volume of the unit.

The optical surveillance of the storage unit is performed by the same cameras used for the surveillance of the storage area. On the doors an identification code and a seal is being applied. Heat transfer detectors will be used for the external monitoring of the units.

The physical sensors under study for the monitoring of the internal volume are, for instance, vibration detectors, heat flow meters.

Monitoring of the Individual Nuclear Material Container

Each container is sealed and identified with a concentric bar code. In the case of a long term storage sensors can be placed around the container itself.

Temperature gages, infrared sensors are applied directly on the cell panels. Different types of weight sensors are also installed and their characteristics are being studied.

The analogue signal obtained from each of the various sensors is connected to a universal process meter, as shown in *figure 2.51*. This instrument is a signal conditioner and can be used for some sensors as a power supply. This meter provides setpoints to latch any alarm conditions, which are programmable either by the process meter's keyboard or by software of the
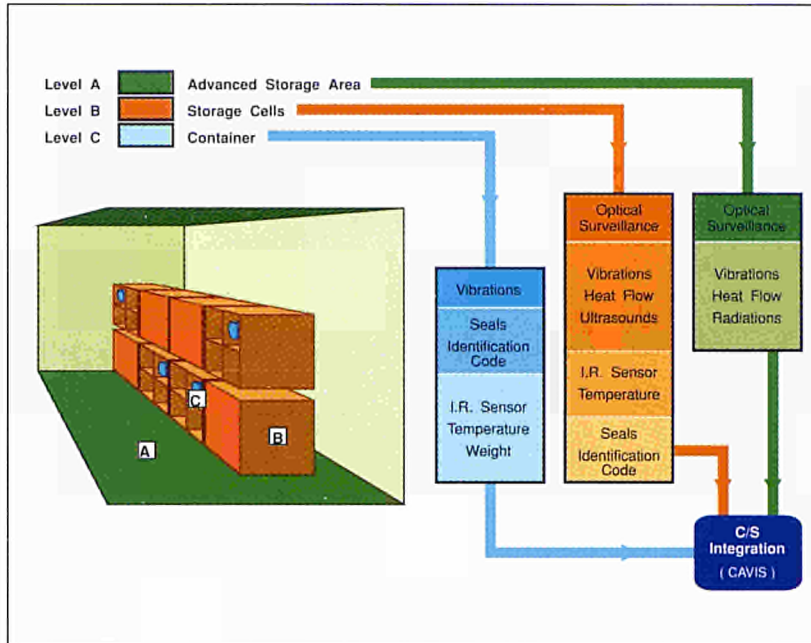
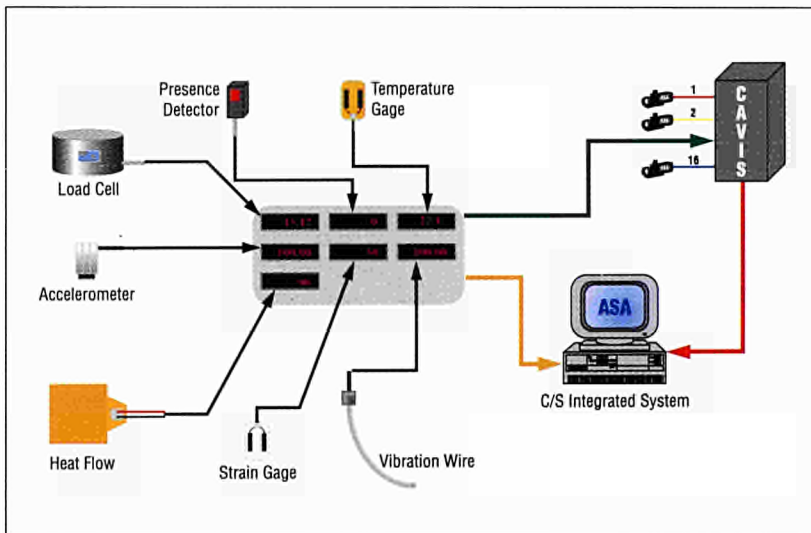**Fig. 2.50.** Basic Structure and Examples of C/S Systems in an Advanced Storage Area

One action is the integration of individual sensors, tested at JRC, in an overall system, for which a design study is now in course.

Secondly the integrated monitoring system, mentioned above, has been integrated with the computer aided video system (CAVIS) developed at JRC.

Both SNL developed system will be integrated in the ASA Integrated C/S System (AICS). The AICS Software for the full management has been defined and the first version will be in operation next year.

This integrated system is to be considered as a demonstrator which will enable further study of data and safeguards analysis of complex systems, taking into account also remote monitoring requirements.

Fig. 2.51. Description of the ASA Sensors

Integration of Safeguards Techniques

The activities performed in this research area are oriented towards the development of tools for the evaluation of the nuclear fuel cycle and the trend of safeguards R/D activities. Furthermore some efforts are dedicated to the management of the European Safeguards Research and Development Association (ESARDA) which is a wide ranging R/D association in EC. In the framework of this research area, the planning and evaluation of experiments for evaluating performances of mass and volume measurement in liquids is also performed.

Central Control Unit. According to the signals received, the process meters analyse if an alarm is produced, and of which type.

Two systems, developed by Sandia National Laboratory are also being tested for its long term reliability. They are the Integrated Monitoring System and the Authenticated Item Monitoring System.

A further important objective in LaSCo is the integration of different type of sensors.

Data Base on Nuclear Fuel Cycle and R/D Activities

The establishment of nuclear fuel cycle data base on existing facilities in EU has been continued. A bulk handling facilities file has been completed.

Concerning the EU safeguards R/D data base, ESARDA

partners have continued to supply the required data for the 1993 updating.

Furthermore an analysis has been conducted with the ESARDA partners on the R/D activities related to the fabrication and reprocessing plants. The results of this analysis are to be published in the ESARDA bulletin.

Management of ESARDA

The management of the European Safeguards Research and development Association was performed through the general secretariat, held by ISEI staff. In particular, support was provided to the organisation of the 15th ESARDA Symposium on Safeguards and Nuclear Materials Management, which was held at Rome (Italy) on May 11-13, 1993, with the participation of 220 people and the presentation of 150 papers. Special sessions were organised on:

– Challenges and trends in modern safeguards

– IAEA safeguards

– Safeguards in highly automated plants using advanced techniques

Support was also given to the organisation of the IAEA Symposium on Safeguards, to be held in March 1994. ISEI staff actively contributed to the redefinition of the ESARDA activities and contents, which was carried out with a view to adapt the structure and the scopes of the Association to a changed safeguards scenario and to streamline its operation. ESARDA is now preparing itself to open its activities to new partners (from Sweden,

Finland, Austria) and to consider also safeguards issues arising from the interaction of the European nuclear fuel cycle with other fuel cycles, in particular that of the former "Eastern block".

Mass and Volume Measurements

The construction of the Tank Measurement Facility (TAME) has been continued and an important part of it has already been commissioned. The annular vessel of 12 cubic meters, representative of a reprocessing input accountancy tank, is now operational, with full remote control and automatic data acquisition system. Another annular vessel of 250 litres, originally designed as the product tank of the Saluggia reprocessing plant, is also operational. A third vessel, "harp" shaped, has been received from the UKAEA, together with a "load cell" weighing system, and will be installed in the near future. The TAME project is a joint project executed between the Institute of Safety Technology (IST) and of System Engineering and Informatics (ISEI).

On October 6-7, 1993, the second expert meeting was organised at Ispra on "R/D for Volume and Mass Determinations in Liquids". This meeting was intended to collect suggestion on the possible activities of TAME and to explore the feasibility of bilateral and a multilateral collaborations The meeting was attended by representatives of all present technology holders of reprocessing plants in EU and Japan, EURATOM and IAEA safeguards Inspectorates, R/D laboratories in EU, Japan and US which have development programme in liquid mass and volume measurements.

CONTROLLED THERMONUCLEAR FUSION

Fusion Technology and Safety

The Fusion activities at the ISEI concern the safety aspects of fusion plants, with the objective of evaluating feasibility and acceptability of fusion energy.

These activities pertain to the following critical areas:
- Structural integrity during disruptions off-normal events;
- Operational safety and reliability during Remote Handling maintenance;
- Envelope Accident and Passive Safety Analyses;
- Neutron induced activation analysis and activated waste management.

The ISEI Fusion activities, fully integrated in the European Fusion programme and coordinated by the European Fusion Directorate, are subsidiary to the activities performed by the other European laboratories. They are intended to assess and compare, from the safety and reliability point of view, the Design proposals of the project teams and of various national laboratories, and to define the Design conditions in the most safety critical areas.

These activities are complementary to the other Fusion activities performed at JRC, which are:
- Safety aspects of Tritium Technology (Safety Technology Institute);
- Developments of materials for Fusion applications (Institute for Advanced Materials).

The ISEI Fusion activities in 1993 can be subdivided in two main chapters:
- "Next Step Activities", concerning the design of the Next Experimental Reactor, as ITER;
- "Long Term Studies", concerning DEMO and Commercial Reactors and including the Safety and Environmental Assessment of Fusion Power.

The main customer has been the NET Team, as European Home Team for the ITER contributions and directly for the Long Term activity SEAFP (Safety and Environmental Assessment of Fusion Power).

Structural Integrity Assessment during Disruption Off-Normal Events

The study of electromagnetic (EM) forces caused by variation of magnetic fields in the conducting structures surrounding the plasma remains one of major items in fusion with magnetic confinement. The design of the plasma-facing components (PFCs), the related vessel interfaces and the vacuum vessel itself are strongly affected by the necessity of maintaining the stresses caused by rapid and abnormal magnetic field variations, e.g. during disruptions, within acceptable limits, in order to avoid damages (e.g. permanent deformations and vacuum losses). ISEI is working, both theoretically and experimentally, in this field.

ISEI has developed the tools (an integrated computer-aided- engineering-CAE system and a validation laboratory-TESLA) for ensuring the support to the Design, Analysis and combined Validation in the context of the Tokamak Structural Integrity Assessment /1/2/.

In addition to the proposed Attachment Locking (AL) Systems, designed to support the blanket segments and to transmit huge reaction forces at the level of the vacuum vessel (VV), and satisfying Remote Handling (RH) Requirements of an easy discountability, the internal reinforcement system of the blanket modules has bee investigated. Specific studies and tests in transient conditions are needed with the aim to choose a reference solution and to attain a design optimisation.

Evaluation of the Electromagnetic Forces Induced in the in- Vessel Components and their Supports (Next-Step Activity - NET Task CS 20-2).

The "Toroidal Belt Concept", proposed by JRC Ispra, for the Attachment Locking (AL) system of the First-Wall Blanket Segments (FWBSs) to the Vacuum Vessel (VV) is still of actuality for segmented blankets, which can be circled by continuous structures (see figure 2.52). But the recent ITER- EDA design recommends toroidally continuous PFCs. In that case, the eddy current pattern is characterised by higher eddy currents flowing toroidally without box-type current circulation.

As a consequence, results of the recent eddy current analysis have shown the radially oriented magnetic pressure for the flat FW component, mainly in the inboard region (see figures 2.53 and 2.54). Otherwise, a canister-type blanket with curved FW panels should still generate vertical EM forces (interaction of radial eddy current components with the high toroidal magnetic field) and, thus, high shear stresses.
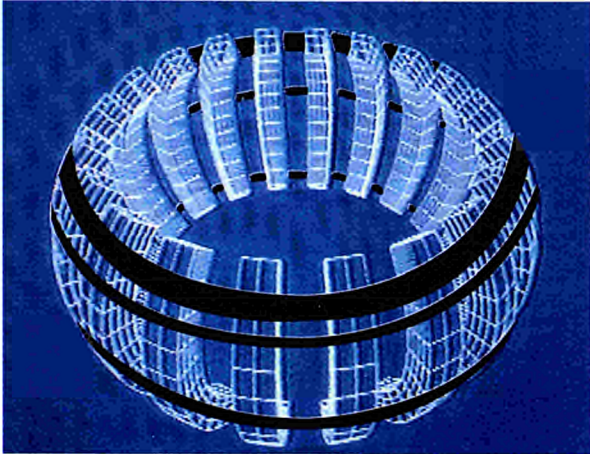
Fig. 2.52. Blanket segments circled by continuous structures, according to the Toroidal Belt Concept
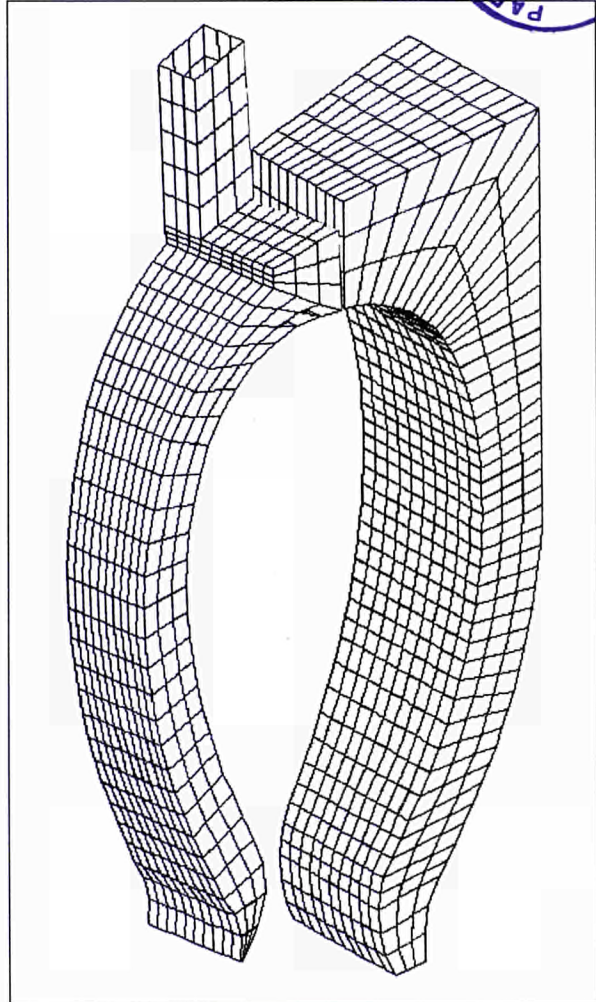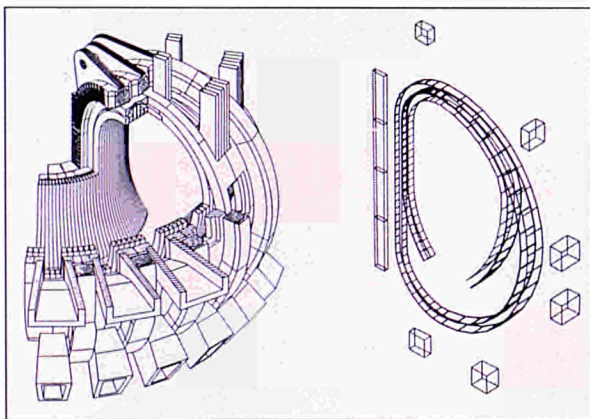

Fig. 2.53. CAD model of the ITER/EDA configuration (by Courtesy of the Home European Team) & FE mesh of a 5° Tokamak sector

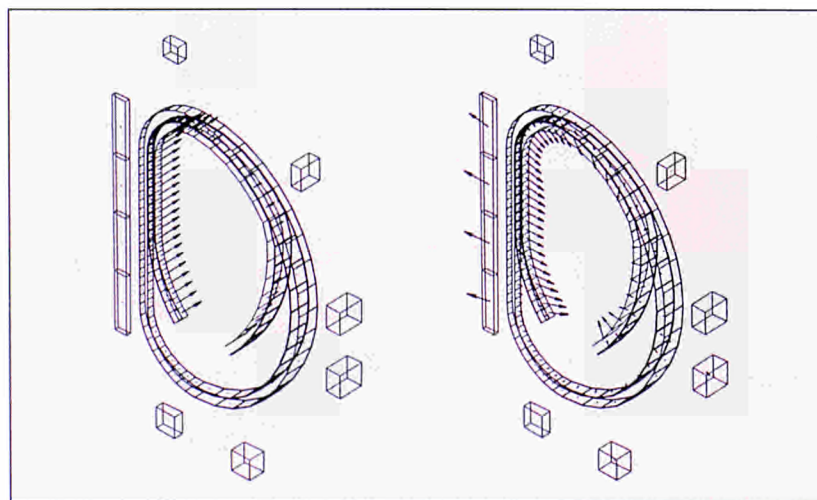**Fig. 2.55.** FEM model of segmented blanket modules (SEAFP)

Fig. 2.54. EM analysis results terms of eddy currents and forces

To perform these analyses, 3D CAD/FEM models have been generated by CATIA and PATRAN. Then, ABAQUS and CARIDDI codes have been extensively used.

Safety features Improvement of a Baseline Reactor Design (SEAFP Task M6-1)

Studies of modification of the blanket region for supporting the disruption loads have been undertaken. As no significant structural deformation should be allowed after the accident, the real affects of the transient EM forces induced in the blanket representative mod-

els have been estimated /5/. Three internal box reinforcement concepts have been considered, based on the use of radial/poloidal ribs, toroidal shielding panels, horizontal diaphragms, respectively (see *fig. 2.55 and 2.56*). During the first half of next year, guidelines on proposed reinforcement systems will be developed.

Validation of Computational Modelling in Electromagnetic- Mechanical Coupling

The first experimental validation study of the damping effects on magnetically induced vibrations has been undertaken on the ELBA test-rig /3/4/. The improvement of the measurement technique, with the use of a laser-based instrument and analyser, has been of major concern. A first definition of the operating parameters of the dynamic loading test facilities has been performed as proposal for an ITER task.

Definition of Dynamic Simulation Testing of Partial Blanket and Vacuum Vessel Mock-ups(Next Step Activity-ITER Emergency Task ETA-BLR7)

The European Coordination of an Emergency ITER task has been assigned for the definition of "Dynamic Text Facility and Text Programme". This task deals with the real performance of the Vacuum vessel and blanket design solution against plasma disruption and off-normal events. The follow up of this task for 1994, in the context of the ITER/EDA design is in preparation (ITER task T15).

References

/1/ CRUTZEN, Y., PAPADOPOULOS, S., RICHARD, N. and SCHNEIDER, J. - "Modelling of Transient Electromagnetics in Tokamaks during Off-Normal Conditions", Journal de Physique III France 3, pp. 469-483, 1993
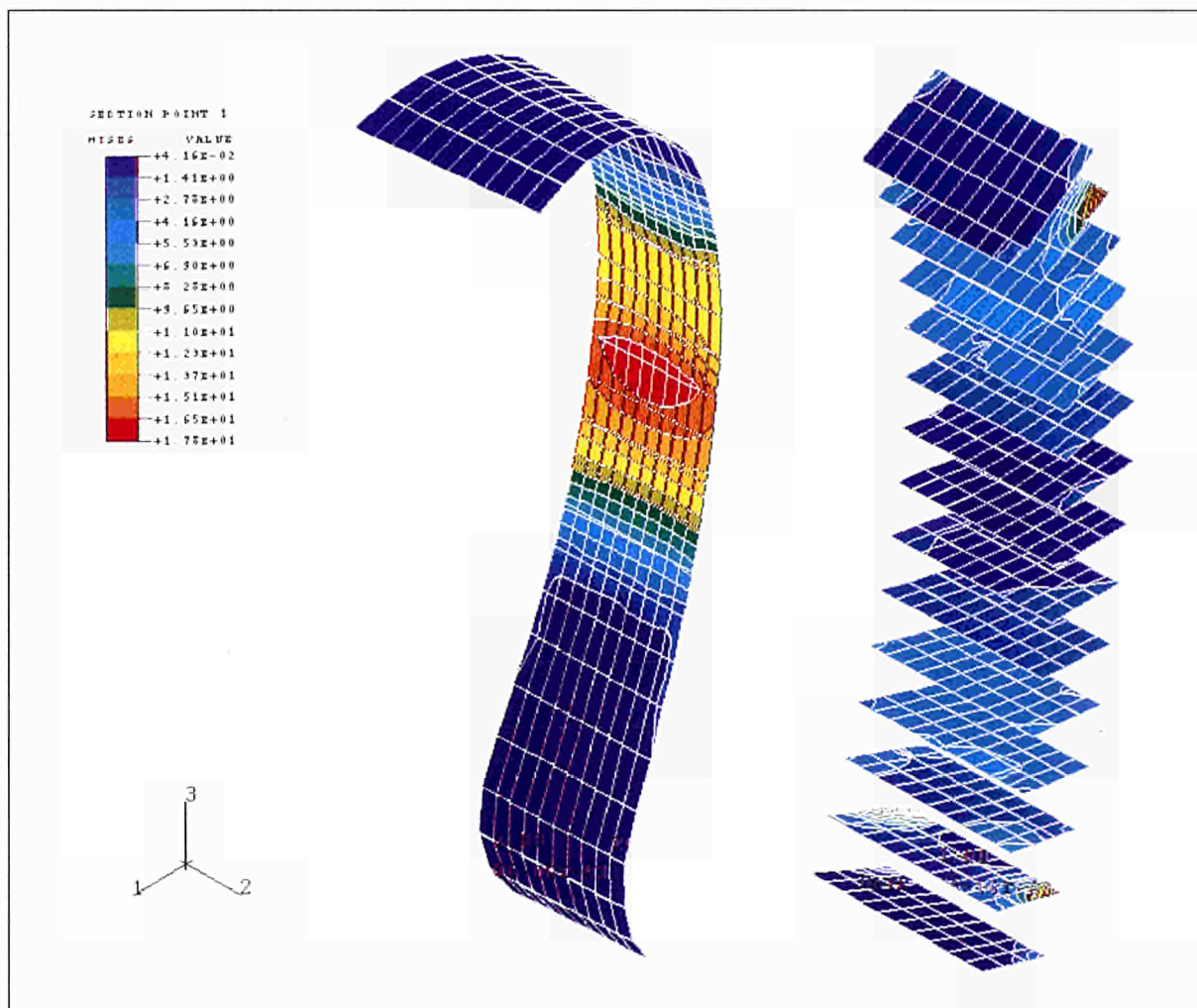
Fig. 2.56. Stress Distribution in First Wall and Horizontal Diaphragms

/2/ CRUTZEN, Y. and SAKELLARIS, I. - "R&D on the Magnetomechanical Design of Tokamak Blanket Structures using Combined Numerical/Experimental Techniques", Proceedings of 2nd Workshop on EM Forces, Tokai, Japan, 1993

/3/ CRUTZEN, Y., PAPADOPOULOS, S., RICHARD, N. and VAN PAEMEL, F. - "Modelling Analysis & Validation of Electromagnetic-Mechanical Coupling on Clean Test Pieces", Compumag Conf. Proceedings, Miami (USA), 1993

/4/ CRUTZEN, Y. (et al.) - "Solution of TEAM Problem 16: Magnetic Damping of a Cantilever Plate in Torsional Mode", TEAM Workshop, Miami (USA), 1993

/5/ CRUTZEN, Y., FARFALETTI, F.-CASALI, INZAGHI, A., ROCHEZ, E., SAKELLARIS, I. - "Reinforcement Systems Satisfying Disruption Problematics of Segmented Blanket Concepts", intermediate SEAFP report of Task SEAFP/R-M6-1, CEC-JRC Ispra Techn.Note ISEI I.93.166, 1993.

Operational Safety and Reliability during Remote Handling Maintenance

The Fusion Reactors will become radioactive during operation to such an extent that they will not permit any human intervention and will require, during maintenance, tight containment of tritium and activated dust. Moreover, the dimensions (up to 20 m) and weights (several tons) of the internal components (such as first wall/blanket modules), to be removed with precisions of few mm, pose unresolved problems. If a Remote Handling Device fails within the reactor, it can damage the internals and cannot be repaired or removed by humans. If an exceptional disruption event damages the PFCs, they must be substituted remotely. If the containment of the activated products leaks during maintenance, it can have severe consequences on the environment.

This means that the reliability of Remote Handling devices and operations, and the containment during maintenance are key problems for the design, in order to demonstrate that a Fusion Reactor can be remotely operated, maintained and decommissioned in a safe way. Because of the requirements to work in such a radioactive environment on huge heavy components, neither the conventional industrial robotics technology nor the "in space" technology are adequate.

It follows that specific studies and tests are needed to achieve operational safety during maintenance. ISEI has the experience and the tools (an advanced CAE System and a Teleoperation Laboratory TELEMAC) for ensuring a support to the design, reliability analysis and testing of maintenance equipments and operations, which could satisfy the previous requirements.

The engineering support to the Remote Handling problems is provided by Computer Simulation, Experimental Validation on mock-ups in scale and Reliability Analysis. TELEMAC Laboratory, by using the ROBERTINO facility, allows validation tests to be performed on mock-ups of whole complex systems in a scale big enough to give, at an acceptable cost, significant indications of the behaviour of the full-scale systems and prototype equipments.

The facility ROBERTINO is a large gantry robot, the purpose of which is to test the replacement of the blanket modules mock-ups from the mock-up of one sector of a Fusion Reactor (see *figure 2.57*).

Studies for the Application of Remote Handling Simulators (Next Step Activity - Task RHB 1-1)

The studies for development of a domestic Ispra Simulation package, supporting the design of Remote Handling Systems for the assembly and maintenance of a nuclear Fusion plant, have been completed. As a consequence of the adoption of a new CAD system, CATIA, a new interface has been created, in order to allow to use models taken from CATIA.

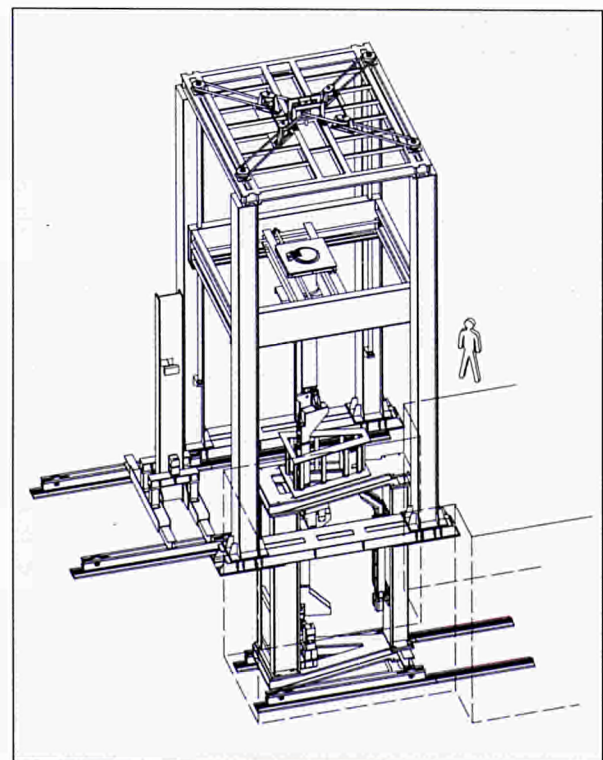In the same time, a commercial simulation package,

Fig. 2.57. The ROBERTINO facility

developed at KfK, KISMET, has been installed and it is now available.

The task of evaluating various candidate commercial packages for Remote Handling simulation has been performed on request of the NET Team.

This evaluation will be the basis for selecting the most suitable simulation package, as an European proposal for use inside the Fusion community. The selected simulator will be also adopted for the Remote Handling workstation, that will be developed for application inside the TELEMAC Laboratory.

Development of a Remote Handling Workstation (Next Step Activity - Task RHB 1-2)

The purpose of this activity is to develop a Remote Handling Workstation for the control of the RH equipments and tools envisaged for the operation and maintenance of the Next Step Fusion Reactor. This task is carried out in collaboration with KfK - Karlsruhe, in the frame of the European Fusion Technology Programme. The activity benefits from the Control Station of the ROBERTINO facility, used for the experimental validation inside the TELEMAC Laboratory, and from the improvements which will be applied to this Control System.

The development has been pursued on the basis of the Requirements Definition Document, reviewed in agreement with KfK.

The activity has been focussed on the Definition of the layout of the Direct Operator Interface (DOIF) with the Control System of the ROBERTINO facility.

The studies for the man-machine interface and the communication channel with the Control System have been undertaken in parallel with the development of a new upgraded ROBERTINO Control System.

Blanket Handling Device Testing (Next Step Activity - Task RHI- 1 - ITER Emergency Task ETA-EC-RHI.1)

This activity provides support to the design of the Blanket Handling Device (BHD) full-scale prototype, which will be used, in case of damage, for the replacement of the First Wall/Blanket modules of the Next Step Reactor, with reference to the NET/ITER design. This task is carried out in collaboration with ENEA, in the frame of the European Fusion Technology Programme. The activity has been pursued along the two main lines, namely computer simulation and experimental validation on a reduced scale mock-up of one NET/ITER sector, by using the ROBERTINO facility (see *figure 2.57*) inside the TELEMAC (Teleoperation) Laboratory. In parallel, the reliability analysis of the BHD has been also pursued.

COMPUTER SIMULATION

The dynamic analysis of the ROBERTINO facility behaviour during operation, performed by using the ADAMS code, has been completed and it is the subject of a Technical Note /1/, which includes the assessment of the most suitable range of the reduced scale models values used for coupling Computer Simulation and Experimental Validation.

By taking into account the cost/benefit ratio, the optimisation study demonstrates that the reduced scale used in TELEMAC Laboratory (1/3) for linking Computer Simulation with Experimental Validation on the ROBERTINO facility, is appropriate for the validation studies undertaken in view of the design and construction of the BHD full scale prototype.

EXPERIMENTAL VALIDATION

The purpose of this activity is to validate the results of the simulation activity and to test components and tools on reduced scale mock-ups.

The test campaign planned for 1993 on the ROBERTINO facility, in collaboration with ENEA, has been completed and it is the subject of a Technical Note /2/.

Two concepts of BHD have been considered and compared, the "Single Gripper" and the "Double Grippers" concepts.

In the "Single Gripper" concept, a Blanket segment withdrawal (or insertion) can be performed by using a single gripper, but the gripper has to be limited in dimensions and it results to be deformable, so requiring to be provided of tilting for compensating the gravity deformations. In this case two different types of grippers are necessary, one for the inboard and one for the outboard segments, with the consequence of requiring their substitution during BHD operation.

In the "Double Gripper" concepts, a simple gripper with a rigid bulky arm handles the segments to expose their centre of gravity inside the access port. A second arm, gripping the segments at their barycentric position, can complete their shifting and lift them upward through the access port. In this concept the two rigid grippers for inboard and outboard segments can be integrated in only one gripper unit, but it is necessary to transfer the segments from the first gripper to the second barycentric gripper.

The tests carried out were related to both BHD concepts, in order to validate the concept of gripper with active tilting ("Single Gripper" concept) for the inboard segments, and that of rigid gripper with load transfer to a barycentric gripper ("Double Gripper" concept) for the lateral outboard segments.

In all cases, preliminary features of the segments supports inside the Vessel have been considered, being the real attaching locks system not yet defined.

The results of the tests confirmed the necessity of validation experimental activities on mock-ups, for the design support, in particular for simulating conditions that cannot be forecast by the normal design activity (f.i. the jamming conditions, the accidental events, etc.). Moreover the tests confirmed the validity of the scale 1/3 of the mock-ups; this scale has allowed to have appreciable deformations for significant tests, and appears to be convenient also for the future test campaigns.

Various types of grippers have been tested:
- an active articulated, thermally driven, gripper for the inboard modules (for the single gripper concept);
- an active articulated, electro-mechanically driven, gripper for the inboard modules (for the single gripper concept);
- a passive rigid gripper for the lateral outboard modules (for the double gripper concept);
- a barycentric gripper for the lateral outboard modules (for the double gripper concept).

The results of the tests gave the first important feed back indications on the design, as well as on the sensors and the control system to be used for the BHD prototype. A new test campaign, to be performed during 1994, has been defined on the basis of the results of the tests carried out so far.

A further indication of the tests performed during 1993 concerns an upgrading of the ROBERTINO facility. The specifications for the new control system have been prepared.

RELIABILITY STUDIES

The FMECA analysis of the ROBERTINO facility has been completed.

A comparative reliability analysis of two different concepts of BHD has been carried out /3/.

Reliability Assessment of JET Remote Handling Transporters

A collaboration with the JET RH Laboratory, aiming to the improvement of the overall reliability of the RH Transporters, through the direct participation of an engineer on the JET site, has been concluded with the definition of the test cases specifications for diagnostic tasks of the control system for the Articulated Boom. The experience gained is now applied to improve the control system of the ROBERTINO facility.

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/2/ DAMIANI, C. (ENEA), FARFALETTI, F.-CASALI (JRC, ISEI) et al. - Final Report of ITER Emergency Task EC-RHI.1 (NET Task RHI 1.2), "Remote Handling of the Blanket Segments: Testing on Reduced Scale mock-ups", CEC-JRC Ispra Tech. Note No. I.94.08, Jan. 1994

/3/ MAIER, T. - "Comparative Reliability Analysis of Two Mechanical Concepts for a Blanket Handling Device", CEC-JRC Ispra Tech. Note No. I.93.167, Dec. 1993

Envelope Accident and Passive Safety Analyses

During its normal operation Fusion Reactors structural materials (especially those near the plasma) are subjected to a high energy neutron flux and are thus activated. One of the consequences of the activation is the volumetric production of heat, called decay heat (or after heat). Due to the very efficient thermal isolation of the reactor, in conditions of absence of active cooling, the redistribution of the initial temperatures (at short term) and the decay heat (at medium and long term) can cause a substantial increase of the temperature of some components, leading even to their structural failure.

The demonstration that no significant thermally induced damage can de done to the containment, even in these "envelope" conditions (i.e. instantaneous, completed and permanent loss of all active cooling), is a significant contribution to demonstrate the passive safety of a Fusion Reactor. Moreover, a reliable prediction of such an "envelope" temperature history is important because many safety related processes (such as oxidations rates, tritium release rates, etc.) are temperature dependent.

Such envelope calculations are extremely complex, not only because of the complicate layout of a Fusion Reactor but also because of the complexity of the physical phenomena involved. These calculations have been undertaken at the Engineering and Safety Design Analysis (ESDA) Lab. of the Conceptual Studies Sector. For the last 3 years, a wealth of Numerical Analysis Computer codes, were tailored to work together with the task of modelling the post accident temperature transient of the whole Fusion Reactor for as long as 3 months after the accident. Results were tested extensively by independent parties.

As result of this and other activities, the ESDA Lab. has acquired a significant experience in complex non-linear thermomechanical calculations. Computer codes that

are available at ESDA/CS include: PATRAN (FEA), P-Thermal (F. Diff.), ABAQUS (FEA Struct.), Fispact and ANITA (Activation). In parallel to that exists a considerable expertise in CAD, both 2D drafting and 3D modelling.

Envelope Accident Analysis of Loss of Cooling for the long Term Studies of Power Reactors (Long Term Studies - SEAFP Task A2)

The modelling of the complete Fusion Reactor under envelope post accident conditions involved extensive CAD-CAE activity, neutronic and thermal calculations, which have been done, in the context of the Safety & Environmental Assessment of Fusion Power (SEAFP) studies, Task A2.3. The model of a complete 11°15' sector (including inboard and outboard components with poloidal conducting links) of the reactor midplane was developed at the ESDA Lab. of the CS sector using validated and mostly commercially available computer codes. The results of the model, for the SEAFP preliminary and reference design parameters, have been reported in /1/2/3/. Among other things, this work resulted in a modification of the SEAFP reference cryostat design, as to be able to state that the temperatures of the containment structures remain acceptable even at the envelope conditions of total & permanent loss of all active cooling.

References

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Envelope Accident Analysis of loss of cooling for ITER/CDA & ITER/EDA (Next Step Activity - Task SEA 3.4)

The work on the Envelope Accident Analysis of Loss of Cooling for ITER/CDA design performed during the last 3 years was completed. A preliminary assessment of its implications and possible extrapolations to the ITER/EDA design was the subject of the ITER/EDA emergency Task SEA 3.4. The follow up of these tasks for

1994, in the context of the ITER/EDA design has already been approved (ITER Task NID 7a, European Tasks SEA 3.4 & SEA 3.5).

References

/1/ ANDRITSOS, F. and ZUCCHETTI, M. - "Envelope Transient of ITER with Driver Blanket, Preliminary Calculations", CEC-JRC Ispra Techn. Note No. I.93.62, May 1993

Neutron Induced Activation Analysis and Activated Waste Management

The large dimensions and materials amounts of the Tokamak Fusion Reactors, and the high ratio of fast neutrons per power produced will give rise to large amounts of activated materials.

As a consequence, from the beginning of Fusion studies, it was required to perform neutron induced activation analyses and to identify appropriate waste disposal strategies.

Neutron Induced Activation Analysis

ITER assessments concerned three vanadium alloys: V-15Cr-5Ti, V-5Ti, V-3Ti-1Si, in first wall irradiation conditions, i.e., 5 full power years, with a neutron wall load of 2 MW/m^2, with 1000 s pulses followed by 50 s intervals.

Relevant results are /1/:
- Long-term radioactivity is dominated by the impurities: the main troublesome impurity is silver.
- Decay heat is higher than in steels during the first minutes of cooling. This is not expected to be a problem, due to the better thermomechanical and physical performances of these alloys.
- The potential hazard of these alloys measured in terms of early dose per unit weight to the MEI (maximum exposed individual) in case of accidental release to the atmosphere is lower than that of steels: 1/10 and 1/35 of that of MANET and AISI 316 respectively.

SEAFP assessments concerned three blanket configurations:
- The Reference Plant Model (RPM): Li$_2$O as breeder, Be as multiplier and first wall protection, V-5Ti as structural material, He as coolant.
- The Alternative Plant Model (APM): Pb-17Li as breeder, Be as first wall protection, a low-activation version of MANET (LA-MAN) as structural material, water as coolant.

- The preliminary Configuration (PC): Li_2ZrO_3 as breeder, Be as multiplier, MANET as structural material, water as coolant.

The other components are common to the three configurations. The shield is made of a Mn-based low activation version of AISI 316L steel (MN-SS) and of water. The vessel is made of AISI 316L, water and two layers of lead and boron carbide to enhance the inboard shielding. The toroidal field coils use AISI 316LN as structural material, Nb-Sn superconductor, he as coolant and an insulator (70% boron-free R-Glass and 30% epoxy).

Two different layouts of the divertor were also considered:
the Reference divertor has a 3 mm Be layer coating a V-5Ti structure cooled by helium; the Alternative divertor has a 3 mm Be layer coating a Cu structure cooled by water.
The poloidal mean values of the inboard and outboard fluxes have been assumed. Therefore, as the midplane inboard and outboard neutron wall loads are 2.2 MW/m^2 and 3.2 MW/m^2 respectively, the mean values are 1.65 MW/m^2 and 2.4 MW/m^2, or 75% of the maximum.

The irradiation times are:
- 20 months for the divertor;
- 5 years for all the first wall and blanket;
- 25 years for all other components.

All produced data have been forwarded as inputs to other SEAFP evaluations. The following results are relevant /2/:

- Long term radioactivity of the RPM structure is very low, mainly due to impurities. The higher values of the 50 years contact dose are lower than 2 mSv/h, except for the first wall and front blanket structure. The activation of the breeder is also very low.
- Long term radioactivity of the APM structure is higher than that of RPM but still very moderate. The maximum values of the contact dose are higher than 2 MSv/h but lower than 20 mSv/h only in the first wall and most of the blanket structure. The 50 years dose of Pb-17Li is below 2 mSv/h.
- The shielding capability of the APM is higher than that of the RPM.
  Therefore, all the components beyond the blanket show a lower activation in the APM.
  For instance the 100 year contact dose of the inboard shield structure (MN-SS) is 61 x 10^{-6} Sv/h

and 110 x 10^{-6} Sv/h respectively in the APM and RPM.
- The activation of the PC is relatively high, if compared with that of the other blankets.
  The 50 years contact doses of structure are higher than 20 mSv/h.

References

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Activated Waste Management

The proposed classification for activated waste was described in the 1992 Annual Report. The three classes of activated waste, High-, Medium- and Low-Level Waste (HLW, MLW and LLW) are identified by limits of the contact dose and decay heat (after 50 years of cooling at least), that is > 20 mSv/h, < 20 mSv/h, < 2 mSv/h and > 10 W/m^3, < 10 W/m^3, < 1 W/m^3 respectively. These limits were assigned with the purpose of reducing heat transfer and shielding requirements during remote handling and disposal. Applications of this classification to specific cases are found in /1/ and /2/.

The activated waste management aspects of the SEAFP configurations have been analysed in /3/.
The identified suitable strategies are:
- Declassify the very low activity materials to non-active waste. The activity limit of this waste is assumed to be 400 Bq/kg.
- Reduce the amount of activated waste by remote handling recycling, which is assumed to be feasible for contact dose rate up to 1000 times higher than the (theoretical) limit for hands-on recycling (HOR) or 25 x 10^{-3} mSv/h.
  The LLW class defined above largely complies with this requirement and should be essentially recycled.
- Dispose the remaining waste into geological repositories with simple requirements. The MLW class should preferentially follow this route, but alternatively could be recycled. The HLW class should possibly be avoided.

The results of the activation calculations show the following:

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- The long-term radioactivity in the RPM and APM is lower than that of the PC. The HLW arising from plasma facing structures of the PC becomes MLW in RPM and APM and a general improvement is attained in the other in-vessel zones. The long-term behaviour of V-5Ti gives only marginal advantages on that of the reduced activation steel.

- The ex-vessel structures are generally LLW, with the possibility of hands-on recycling for the outer zones. The structures in the coil zones can be declassified to non active waste.

- The breeding materials, Li_2ZrO_3, Li_2O and Pb-17Li respectively for PC, RPM and APM, are LLW.

- Concerning the divertor materials, V-5Ti adopted in the RPM is LLW, whereas copper, adopted in the APM, is HLW. Beryllium is hands-on recyclable.

- The shielding requirements for the transport of the most active waste of the cases examined vary between 5 and 10 cm of steel. Extrapolating the characteristics from the 105 tonnes-shipping casks for spent fuel from fission power plants, 55-65 tonnes of irradiated steel could be shipped in a cask with a total weight of 90 tonnes. These transports should be performed by rail.

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HUMAN CAPITAL AND MOBILITY NETWORKS

SMART (Semi-autonomous Monitoring And Robotics Technologies)

The Human Capital and Mobility Programme SMART Research Network was approved in November 1992 and activities started officially in June 1993. Apart from the JRC/ISEI, 10 research laboratories and 3 small/ medium industries from six different countries (DK, F, I, IRL, P, UK) are involved. The network aims at the development of human resources for the technologies of monitoring and surveillance, autonomous robotics and tele-operation. This objective will be achieved by having coordinated projects, and by transferring technological results to industry. Several post-doc fellowships are being paid by the network.

Partners

LIFIA - ADR (Univ. Grenoble, France (coordinator)
Robosoft SA, Paris, France
Cybernetix, Marseille, France
DIST, Univ. Genoa, Genoa, Italy
ARTS Lab, Scuola Superiore di Sant'Anna, Pisa, Italy
CSata, Bari, Italy
Aitek, Genoa, Italy
University of Leeds, Leeds, United Kingdom
University of Reading, Reading, United Kingdom
University of Edinburgh, Edinburgh, United Kingdom
Trinity College of Dublin, Dublin, Ireland
Instituto de Sistemas e Robótica, Lisboa, Portugal
University of Aalborg, Aalborg, Denmark
Joint Research Centre, Ispra, Italy

Interactive Image Synthesis and Processing on Innovation Computer Architecture

The most important collaboration has been initiated with CERFACS (European Centre for Research and Advanced Training in Scientific Computation). The joint activity is considered to be an advanced research programme in computer vision on innovative massive parallel architectures.

The proposal of this Human and Capital Mobility Network has been submitted on July 1992 under the final registered number 2/ERB4050PL92379 which title is: Interactive Image Synthesis and Processing on Innovative Computer Architecture and has been adopted by the Human Capital & Mobility Programme on December 1992 and notified on January and June 1993.

The official starting date is foreseen on december 1993 when the final document will be designed by CERFACS, JRC, CSCS participants and DG XII responsibles.

Partners

CERFACS - Toulouse (F)
Manchester Victoria University (UK)
LABEIN Centro Tecnologica - Bilbao (SP)
Laboratoire Informatique - Besançon (F)
Università degli Studi di Milano (I)
Rutherford Appleton Laboratory (UK)
Inforop Image - Toulouse (F)
JRC - Ispra (I)
Swiss Federal Institute of Technology - Lugano (CH)

Diagnostics and Reliability of Composite Materials and Structures for Advanced Transportation Applications

Technical objective of this co-operation network is: implementation of diagnostics techniques for assessing transportation employed composite materials and structures; calibration of approaches; development of theoretical methods. ISEI will focus its activity on laser interferometry and acoustic emission.

The Network foundly started in November 1993. Specimen for the first thesis have been prepared.

Partners

Dept of Mechanics and Materials. Ecole, Nationale Supérieure des Mines de Saint-Etienne, F (coordinator: Prof. Alain Vautrin).
Institut Supérieur de l'Automobile et des Transports, Nevers, F.
Università di Napoli, Dip. Ingegneria Materiali e Produzione, I.
Hellenic Aerospace Industry Ltd, Research and Development, Athens ,Gr.

Dept.of Eng. Science, Section of Mechanics, Technical University of Athens, Gr.

Dept. of Metallurgy and Materials Eng., Katholieke Universiteit Leuven, B.

Instituto de Engenharia Mecanica, Polo I.S.T., Lisbon, P.

Instituto de Engenharia Mecanica e Gestao Industrial, Porto, P.

Institute for Systems Engineering and Informatics, CEC-JRC- Ispra.

Operative commencement date: November 1993

Design of Robust Human Machine Interaction

The objective of the network is to analyse and predict human behaviour interacting with complex and dynamic systems equipped with advanced controls. These studies will consider different work load conditions, changes in the work structure, and the impact of automation and Information Technology in the control of complex systems.

The network has been formally started in September 1993, with the definition of the goals of each partner. The role assigned to ISEI is to analyse and model human behaviour. As an example, the simple procedural simulation of a pilot and aircraft have been selected for flight control analyses.

Partners

– Eurisco (F),
– ISEI (JRC),
– Bonn University (FRG),
– Delft Uni. (NL),
– Technical Uni. of Denmark (DK),
– Human Reliability Associates LtD (UK),

– Uni. of Kassel (FRG),
– Uni. of Reading (UK),
– Uni. of Salford (UK),
– Uni. of Valenciennes (F),
– Uni. of Strathclide (UK).

Human Factors in Complex-Real Systems

The objective of the research is twofold:
• Analysis of the cooperative work in the domain of Air Traffic Control.
• Development of a method and a computerised tool for Human Factors studies.

The network has been formally started in November 1993, with the definition of the goals of each partner. The work assigned to ISEI concerns the validation from the real world experience and the implementation into computerised tools for direct application. The domain of application will be the Air Traffic Control (ATC).

With regard to the Human Factors studies, a methodology, named HERMES (Human Error Method for Event Sequences) has been developed for retrospective studies of data collected from real accidents and for prospective analyses of consequences due to hypothetical accidents. This methodology will be further developed for ATC application.

Partners

– ARAMIIHS (F),
– ISEI (JRC),
– Centre Etude Navigation Aérienne (F),
– Uni. of Laughborough (UK),
– Technical Uni. of Crete (GR),
– Centre Etudes Ergonomiques et Recherches Industrielles (F),
– Russian Centre for Space Control (Russia).

3 EXPLORATORY RESEARCH

EXPLORATORY RESEARCH

Neural Networks for Navigation of a Teleoperated Vehicle

A key issue for the use of autonomous robots is vehicle navigation, i.e., all the aspects determining the trajectory taking the vehicle from an initial position to a target position. Many approaches to navigation consider the problem at different hierarchical levels. At the highest level is path planning, i.e., the selection of the intermediate steps (sub-goals) and trajectories to follow. At the next level is position localisation, i.e., the methods used to know at any instant the position of the vehicle in respect to its surrounding environment. At the lowest level is local navigation, i.e., the setting of steering commands taking into account the vehicle's position, the next immediate goal and the free space around the vehicle. The division of the navigation problem into the three above levels is not always that clear, depending on the particular implementation. Indeed, the strategy for the navigation problem is very much dependent on how position localisation is achieved, which is in itself dependent on the sensorial information available. It can be said however, that in spite of the diversity of approaches and implementations, there is always a common aspect: the need for sensing the environment.

The first line of the project consisted in providing an adequate description of the free space around the vehicle, and from which build appropriated motion directives. Data from the on-board ultrasonic sensors is used to build perception maps of the free space around the v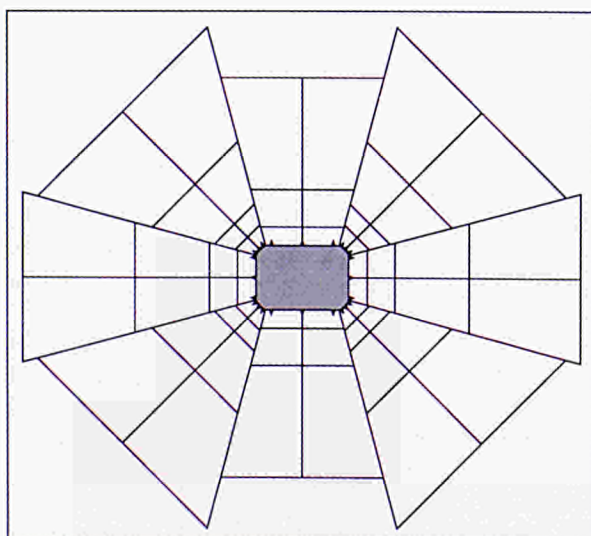ehicle. These maps exploit the spatial redundancy of the ultrasonic sensors and assume the definition of ultrasound firing strategies in order that cross-talk between sensors is minimised /1/. A Generalised Geometry Grid (*figure 3.1*) adapted to the characteristics of the sensors (i.e., spatial resolution, measurement accuracy, etc.) was defined as the topological support of the perception maps.

Mapping between real ultrasonic data and grid cells was achieved using an artificial neural network /2/. Earlier networks were fully connected, but it was soon verified that partial independent nets were better in terms of their generalisation abilities. *Figure 3.2* shows the results achieved with the neural network. It can be seen that the network can compensate for measurements affected by specular reflections. A real-time implementation of the perception maps was recently achieved, allowing for their immediate use in robot's local navigation.

The second line of this research aimed at controlling a real autonomous mobile robot so that it reaches effi-
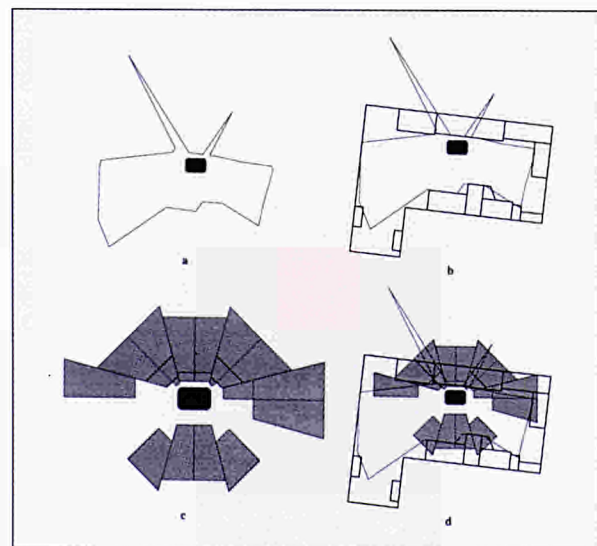

Fig. 3.2. Performance of the neural network based perception map:
a) Raw ultrasonic measurements
b) Overlay of raw measurements with room model (note specular reflections)
c) Occupancy grid generated by the neural network
d) Overlay of raw measurements, calculated grid and room model

ciently a goal location in an unknown indoor environment. Efficient navigation is critical for autonomous robots operating in hostile environments, which are usually unknown the first time robots face them. In particular, we have developed TESEO, an autonomous mobile robot controlled by a neural network. The test

Fig. 3.1. Generalised Occupancy Grid adapted to the characteristics of the sensor (i. e. spatial resolution measurement accuracy, etc...)

robot (*figure 3.3*) is equipped with 16 infrared sensors, 16 ultrasonic sensors as well as 20 tactile sensors for collision detection. The neural controller continually maps the current perceived situation into the next action. An action controls the robot's motors and determines the next direction of travel. TESEO acquires the appropriate navigation strategies in a few trials through reinforcement learning; that is, by learning to associate with each perceived situation the action that optimises the total reinforcement (or performance feedback signal) received along the trajectory to the goal. The reinforcement signal measures the cost of doing a particular action in a given situation. Experiments have shown that efficient trajectories can be generated in less than 15 trials. In addition to quick convergence, three learning requirements are fulfilled: a) the robot is operational from the very beginning; b) the robot's performance improves incrementally as it interacts with the environment; and c) the robot's exhibits high tolerance to noisy sensory data and good generalisation abilities. Several ideas are essential to cope with these requirements: i) a fixed set of basic reflexes is used whenever the neural network fails to generalise correctly from previous experiences; ii) a resource-allocating procedure builds dynamically a modular network coding a consistent set of reaction rules; iii) the action space is explored by concentrating the search around the best actions currently known. TESEO's architecture is an improved version of our previous work with a simulated version of the real mobile platform /3/ describes partially TESEO and reports first results /4/.

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/3/ MILLAN J. DEL R. - "Reinforcement learning of goal-directed obstacle-avoidance reaction strategies in an autonomous mobile robot". Robotics and Autonomous Systems, 1994. Invited Article.

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Three Dimensional Surface Sensor (coherence radar)

The coherence radar is a hybrid method combining optical interferometry and time of flight techniques used for contouring rough surfaces. The main advantage of this technique is the theoretical possibility to combine high resolution and wide dynamic range. Work on coherence-radar has been for the first time presented in March 1992 by Dresler and coworkers /1/, but its potentialities were not fully explored. The authors pointed out the existence of some open problems, namely:

a. the presence in the image, obtained by a CCD camera, of "black pixels", i.e pixels never showing intensity variation;

b. the dependence of the contrast of the speckle field on the roughness of the inspected surface and on the length of the temporal coherence of the used light source;

c. the dependence of the contrast of the speckle field also on the spatial coherence of the used light source.

Furthermore, having performed a careful literature search, we noticed the lack of an exhaustive theoretical treatment.

Our first work has consequently been the development of an adequate and complete theoretical analysis, whose main result has been the identification of an

Fig. 3.3. TESEO: the test robot used for reinforcement learning navigation. The hardware is a commercially available Nomad 200 mobile platform

analytical relationship between the field contrast and the parameters of the system, i.e.:
- space and time coherence of the light employed
- statistical properties of the inspected surface roughness
- optical characteristics of the image acquisition system
- optical path length difference between the two arms of the interferometric system.

This theoretical result is very important because it allowed us to explain points a,b,c and to optimise the parameters of the experimental set-up. In particular:
- choice of the light source:an halogen source was chosen combined with an interferential filter which can be easily changed to give more flexibility to the instrument;
- experimental set-up: improvement of the performances and of the reliability has been obtained by maintaining the object in a fixed position while piezoelectric and micrometric translators were used to obtain the required difference in optical path lengths;
- the understanding of the physical phenomenon led to an easier method for data acquisition and interpretation.

Fig. 3.4 shows schematically the experimental set-up /2/. The complete presentation of the results will be
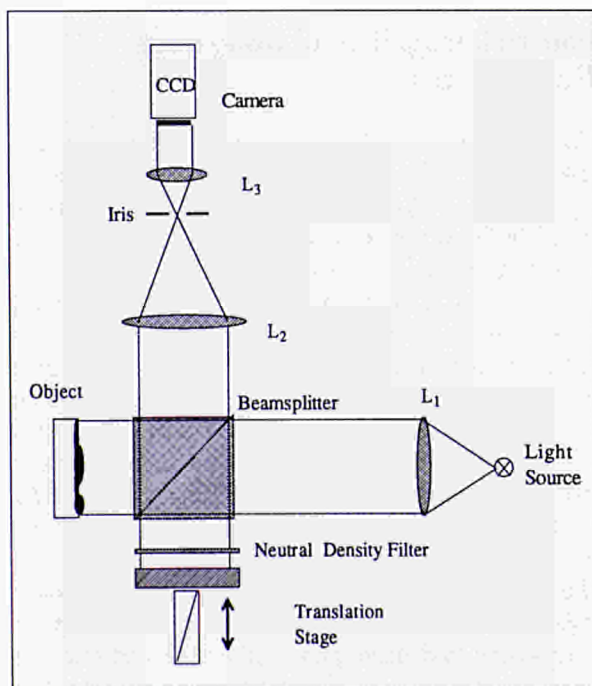
Fig. 3.4. Schematic representation of the experimental set-up and crack propagation

made by the middle of 1994 as a degree thesis in electronic engineering.

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/2/ GIANIKAS, K., LUCIA, A., LULLI, A. - "A three dimensional surface sensor" Technical Note (in press) ISEI/IE/2671/94

Computer Modelling Studies of Soliton Propagation in Crystals

Computer modelling techniques are used to examine the possibility of soliton propagation in the layer silicate mineral muscovite. A demonstration of the existence of lattice solitons in crystals (inorganic and metallic) would provide a mechanism explaining the transportation of energy from one region of the crystal to another. Such a mechanism would increase current knowledge of radiation damage processes and crack propagation. Indeed an understanding of the transportation of energy through solids by the vibratory motions of nuclei is of fundamental importance in science and technology.

Since most media are dispersive, small amplitude displacements generally broaden and eventually lose all spatial variation. In contrast, a soliton is a coherent structure that propagates in a dispersive medium without change of shape. For a soliton to propagate, the non-linear forces due to the disturbance must cancel exactly with the dispersive nature of the medium supporting the solitonic motion. To achieve the required non-linearity most solitons have large amplitudes of displacement, although in highly non-linear media small amplitude solitons are possible. The amplitude of the soliton is found to be proportional to the velocity of propagation, and the width proportional to the square root of the velocity. Solitons are stable in the presence of other solitons and when two collide they survive unchanged.

It is well known that solitons can propagate in liquids and plasmas. Optical solitons have also received much attention in recent years. It has been postulated /1/ that lattice solitons can propagate in crystals. Although a direct observation of lattice solitons has not been made, due to the absence of a suitable electromagnetic effect and their resistance to small perturbations, there exists strong indirect evidence that lattice solitons do propagate under certain conditions. To date most of this evidence /1/ has been found in the mica mineral

muscovite in the form of decorated linear tracks predominantly of magnetite.

These tracks are found in certain crystallographic directions that correspond to linear chains of potassium atoms. Two types of chains are present, those with potassium atom spalings of 5.3Å and 9.2 Å.

Owing to the obvious experimental difficulties in detecting lattice solitons in flight, the use of computational techniques has been investigated. Such techniques are able to provide an insight into properties of materials at the atomic level that are inaccessible by direct experimental measurements. In this work the nature of interatomic forces arising from potassium atom displacements in these chain directions and other non-chain directions is investigated. For solitonic solutions to the equations of motion for disturbances propagating along the chain directions, the forces acting on the perturbed potassium atoms must be a non-linear function of the displacement. Previous work /2/ has shown that the exact form of the non-linearity is not of critical importance. The behaviour of solitonic motion in periodic chains is described by the Toda potential /3/ whose exponential form yields integrable equations of motion.

Atomistic simulations of muscovite involving displacing potassium atoms from their equilibrium positions have been employed to examine the nature of the interatomic forces. The reliability of the interatomic potential model has been demonstrated previously /4/ by reproducing accurately a number of crystal properties including, the crystal structure, the dielectric and elastic constants and longitudinal acoustic phonon dispersion relations. Two sets of data are calculated for each potassium atom displacement. The first is for the unrelaxed case where all atoms are held fixed; this represents the initial impulse state when a potassium atom is impacted, for example by a charged particle. The second is the relaxed case where the positions of atoms surrounding the fixed displaced potassium atom are adjusted to zero force; this corresponds to the propagation of the soliton.

It has been found that the interatomic forces acting on the potassium atoms displaced in both chain directions vary non-linearly as a function of displacement. For displacements in the 9.2Å Chains both the unrelaxed and relaxed configurations produce forces acting on the displaced potassium atoms that are confined to the direction of displacement. The ratio of transverse forces to forces acting along 9.2Å is of the order 10^6. In the 5.3Å Chains lateral forces are found to be significant in the unrelaxed case, however, their effect is reduced greatly after relaxation. Thus, except for the unrelaxed case in the 5.3Å, the interatomic forces are confined to

act along the chain in both the 5.3Å and 9.2Å Chains directions. Such behaviour is consistent with the propagation of solitons along a one dimensional chain structure.

In conclusion, using computer modelling techniques it has been demonstrated that the conditions necessary for lattice solitons to propagate in the chain directions of muscovite exist. Such conclusions are consistent with experimental observations of decorated tracks. The computational and experimental data when combined together provides strong evidence for the propagation of lattice solitons in the monatomic potassium atom planes of muscovite. Work is now in progress to model the atomic motions and propagation of energy in muscovite using molecular dynamics techniques. It is also planned to extend the modelling techniques to other layer structured systems.

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Pattern Recognition of Dangerous Goods Trucks

Up to the end of 1992 only manual counting and identification procedures have been used to examine the transport patterns of dangerous good. Due to the delay in the arrival of a grantholder to work on the project, progress in 1993 has therefore been limited. However, the current planning indicates, that the key question is the identification of the area where the label with the identification of the hazardous material is found. It has been tested, that an automatic registration of trucks is possible, based on existing techniques. A test of identification of (general) trucks and busses, showed that a count with an accuracy of 10% is possible without sophisticated equipment. With improvement in software and hardware an accuracy of 1% is expected. The key issue is the acquisition of a high resolution image of the hazardous materials label. With such an image, standard techniques of optical character recognition may be applied. Current planning indicates that one possibility here, is the acquisition of a dual image of the trucks, with subsequent data processing.

4

SUPPORT TO COMMUNITY POLICIES

SUPPORT TO THE SECRETARIAT-GENERAL OF THE COMMISSION

Antifraud Documentation (DAF)

In the framework of the project DAF (the text database on Antifraud Documentation), the Ispra team assured maintenance and further development of the DAF authoring system, including installation and training aspects for new functions at the two author sites (Brussels and Florence). With the help of external contractors, the team, i) continued work towards the conversion of author files from a proprietary representation format to an ISO standard for document description (SGML), and, ii) developed specifications for a new authoring system based on state-of-the-art database and document management technology. A hypertext prototype of the DAF end-user system using the latest commercially available technology was developed in Ispra and demonstrated in Brussels in October.

In addition, the Ispra team has contributed to the definition of a charter and a work programme for the proposed Antifraud Policy Support Office (APSO) to be created in Ispra. APSO is intended to offer longer term support to UCLAF (for the period 1994-1998).

Computer-Base Management for Parliamentary Petitions

The transition of the Petitions Database from project to User Service took place in early 1993. Ispra, in collaboration with the Informatics Services of the Secretariat-General and the User Service, provided user and system support, and was responsible for a significant set of system enhancements completed in June 1993. The Ispra team drafted the detailed specifications, was the intermediary between the User Service and the subcontractor and offered a testing environment for all new deliverables. The system is today fully operational.

SUPPORT TO THE COMMUNITY STATISTICAL OFFICE

Statistical Applications of Artificial Neural Networks

The objectives of this multiannual support activity consist of developing connectionist tools for statistical applications, and to implement these new techniques for solving various problems selected by the Statistical Office (SO, or EUROSTAT).

Within an agreed list of problems or topics that had been selected for their potential in terms of effective neural network solutions, and in compliance with EUROSTAT's requests, the work undertaken in 1993 concerned two applications pertaining to the field of unsupervised clustering. Related theoretical results have also been obtained.

A connectionist model called Kohonen Map has been used, adapted and enhanced for addressing both applications. The algorithm maps the typically high-dimensional feature of socio-economic datasets onto a two-dimensional lattice, while attempting to preserve most of the topological properties of the sample distribution in the original space. The results obtained so far have demonstrated that the connectionist approach provides a promising alternative to traditional techniques for unsupervised data analysis. It deals easily with missing data, has a wide applicability range, and provides an original data representation that has no close counterpart amongst the traditional statistical methods /3/4/. The two applications have been developed as follows:

Typology of European Regions /1/

This study has been completed early this year. The dataset consisted of 227 European Statistical Territorial Units (STU) described by 14 socio-economic variables, like unemployment rate, population density, activity rates and so on, with many missing values. The request was to find groups of STU's that have similar feature vectors.

Time Series of Foreign Trade Statistics

This task deals with the estimation of missing data in yearly foreign trade statistics. The dataset consists of yearly import/export figures for about 200 countries, 10 product groups, and about 15 years. In this study,

the Kohonen Map should also act as a pre-processing device for selecting time- series forecasting methods or hyper parameters.

When the Kohonen Map model is to be used for estimating missing data, it is important to understand its vector quantisation properties. Two related studies have been carried out and have led to theoretical progress /2/5/. On the other hand, for the missing values problem itself, the results obtained so far with a compound technique using Kohonen Maps are quite promising, in the sense that:

– Experiments on false missing data (a known value is treated as if it were missing) have given a satisfactory mean squared reconstruction error.

– Experiments with a more traditional technique (K-means, selected for its strong similarities with the Kohonen Map), suggest that the smoothing properties which characterise the Kohonen Map approach to quantisation tend to improve the missing data estimation process.

The mathematical foundations of the new approach are still to be set, but it is thought that the connectionist approach provides an alternative to traditional techniques for missing data estimation which is definitively well worth considering.

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SUPPORT TO THE INTERNATIONAL COOPERATION (DG I)

Collaboration with IAEA on Safeguards

Optical Surveillance

The main activity concerned the development of techniques for design information verification (DIV). For complex plants, such as large reprocessing facilities, a large number of vessels and their associated pipe work must be physically checked and compared to plant design drawings. Once these checks have been completed, the continuity of knowledge for verified plant structures has to be maintained. Two techniques are being developed by the JRC in this area. A short term solution is based on the use of image processing for comparing video pictures taken at different times. The long term solution will consist in the development of a laser range measurement system (LRDS) generating a 3D representation of the distance measurements for identifying changes in the structure.

A prototype, based on the first technique, has been developed. The system includes a colour TV camera and a portable PC equipped with a digital image capture board and a high capacity disk of 520 MB for the digital storage of video pictures /1/ (fig. 4.1). The application software comprises two parts: one for creating reference image files and the other for comparing images and evidencing changes in the structure. The changes are shown by flashing elements in the picture. The first programme and the inspector interface have been completed. A demonstration of the system was done in September together with the task officer of IAEA. The second part of the software will be completed in the first semester of 94.
Concerning the second technique a laboratory prototype has been set up. It uses a commercial laser range

Fig. 4. 1. Computer vision system for design information verification

finder which is scanned horizontally and vertically for generating range images (fig. 4.2). The processing of the range images aims at the extraction of geometric primitives or features relevant to the DIV application. Two segmentation techniques have been developed: edge and region detection /2/. Current work is in progress to use a segmentation approach that combines both techniques. Ambiguities caused by occlusions are resolved by merging images taken from different viewpoints. Several verification strategies have been investigated.
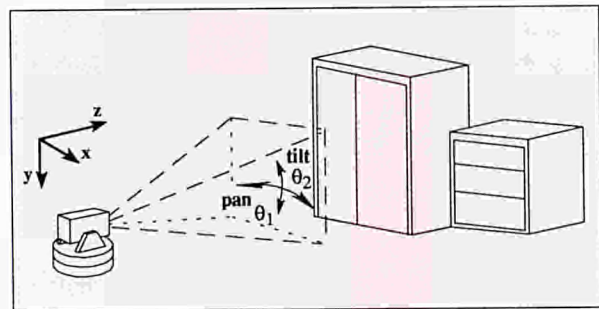

Fig. 4.2. Acquisition of a range image by scanning a laser range finder

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Information, Data Treatment and Evaluation

The Agency's Secretariat has proposed several initiatives to strengthen Safeguards. One of these is the Universal Reporting Scheme of all exports and imports of nuclear material and the Universal Reporting Scheme of all exports and imports of certain equipment and non-nuclear material. At the suggestion of the IAEA Board of Governors in June 1992, the Secretariat has invited all Member States to voluntary report the above information. A general design of a computer system and some software applications has been developed to process the information provided by Member States.

The objective of the system is to provide the capacity to store and retrieve the information, and to obtain as far

as possible the confirmation of the receipt of the import-export information based on the data received by Member States and to provide management with early indication of findings inconsistent with a State's declaration.

The computerised system will be composed by the following processors:

a front end processor, a retrieval and a report system.

The computer programmes for the front end processor have been developed, tested and implemented in 1993 and include:

— The data entry system for new reports performs on-line quality-control checks, to ensure the accuracy of all data elements of all newly entered reports. However considering the nature of the data, the system allows the user to force acceptance of rejected values by using a specified function key.
— Verification of the input reports based on comparison between the input report and the verified report.
— Loader for transferring of all the verified report from the input buffer file to the Adabas database file.
— Quality Control for performing checks on the report and field level.
— The Agency receives the licenses data from Member States in machine readable format. Work will be initiated to develop computer programmes to convert and accommodate this information in standard IAEA format.

Sealing and Identification Techniques

— Based on the field experience acquired by JRC-Ispra in installing and verifying ultrasonic sealing-bolts on nuclear storage containers, at the THORP plant of the BNFL facility in Sellafield (UK), where Canadian experts were invited to witness a field demonstration end 1992, the exchange of know- how and equipment on seals has started in 1993 with experts from AECL. Ispra staff was invited at the Gentilly-II facility in Québec to witness a demonstration on the Canadian stack seals. The cooperation aims at the development of a single instrumentation for reading the respective types of sealing system, namely stack seals and ultrasonic sealing-bolts to be delivered to IAEA. Part of the collaboration effort is aimed at delivering to AECL adequate JRC developed software programmes and codes and providing facilities for quality tests.

The organisation of an engineering support the the IAEA who is using JRC manufactured sealing-bolts jointly with the EURATOM Safeguards Directorate has been started and several visits from IAEA staff to Ispra were arranged.

A training course to IAEA staff was delivered in Ispra on the use of ultrasonic reading device seals.

SUPPORT TO THE COMMUNITY INDUSTRIAL POLICY (DG III)

Safety Critical Computer Systems

The objective of this work is to disseminate information on ESPRIT results and to encourage cross-fertilisation between research workers. The work during 1993 has been centred around the collection of information on research activities in the area of safety-critical computing systems (SCCS). A survey of the activities in Europe has been performed with a view to publishing a directory and setting-up an online information system. The activity within the institute in this area has been focused towards the preparation of a full online information system in the area of SCCS to be implemented in 1994. During 1993, ISEI participated and assisted in the preparation of a workshop on SCCS organised by DGIII.

High Performance Parallel Computers

The objective of this activity is to contribute to the valorisation of ESPRIT results an advanced competitions with particular reference to the SUPER NODE computers (ESPRIT Basic Research). The following achievements have been accomplished:

– In collaboration with the VALUE Programme, several new enhancements of the 3D Image Ray-tracing and radiosity software have been pursued and the extension to the animation aspects in real-time have been fully tested on standard working stations (*fig. 4.3 a/b*) /1/.

– Implementation of a CONCERTO CS-1 parallel machine with 12 nodes and with special peripherical devices.

– Development, tests and implementation of special algorithmic tools for designing parallel network applications /2/.

– Preliminary evaluation about the feasibility and the implementation of the previous software on the European CS-2 parallel machine.

– The implementation and the tests of this complex softwares have been started on the CONCERTO CS-1 parallel machine.

SCENE SYNTHESIS ON EUROPEAN PARALLEL COMPUTER
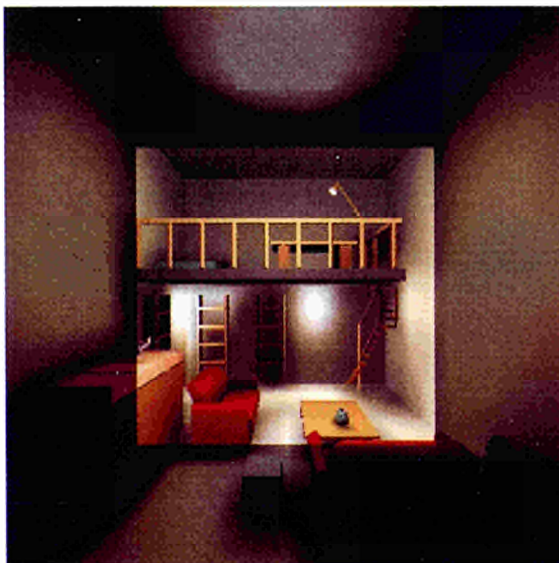
RADIOSITY - PHOTOCOLORIMETRY
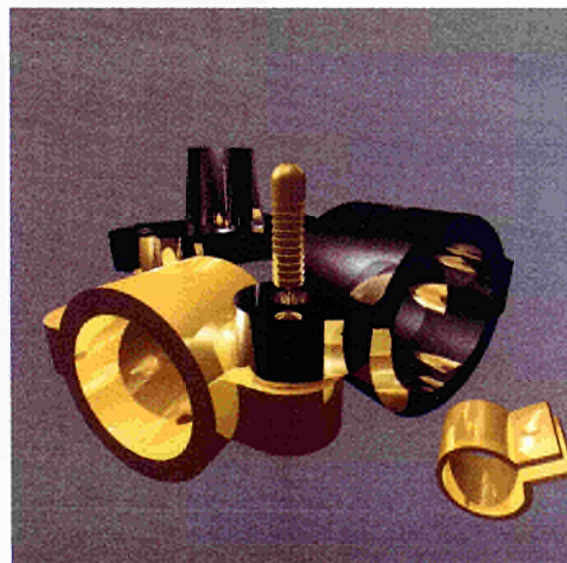
RAY TRACING - PHOTOCOLORIMETRY

Fig. 4.3 a/b. Scene Synthesis on European Parallel Computer Radiosity-Photocolorimetry

References

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/2/ PINTI, A., GROSSETIE, J.C. - A Methodology for dimensioning
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World Shipbuilding Data Bank

The objective of the work is the production of statistical tables (quarterly, annual and historical) on world shipbuilding production, by ship type, size and flag. The aim is to supply this information to DGIII, independent of national bodies, to be used for the preparation of an annual report from the Commission to the Council of Ministers.

Work in 1993 continued towards the finalisation of the Personal Computer version of the system. A pilot version of the system was completed in December 1993. This is intended to provide autonomous access to the information for the DGIII client, with standard procedures plus open-ended alternatives for ad-hoc developments.

SUPPORT TO THE COMMUNITY TRANSPORT POLICY (DG VII)

Aircraft Incident Data Base (ECC-AIRS)

The objective of the present work is to set-up a prototype system of a European Coordination Centre for the mandatory Aircraft Incident Reporting Systems (*fig. 4.4* ECC-AIRS).

In the first months of 1993 the development of the system has been completed by installing the application software on server- (UNIX with Oracle 7) and client-side (Windows 3.1 with MS-Access).
To guarantee the quality of the project's final deliverable, the European Space Agency's software engineering method (based on ANSI/IEEE/ISO standards) has been applied to create the required software documentation, and to subdivide the software development life cycle in standard phases. This approach resulted in a set of documents that formally define the user requirements, software requirements and the architectural design. These documents have been accepted by the project's steering committee during 1993. In 1994 additional documents covering detailed design, user manual and software transfer procedures will be produced.

In the second half of 1993 the architectural design of the system has been completed (*fig. 4.5*). Based on evaluation of technical alternatives, visits to similar external systems (NTSB Canada) and various prototypes (in particular the query builder and the data entry component) the main components and their mutual interaction have been identified, defined and approved. At the end of 1993 the project staff is ready to start the implementation phase of the development cycle.

During 1994 most of the time will be used to implement the system components based on the definition of the architectural design. The last months of 1994 will be used for testing the design.
In parallel with the implementation of the system, test data will be imported from some of the member states. A study on the feasibility of long term statistical analysis on the imported data will be made during 1994.
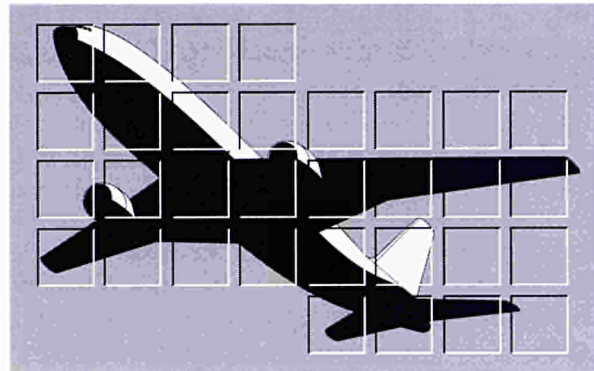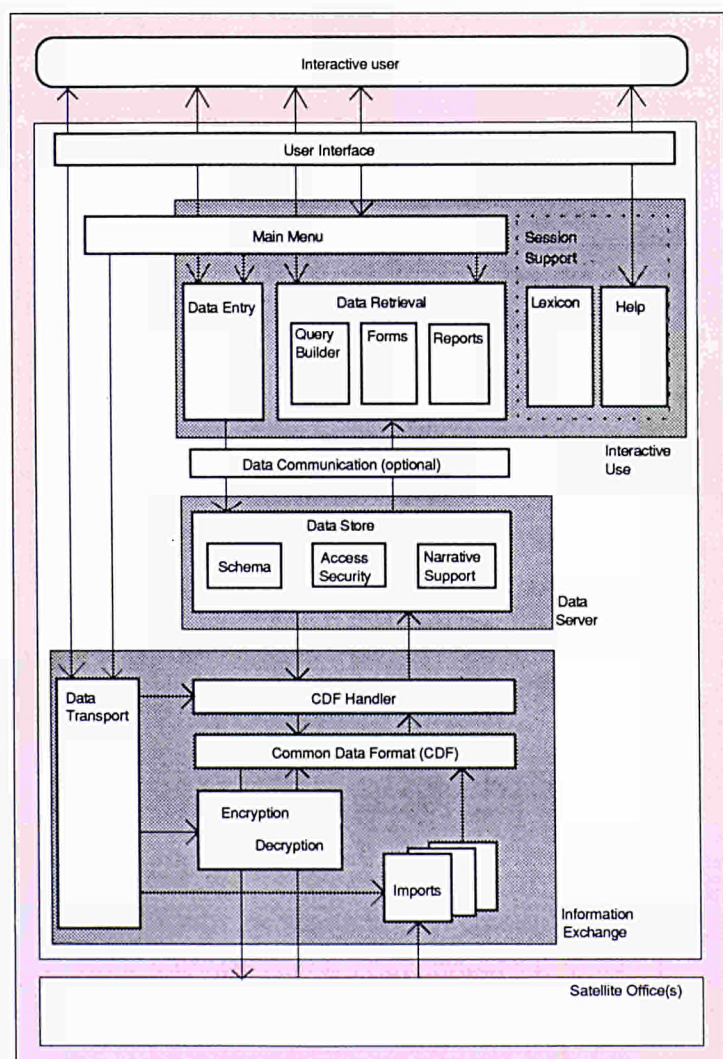

Fig. 4.4. ECC-AIRS Logo

Fig. 4.5. ECC-AIRS: Architectural Design Central Office

SUPPORT TO THE COMMUNITY ENVIRONMENTAL POLICY (DG XI)

Major Accident Hazards connected with the Industrial Activities involving Dangerous Chemicals

In 1993 the activities in supporting the implementation of the Major Accident Hazards Directive 82/501 and its revisions have been reinforced to cover not only the documentation centre and the accident reporting system, but also the organisation of working groups created to enhance harmonisation of national practices.

Community Documentation Centre on Industrial Risk (CDCIR)

The Community Documentation Centre on Industrial Risk (CDCIR) has continued the collection of documents on safety regulations, codes of good practice, accidents investigations etc. The Bulletin N.8 (Masera & Rasmussen, 1993) which describes the new entries has been published; and information to authorities, industry and research organisations has been diffused.

At the same time the CDCIR publication series has been enlarged by five new volumes on investigations of causes and management of major accidents:
- Vol.13. Lessons Learnt from Emergencies after Accidents in France Involving Dangerous (EUR 15059 EN, 1993)
- Vol.14. Major Accident Reporting System. Lessons Learned from Accidents Notified. Updated 2nd Issue (EUR 15060 EN, 1993) published as a book by Elsevier
- Vol.15. Lessons Learnt from Emergencies after Accidents in Ireland Involving Dangerous Substances (EUR 15565 EN, 1994)
- Vol.16. Lessons Learnt from Emergencies after Accidents in Denmark Involving Dangerous Substances (EUR 15562 EN, 1994)
- Vol.17 Lessons Learnt from Emergencies after Accidents in The Netherlands Involving Dangerous Substances (EUR 15563 EN, 1994)

The studies on emergencies have been extended to cover all remaining European countries. The last results should be published during 1994.
Transfer of information on the new data base has been initiated. This will allow distribution of the bulletins on a user-friendly electronic support in the future.

Major Accident Reporting System (MARS)

The activity has been pursued by recording, analysing and diffusing information on accidents notified (a total of 170 accidents have been inserted in MARS by end 1993). The lessons learnt for a preventive policy have been subject of regular reporting to the Committee of Competent Authorities, and subject of open publications (CDCIR Vol.14 and Ref.1). Further information on the activity is given in the following, where the progress of the working group on accidents is described.

Technical Working Groups

To procedure guidance on selected aspects of the implementation of the Directive, DGXI has started activating Technical Working Groups (TWGs). Such groups are supported by ISEI as far as both the organisation of the meetings and the finalisation of the expected results are concerned. As such groups are constituted both by representatives of authorities and control organisations, and by representatives of industrial parties (CEFIC, CONCAWE, EP FORUM, AEGPL, EPSC), ISEI is becoming a focal point for elaborating guidance notes of interest of both authorities and industry. The objectives and the results of the TWGs can be summarised as follows:

TWG1 - Accident Reporting

After three meetings in Ispra, this working group, for which ISEI and the Rapporteur from the French Ministry of the Environment have had close and efficient collaboration, has already finalised its mandate. The group succeeded to elaborate the MARS new collection forms and reporting procedures. In the future the accident reporting will take pace in two phases: in a first phase a short notification form has to be supplied after the occurrence of an accident; in a second phase, when the investigation on the accident has been completed, a very comprehensive collection form has to be filled in. This procedure has been already implemented, and the old notifications are being transferred into the newly developed MARS data base. Furthermore a new accident gravity scale has been adopted for a trial period of two years, as the experience with the previous scale suggested that changes would be an advantage. Both the short reporting form and the gravity scale are being used as a basis of further international cooperation (OECD, ECE).

TWG2 - Inspection Systems

Also this working group has practically concluded its mandate, i.e. to produce a guidance note for inspecting the plants with respects to major accident hazards.

TWG3- Safety Report

The safety report is the central item within the control process implemented by the Directive (see *fig.4.6*).

The mandate for TWG3 is the elaboration of guidance notes for the production and the assessment of the safety report. Two meetings have been organised at Ispra in July and in the December '93, with strong participation of the industry, very sensitive to the need of harmonisation of practices and "costs". The meetings allowed comparison of the actual national practices and guidelines, and the establishment of an intensive working programme.

TWG4 - Safety Management Systems

The need for the adoption of formal safety management systems was demonstrated by the analysis of the accidents notified in MARS /1/. The working group started establishing the state of art by reviewing a study contract being performed by the TNO Firm on behalf of DGXI, and by contributing to the programme of the seminar on SMSs which was organised by ISEI on October 6-8, 1993, hosted by the European University Centre for the Safeguard of the Cultural heritage in Ravello (I). The seminar had a strong support and participation from industrial representatives. Three main subject were discussed: Key elements with respect to the Directive; Practical Experience with Safety Management Systems, and Performance Measurements. The pre-print of the proceedings (eds. Cacciabue & Gerbaulet) are already available. This state of the art review will constitute the basis for the next step: starting elaboration of guidance note on SMSs.

Implementation of the Directive

Furthermore cooperation has been given to the works for the implementation of the Directive in the field of information of the public by finalising "general Guidelines for Content of Information to the Public" and by other support studies /2/, as well as for the fundamental
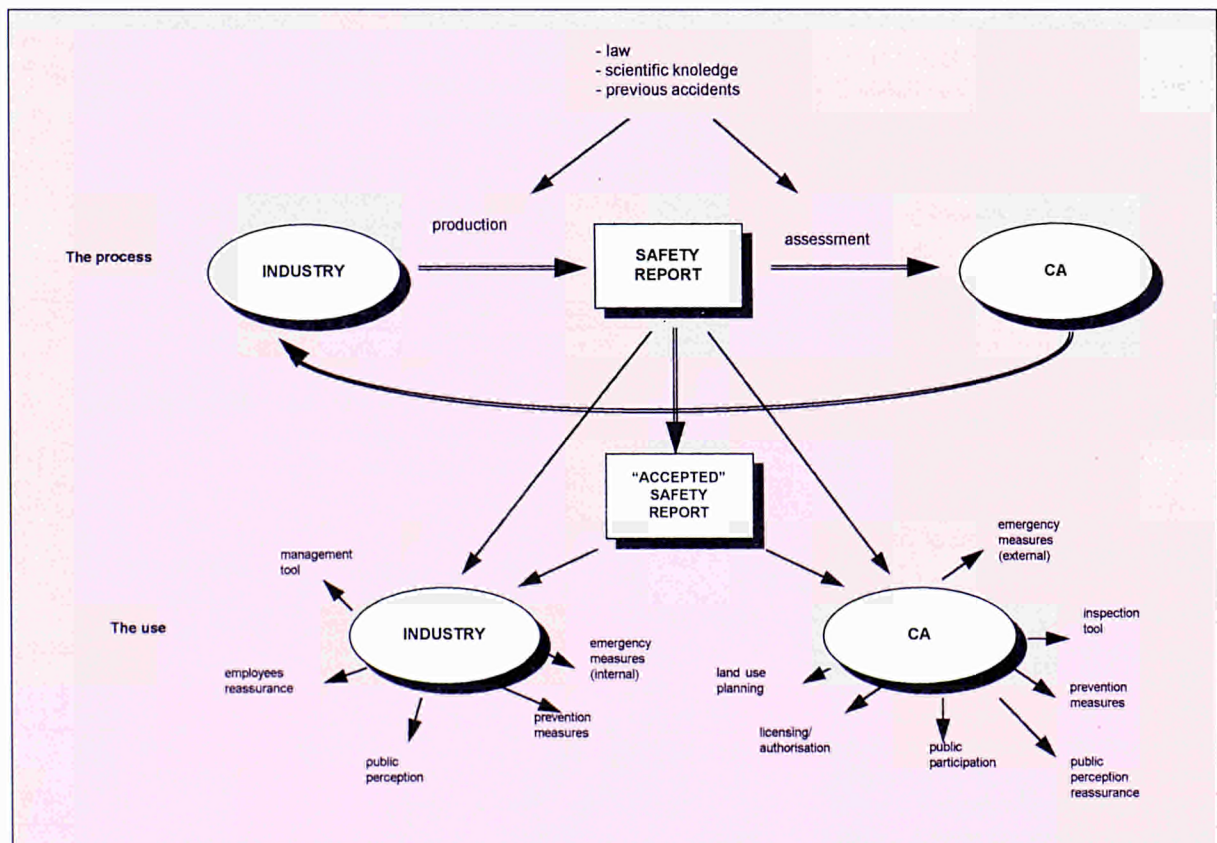

Fig. 4.6. The safety report: its Process and Uses

revision of the Directive, in particular in the field of environmental impact of accidents by sponsoring studies for the identification of industrial installations presenting major hazards for the surface waters and the ground waters; and, for modelling the effects of related accidents /3/.

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Biotechnology Hazards

Support to the Commission with respect to the regulation on the contained use of genetically modified micro-organisms (Directive 90/219/EEC) and of the deliberate release into the environment of genetically engineered organisms (Directive 90/220/EEC) consists of several permanent man dates such as:

–   the operation of a Community Documentation Centre on Biotechnology Safety and regulations (BIOSAFE) that collects relevant information on the legal developments and on safety issues related to biotechnology. In the course of the year, about 900 bulletins have been distributed to Member States Offices, Commission Services, university and industrial laboratories;

–   the operation of an information service which aims at the provision of scientific or technical information to the Member States, following their specific requests.The sources of the information are the European Patent Office, other data bases accessible by the JRC, as well as relevant studies commissioned by the Member States or by International Organisations;

–   the technical support to DG XI for the preparation of documents for the meetings of Competent Authorities and for International meetings (most particularly of the OECD and of the EC-US technical working group on the environment). JRC staff regularly attended the above mentioned meetings.

Whilst carrying out these different tasks, ISEI has further strengthened its expertise in software development to provide this assistance to the Services of the Commis-

sion. In particular, the database, BIOMARS, has been thoroughly tested and is ready to record accidents to be reported in accordance with Directive 90/219/EEC. At the moment no accidents have been notified yet. Furthermore the proceedings of the EURO COURSE on "Scientific Technical Background for Biotechnology Regulation" have been finalised. (Eds. F. Campagnari, V. Sgaramella and G. Van den Eede, published by KLUWER Ac. Pbl., EUR 15579 EN).

Natural Disasters

The objective of the activity was the identification of needs for a project on natural disasters in support of the Commission policy , similar to what is already running for the major accidents hazards of chemical sites, as reflections on natural hazards vs technological ones confirmed similarities in the principles for a sound control policy /1/2/. To this end, within the UN International Decade for Natural Disaster Reduction (IDNDR), a Conference on Natural Risk and Civil Protection has been organised at Belgirate (I) on 26/29th October 1993 (fig.4.7) in cooperation with DGXI (Civil Protection Unit) and DGXII (Climatology and Natural Hazards Research Programme), with the following objectives:

–   to generate conducive conditions for an integrated dialogue between researchers and practitioners in different states, which draws on the state-of-the-art knowledge in natural risks and civil protection;

–   to provide a multi-disciplinary forum for discussion of the most relevant needs and priorities in hazards research in the light of the needs of planning and responding authorities and to promote the continuation of such discussion;

–   to explore commonalties in approaching the management of risks posed by both natural and technological hazards, set in the context of a shared culture of safety among public authorities, regulators, civil protection agencies, industry and citizens;

–   to analyse organisational problems associated with emergency response, crisis management, risk communication and citizen participation and to identify effective strategies to minimise these.

This was the first time that a similar event was organised at a EEC level including the participation of earth scientists; scientists from planning, management and communication disciplines; and, civil protection authorities and operators. Especially the round table discussions on data sources, setting of priorities for R&D and

"Towards a better understanding between scientists and civil protection operators" confirmed the need of focal points where experts from different in-field experiences and scientists from different disciplines might met and continue to confront for a better approach to civil protection. The results of the conference are now being exploited together with DGXI for establishing priority actions to be pursued by ISEI.

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Civil Protection Information and Communication System

The pilot system operation period ended in April 1993. A small but important set of system enhancements was also completed by September 1993. Unfortunately, there was a RPCN informal decision in September (RPCN is a regular civil protection delegate forum) to bring all related activities to a halt. No civil protection officials are using the pilot system today for the purposes for which it was originally designed.

The Ispra team also received a mandate to head an evaluation task for the project. For this purpose, Ispra chaired an informal workshop in Brussels in September. The purpose of this workshop was to get member-state feedback for the evaluation exercise, both on operating experiences with the pilot system as well as on future considerations for the project.

The evaluation exercise conducted by Ispra - in collaboration with DG XI.A.5 officials - terminated in December 1993 and a final report was produced. The assessment had both a technical and a strategic dimension.

International Conference on
NATURAL RISK AND CIVIL PROTECTION

Hotel Villa Carlotta
Belgirate (No) - Italy

26-29 October 1993

PROCEEDINGS PREPRINT

Organised by

Commission of European Communities

Joint Research Centre
Institute for System Engineering and Informatics

DGXI (Civil Protection Unit)

DGXII - R&D (Climate and Natural Risks)

within the UN International Decade for Natural Disaster Reduction (IDNDR)

Fig. 4.7. International Conference on Natural Risk and Civil Protection

Risk Communication and Emergency Management

During 1993 research dealt mainly with the psychological and social components of technological risk, which deserve as much attention as its strictly technical ones. The research provided a greater understanding of the problems con-
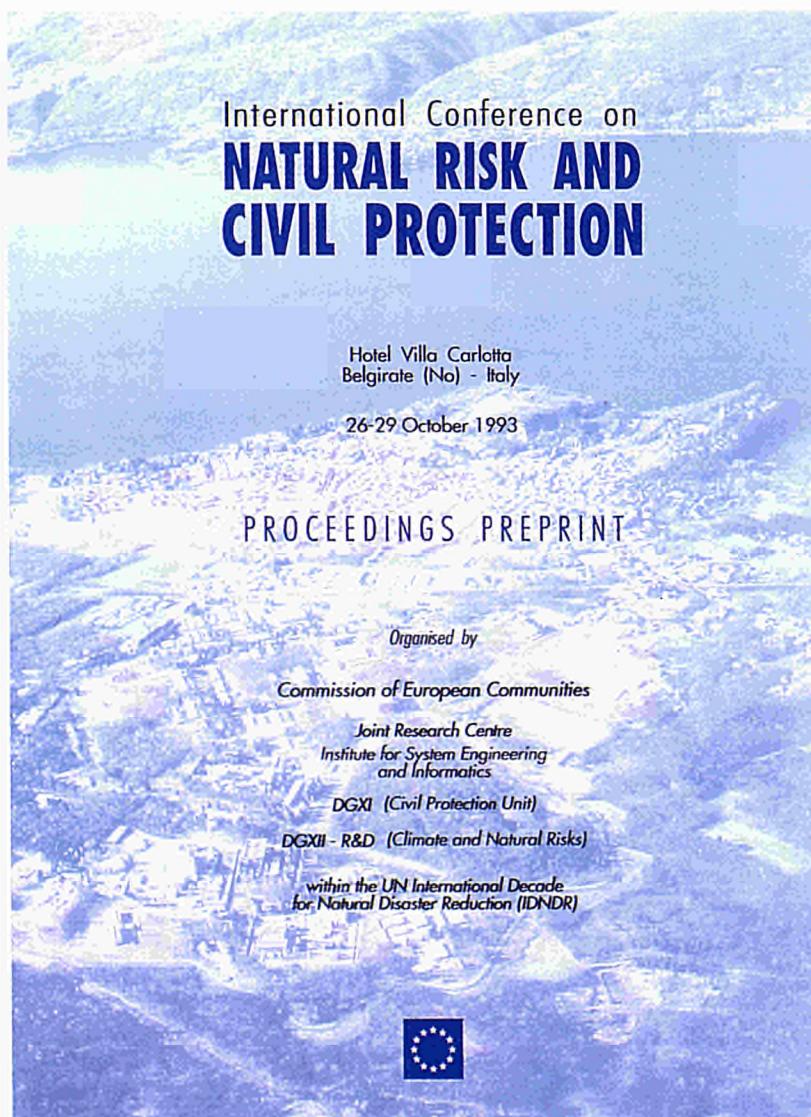
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nected with risk communication, both for the prevention of technological accidents and for the management of civil emergencies. It also produced a set of recommendations and practical guidelines intended for policy purposes.

Research was extended to transportation risks and an attempt was made to adapt the insights gained from experience with fixed installations.

Theoretical research was complemented by field research. In particular two research projects were undertaken, as follows.

Management of Uncertainty in the Communication of Major Hazards

The project was designed as part of the implementation of the Seveso Directive on the Major Accident Hazards of Certain Industrial Activities (82/501/EEC and subsequent amendments). Two centres were chosen for the research, representing different institutional cultures, Italy and the United Kingdom. The project was organised in several phases, alternating between theoretical development and empirical research. Interviews were conducted with leading responsible persons in relevant fields of emergency planning and management, as well as with persons from the media and relevant areas of research.

The main result of the project is a checklist "Uncertainty and its Communication". This facilitates the identification of the different kinds of uncertainties involved in crisis situations. It also allows a comparison between institutional cultures in relation to uncertainties in the communication of hazards, and suggests 'ideal types'.

Community Response to the Seveso Accident

A second study was performed on the community response to the Seveso accident in 1976 and on the long-term social consequences of it. The existing documentation was examined in detail and interviews were conducted with community leaders, people in charge of the management of the crisis and the long term recovery, health officers, journalists.

The research has detected the 'paradoxical aspects' of the Seveso case. In spite of this local success, for the courageous response of the community, "Seveso" remains a symbol of a calamity; the European Community Directive is known by it, and even the notifiable sites are informally named after it. Thus the symbol remains

potent, figuratively and legally, outside Seveso itself; while inside, the visible traces of the accident have been disappearing. But as the recovery continues, the paradoxes of "Seveso "provide new lessons for reflection about future policy. The scientific paradox continues to have its effects, through uncertainty about the effects of Dioxin.

Nuclear Safety

Support has been given for the monitoring, or assessment of the results, of study contracts given by DG XI (formal use of Expert Judgment in Probabilistic Safety Assessment (PSA) and the application of neural networks to process control). ISEI participated, on behalf of DG XI, in some IAEA Technical Committee meetings (e.g., in the series of meetings dealing with the definition of safety principles for the design of new reactors). It participated in some CEC Committees for the evaluation of offers for some assistance actions related to TACIS (Technical Assistance to the Community of Independent States). It has been charged with the task of issuing and updating of earthquakes catalogues. It will represent DG XI in the joint CEC/USNRC project on "Uncertainty Analysis of Probabilistic Accident Consequence Codes". In the following, it is reported in detail on the activity related to the two last items.

Historical Earthquake Catalogues

ISEI has been charged by DG XI/D with the tasks of:

- issuing earthquakes catalogues, containing historical data on seisms which occurred in various geographical areas. "Raw Data" will be received from the Bundesanstalt für Geowissenschaften und Rohstoffe-BGR (Federal Institute for Geosciences and Natural Resources) of Hannover (FRG). This Institute has the task to collect these data, e.g. by extracting them from national catalogues. ISEI will analyse and process these data, e.g. by using a Geographic Information System (GIS), to give them an informatic structure and representation suitable to the user;

- acting as publisher of the catalogues, which will have the status of EUR Reports;

- distributing the catalogues to the national representatives of the "Ad hoc Sub-Group on Seismic Effects", established at the European level, and to other interested Organisations.

It has already been produced by DG XI a first issue of earthquakes catalogue covering EC countries. Ongoing activities of data collection refer to the former Soviet Union area and to the geographic "band" related to the Balcanic region.

It is anticipated by ISEI that the issued catalogues will be used for the seismic assessment of nuclear installations as well as of high risk conventional industries.

Spatial Analysis of Earthquakes Historical Data

Work started to evaluate the feasibility of spatial analysis to explore relationships between sites of nuclear installations, population and earthquake risks. Geographical Information Systems (GIS) can be used to assemble and structure spatially referenced information and subsequently to analyse the assembled data and derive new information and parameters useful for decisions and policy making. A preliminary test was carried out by installing some of the European Earthquake Catalogue /1/ data on the SPANS (SPatial ANalysis System-GIS) and testing the facilities for data interrogation and selection. The SPANS system was found to be highly convenient for selecting events from the map and examining their corresponding alphanumeric data, and also for selecting events from tabular data and finding the corresponding positions on the maps. The system also allows the selection and mapping of events from the catalogue having magnitudes above or below a specified threshold of magnitude or intensity, or within specified ranges. These features are useful for checking the catalogue and in particular for identifying duplicates of events which occur near international boundaries and are consequently reported in two national catalogues. Collection of further data required for the spatial analysis study in digital form, including European regional boundaries, populations of European regions, and locations of nuclear facilities and cities was also made. The activity will be continued in 1994.

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Scientific and Technical Support for the Joint CEC/ USNRC Project on "Uncertainty Analysis of Probabilistic Accident Consequence Codes"

A Joint CEC/USNRC Project on uncertainty analysis of codes for the evaluation of consequences following a radioactive release from a nuclear installation is funded by DG XI (Safety of Nuclear Installations Unit and Radioprotection Unit) and DG XII (Research on Radioprotection). Two probabilistic accident consequence codes are adopted as a reference for the study: MACCS and COSYMA, developed in USA and EC respectively. COSYMA stands for COde SYstem from MARIA. MARIA (Methods for Assessing the Radiological Impact of Accidents) is a CEC's research programme aimed at reviewing and building on the nuclear accident consequence assessment methods in use within the EC. A wide use of Expert Judgment, as in NUREG-1150 for PSA level 1 and 2, is foreseen in the CEC/USNRC Project. This project is clearly relevant to PSA level 3. ISEI is following the project on behalf of DG XI. European contractors are NRPD (UK), KfK (D), GRS (D), SRD (UK), TU Delft (NL), ECN (NL). The two main contractors are Sandia in USA and TU Delft in EC. A pilot study, having as objective the assessment of the uncertainties associated with the parameters of the atmospheric dispersion and deposition modules of the MACCS and COSYMA codes, has been completed. The main aim of this pilot phase was the definition of a methodology of formal expert judgment elicitation. Eight experts have been elicited. In this study uncertainties were only elicited on parameters that were, in principle, observable. In this way the results obtained could be used to determine uncertainties for any dispersion (or deposition) model proposed and had the potential to take into account of model as well as model parameter uncertainty. The drawback of this approach is that post-processing of the elicited data is required to enable the uncertainties in the elicited data to be transformed into uncertainties in the model parameters actually used in the Accident Consequences Analysis codes. This data post- processing asks for a strong mathematical background by the analyst. At present it is the Delft University that deals with this issue. A direct involvement in the project of some JRC experts, in the EJ issue as well as in the data post- processing issue, will be considered.

The main phase of the project should start in April 1994. The expert elicitations should end by 1995. The uncertainty analysis could continue during 1996. As a last step, the connection and significance of the results of the project with PSA level 2 (source term) and level 3 (evaluation of the accident consequences on public and environment) will be analysed.

SUPPORT TO THE COMMUNITY INDUSTRIAL INNOVATION POLICY (DG XIII)

Image Processing and Holographic Processing and Synthesis

The Image Processing and Synthesis techniques are applied to the synthesis of holograms in such a way that one can reconstruct real three dimensional scenes. The developments are based on optical phenomena that were discovered in the JRC 3-D Image Processing Laboratory. The main objectives of the work is to develop a mathematical package to simulate this discovery and thus realise an industrial European prototype for advanced image compression software, 3-D visualisation on advanced parallel computers, and new colour holographic flat screen for industrial applications.

The following achievements have been accomplished:

– Theoretical developments on basic ray tracing and radiosity techniques, initiated one year ago, have been pursued.

– Concerning the holographic synthesis, theoretical developments have also been pursued but the implementations on SUN working station of the first release have been accomplished. Comparison with experimental data have been demonstrated on simple 3D scenes /1/. Experimental setup for holograms in true colours have been started.

– Hologram synthesis has to use a set of basic numerical tools, based on the fast transform principle, thus FOURIER, HADAMARD, WALSCH, PALEY and HAAR's transformations and WAVELET & FRACTALS techniques have been modified and the enhancements still constitute an advanced software package. Such a package, has been applied for image compression techniques and colour holographic synthesis.

The special implementation realised in the laboratory demonstrated that image compression can be achieved by a factor of 10 up to 1000 without any significant loss of information /2/. (Fig. 4.8)

N.O.A.A. SATELLITE IMAGE

S.P.A.C.E. SOFTWARE CONTRAST ENHANCEMENT

FAST TRANSFORM COMPRESSION SOFTWARE
COMPRESSION FACTOR = 50
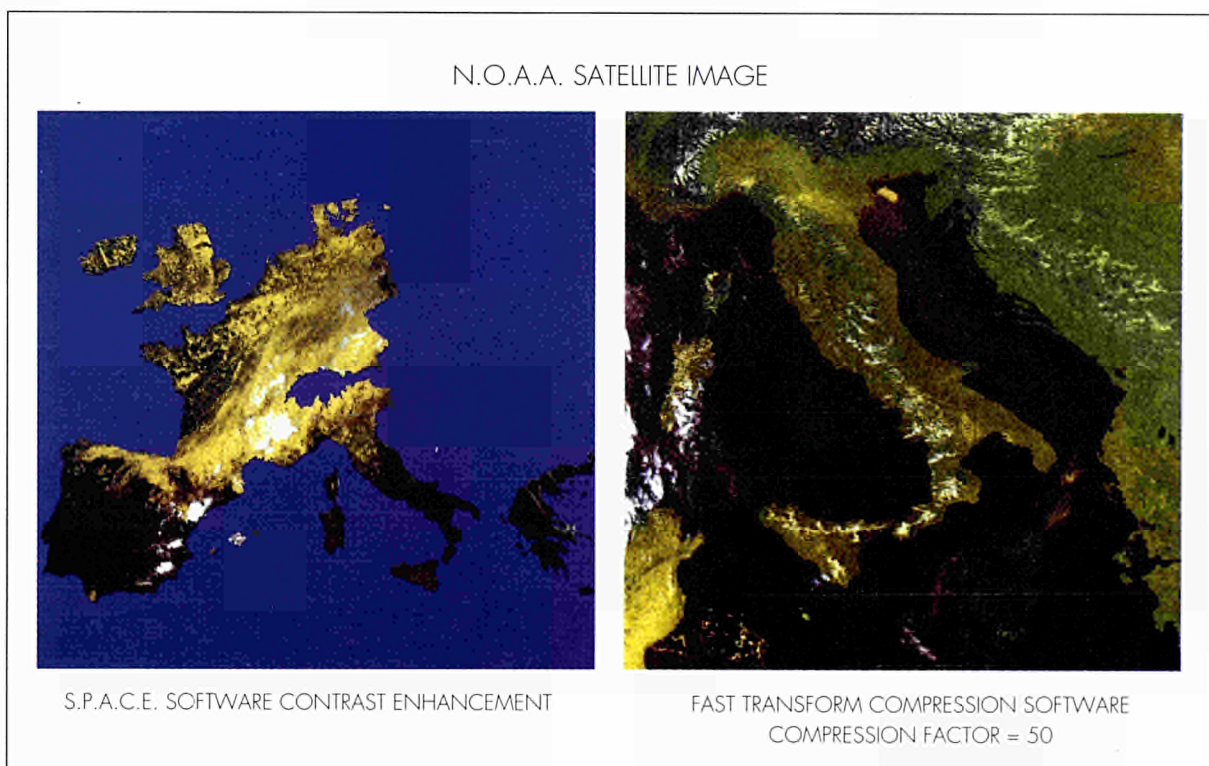
Fig. 4.8. N.O.A.A. Satellite Image S.P.A.C.E. Software Contrast Enhancement

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/2/ GROSSETIE, J.C., HOHENADEL, M., FRANCESCATTI, J.C., First Studies on Image Compression for Philips Medical Systems, Note Technique No. 1.92.143

Ultra High Sensitivity Interferometric Sensors

Further tests have been performed in the laser and Applied Optics Laboratory on two interferotric devices (international patents PCTPE93/02978 and PCTPE93/02977). These tests confirm the extraordinary characteristics (sensitivity, time of response) of the first of them, used as sensor for radiation flux measurement (radiation pressures as low as 10^8 atm can be detected).

The measurement campaign carried out on the optical switch (a full optically driven, light beam modulator which can be used as a bistable as well as multistable device) led us to evaluate that excitation power of 10 microW or less is sufficient to drive the system.

Industrial applications, for which separate patents are being asked, are envisaged.

All the results have been discussed with european experts (Paris VI University; Orsay University; CRN of Strasbourg).

In particular, as the result of several meetings with prof. Miehè of Strasbourg, a detailed plan for the complete characterisation of the devices has been prepared and a collaboration agreement signed.

Key Reading Device for Access Control

A "key reading device" manufactured by the French company SPECTEC on the basis of a JRC patent has been installed as an access control system to command the opening of a door in the LaSco laboratory. The system has been in use satisfactorily for one year. The staff has been also acquainted with operating the initialisation procedure necessary to install the system or while modifying the population of "authorised" keys. Also a similar portable equipment destinated to demonstration has been tested successfully.

SUPPORT TO THE COMMUNITY ENERGY POLICY (DG XVII)

Support to EURATOM Safeguards Directorate

Surveillance Techniques

The objective of the work is the development of equipment and software in the field of optical surveillance and monitoring for applications of EURATOM Safeguards Directorate (ESD). The main tasks are:

Computer Aided Video Surveillance

In the field of multicamera surveillance a second generation of computer controlled surveillance systems (CAVIS-2S) has been developed. This year five units CAVIS-2S, single rack version, have been realised and delivered to ESD. These systems provide the programmed, multiplexed recording of up to 16 video signals during extended periods of unattended optical surveillance. CAVIS-2S retains the unique feature of a built-in data logger with 16 analogous inputs and up to 48 digital input lines. These inputs are used to supervise the recording process and to perform the acquisition of signals from other monitoring sensors used in safeguards. Any malfunctioning, tampering attempts or environment changes are logged by the computer in an alarm history file. The user-friendly inspector interface has been improved according to the comments of ESD. Moreover two additional review stations CARES have been assembled and tested. These systems are dedicated review stations for tapes recorded by CAVIS systems.

Front-end Data Reduction

A problem in safeguards surveillance is the high amount of data to be recorded in the period between inspections; this period may amount to few months. Therefore it is important to reduce the data by recording only scenes in which an activity has been detected. The scene change detection method should not be affected by illumination variations in indoor environment. A method based on the correlation of selected polylines /1/ in the picture has shown good results during tests; about 97% of surveillance images taken in-field was discarded. More selective scene changes can be achieved by secondary detection masks which detect movements in a given direction at a certain speed. In this method has been integrated in an image processing system based on PC which performs the data reduction on eight video channels simultaneously. It is possible to programme the number of images to be recorded before and after the alarm detection. This reduced data set is stored on the computer disk. The software development required particular attention for the severe real-time conditions imposed by videodata rate on several channels simultaneously. This concerns in particular the detection algorithm and the disk access software. A laboratory prototype has been set up and will be demonstrated to ESD inspectors.

Automated Review

The objective is back-end processing of recorded surveillance data and easy review of alarm scenes. In conventional surveillance systems the recording is done in fixed time intervals on video tape. The review of the tape by the inspector is time consuming. A new development has been performed to speed up the tape review by integrating a cyclic image buffer and dedicated software in the review station. The inspector can stop the video tape from the computer keyboard and browse with the mouse through the last 16 images stored in the image buffer. The trigger for freezing the cyclic image buffer can be either from keyboard or from a software module like poly line when detecting a scene change in the video sequence. The second trigger method enables an semi-automatic review procedure. This new development can be added in the existing three review stations CARES presently used by ESD.

Integrated Measurement System

A feasibility study of an unattended low enriched measurement station combining non destructive assay with video surveillance has been carried out by JRC. The surveillance part concerns the identification of the fuel element and the eventual continuity of knowledge after identification. Technical proposals based on pattern recognition and radio- tags have been prepared and submitted to ESD.

Test inconnecting the integrated monitoring system from Sandia Laboratories with the JRC CAVIS system have been carried-out /2/.

Motion detector alarms

A software to store and analyse alarms generated by video motion detectors has been developed. The programme performs the data acquisition from instrumentation to PC and the sorting of recorded alarms according to different parameters. This tool is used at
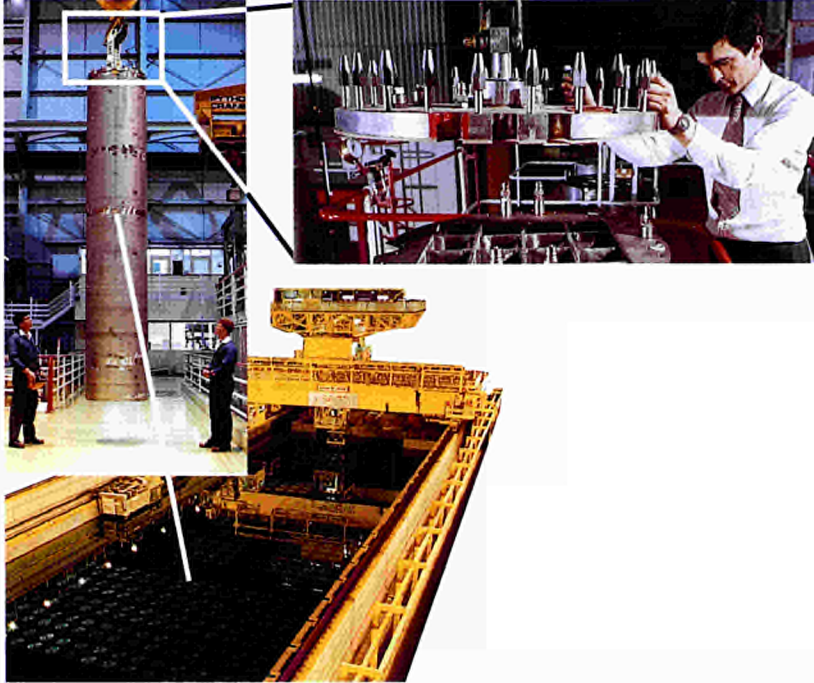
Figure 4.9. A spent fuel element storage and transport container being examined and closed by standard bolts. One of such bolts is then replaced in the storage pond by a JRC development ultrasonic sealing bolt

Installation/Verification campaigns took place in Sellafield in January, April, September and December bringing the installed sealing-bolts to a total amount of more than 200.

Ispra staff was sent to Sellafield in June in order to check the reading instruments and implements and to give some assistance on site while removing a mishandled sealing-bolt. No fundamental problem was discovered.

In August, EURATOM staff reported a successful verification campaign jointly conducted with ESD and IAEA inspectors, where 61 sealing-bolts were verified on sealed MEB at a rate of 10-15 seals per hour, in the THORP storage pond.

Ispra has also started the study and development of a specific Sealing-Bolt Data Bank software, on request of ESD, for use at the Headquarter in Luxembourg to keep all existing sealing-bolts and related MEBs under control.

EURATOM head quarter to evaluate the performance of motion detectors installed in several facilities and used in different applications.

References

/1/ MOL. M.J. - "Image Processing Methods for Scene Change and Monitoring Detection, ESARDA Bulletin No. 19, pp. 9-93, May 1991

/2/ JOHNSON S., SOREL F. - "Cooperation between JRC and SLN in the field of Surveillance", 34th INMM Symposium, Scottsdland USA, July 1993

Sealing and Identification Techniques

Based on the field experience started in 1990/91, JRC-Ispra has continued his support to EURATOM inspectors on duty at Sellafield in order to provide the quantities of sealing-bolts required for the sealing of a large number of Multi Element Bottles (MEB) stored in the ponds (*fig. 4.9*) and to get BNFL staff and inspector teams being able to work in a routine manner.
50 sealing-bolts were manufactured and delivered in March 1993 on request of IAEA and 150, were ordered by EURATOM and delivered by end 1993. Quantities of 500 are planned for order in 1994.

Solar Energy and Rational Use of Energy

THERMIE Programme

Photovoltaic (PV) Systems
The main accomplishments have been as follows:

–   analysis of photovoltaic performance data collected from more than 35 projects with production of the corresponding monitoring reports (11 from Global Monitoring and 8 from Analytical Monitoring);

–   technical evaluation of new proposals (40 Projects) and of current project progress reports. Corresponding updates of the SESAME data bank (66 sheets updated);

–   work on monitoring the PV-utility interface with real data, using the Personal Computer based harmonic analyser developed before;

–   on-site measurements at the LITHARI demonstration plant and 2 control visits to other sites;

– publication of the PV Monitoring Newsletter and Organisation of the Madrid meeting of the European Working Group for PV Plant Monitoring.

Building and Transport

This year, in addition to the usual THERMIE proposals, 67 of which were received and assessed, a new category-"Targeted" proposals-was introduced. These were defined as "major European collaborative projects, designed to have a significant impact on the energy and environmental situation in the EU". Priority was given to projects likely to have a substantial European impact, which in practice meant those with a total cost of more than 6 million ECU. Projects also had to involve substantial collaboration between proposers from at least 3 different Member States.

Following the announcement in the Official Journal, 25 "Targeted" proposals were received in the "Buildings" sector and 20 in the "Transport" sector. An active role was played in the assessment of these proposals and in the selection of the successful projects.

Solar Thermal Systems

– Evaluation of about 20 new proposals as result of a yearly call for tenders;

– Participation in proposal evaluation meeting (5);

– Participation as invited experts in the steering committees for the preparation of call for tenders'94. Preparation and participation of the THERMIE committee meeting with Member States on Solar Thermal Energy Finalisation of study on European standardisation activities for Solar Thermal energy in view of an action in the ALTENER programme;

– Publication of guidelines for tele-monitoring Active Solar Projects.

ALTENER programme

A survey study has been carried-out on European standardisation needs for Solar Thermal energy components in view of a future action in the frame of this programme.

SAVE Programme

Demand Side Management Demand Side Management (DSM) is an option in energy planning strategies, available to utilities, which is already widely applied in the USA. The option is that of investing in demand reduction rather than new generating capacity and the economic analysis of the options is a matter of Least Cost Planning (LCP). In order to introduce this approach in Europe a network of 18 European organisations has been established. The Commission has supported a series of pilot studies in various European countries which served to highlight the chief problems that European utilities will have to face when implementing DSM programmes.

Member States are expected to prepare or modify legislation and norms to allow Supply and Demand options to compete on equal terms. Meanwhile, technical support tools for the dissemination of information related to LCP have been prepared. Among these tools, the Database on Energy Efficiency Programmes (DEEP), developed in the USA, promises to be one of the most important, since it allows transfer and dissemination of the most important lessons learned by US utilities.

During 1993, survey of the European utilities interested in an International Database on Energy Efficiency Programmes.

The framework in which international collaboration in the field of DSM data is developing is that of the International Energy Agency (IEA). A new Implementing Agreement (IA) has been set up, which the CEC will join. ISEI, on behalf of DGXVII, has begun to take part in this Agreement and will continue to participate for the next 2 years. The aim is to ensure that no discrepancies arise between it and the data gathering and evaluation of various European DSM programmes supported by the Commission. There is, in fact, a real risk that differences in data definitions and processing from one country to another may make it impossible to compare the results and efficacy of similar DSM programmes.

Building Parameter Identification Techniques

Parameter identification techniques were used to measure the thermal parameters of occupied buildings and passive solar test cells.

Buildings

This research concerns the in situ measurement of the thermal parameters of occupied buildings for the purpose of energy labelling. In 1993, work concentrated on completing the measurement campaign.

As described in the 1992 ISEI Annual Report, some important data biasing effects complicate the application of regression (identification) techniques to the energy data of occupied buildings and these have to be corrected.
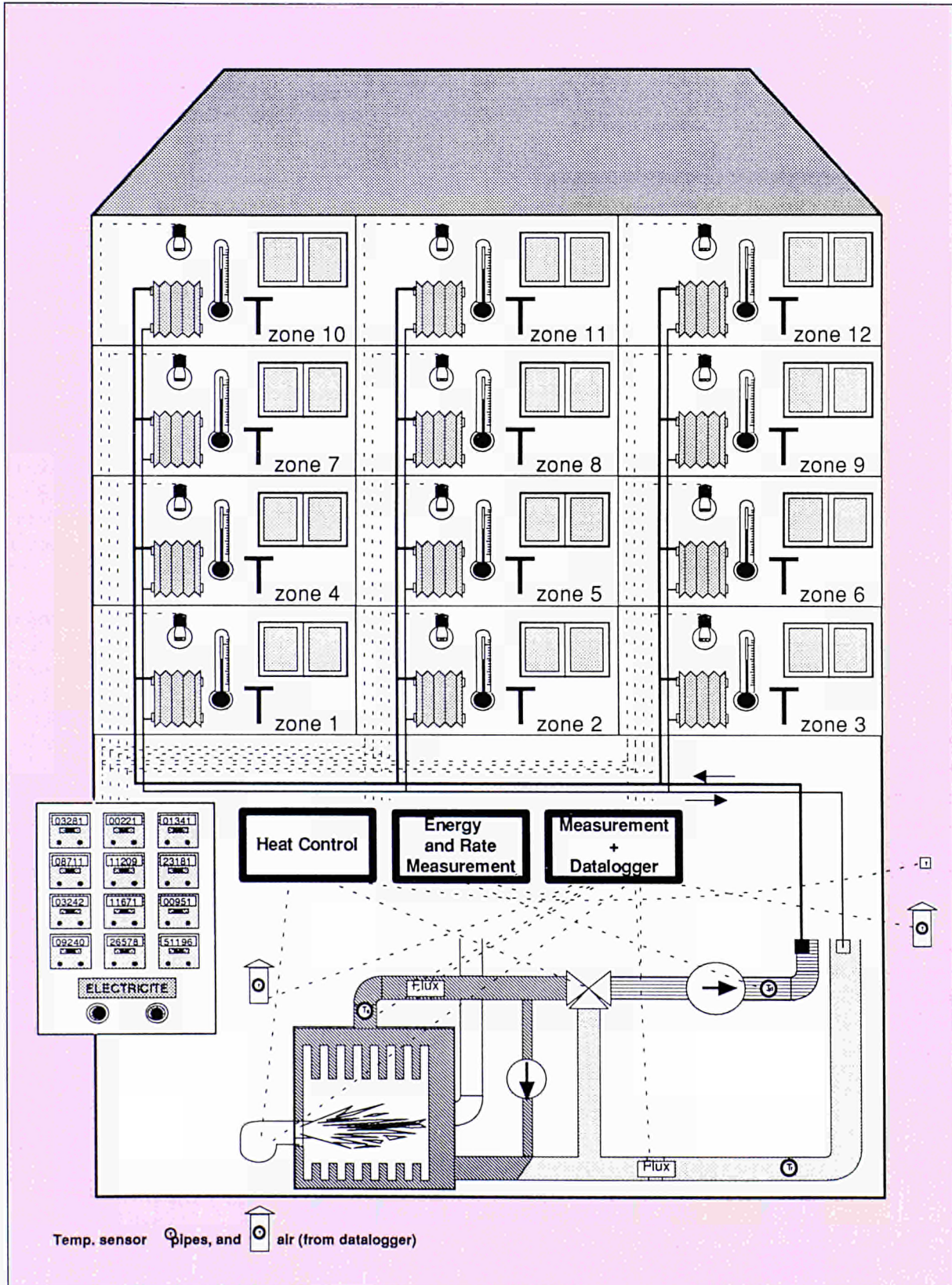
Fig. 4.10. Measurement layout for building parameter identification studies in an occupied building

They are:
- the seasonal variation of heating plant efficiency with load;
- the averaging procedure for the internal temperatures of various building zones;
- the variation of internal gains due to occupant behaviour;
- the variation of external solar gains due to external obstructions.

The measurement layout is shown in *fig. 4.10*.

Investigation of the variation of heating plant efficiency with load continued with another measurement campaign, during which a tentative labelling procedure was tested. The measurement consisted of a combination of a 15-20 days data collection with a time-step resolution of 15 minutes for the identification of building envelope parameters, associated with a 2 day measurement period with 1 minute time-step resolution, for collecting heating plant data. The latter type of data are needed in order to determine the key-parameters of the heating system.

The simulation model TRNSYS, previously used to investigate the thermal behaviour of different building zones, was also used to simulate the heating plant. In this way it was possible to carry out detailed investigations of the building-envelope-plant system.

To assess the effect of occupant behaviour, additional measurements of individual electricity and kitchen gas consumption were made during the 1993 campaigns. These should make it possible to estimate the impact of free gains on the identified parameters.

Towards the end of the year, a new, cheap and simple tracer gas technique was made available thanks to collaboration with the Swedish Institute for Building Research (SIB). This made it possible to plan air ventilation rate measurements that will be carried out early in 1994. With the new Swedish probes it will be possible to obtain values for the air renewal rates of every thermal zone, averaged over the measurement period. Existing techniques had provided only instantaneous (or very short period) values. These measurements, associated with temperature monitoring, should also make it possible to quantify the effects of window opening on the identified parameters.

Passive Solar Cells

Parameter identification techniques are now being used for all measurements on the passive test cells. During 1993, this work was mainly concentrated on the development of techniques, tools and guidelines for promoting the application of passive heating and cooling techniques. It included the use of the facility by the Politecnico di Milano for the testing of a ventilated cavity wall under real climate conditions. Experimental work on building component shading factors (PASCOOL project) was contributed to Working Group 7 of CEN TC89 and will be continued in 1994. An important contribution was also made to Working Group 8 for modification of the ISO (9869) standard on "in-situ measurements of thermal resistance and thermal trasmittance". The standard is now ready for formal voting by the CEN /1/2/3/.

A third workshop, "Application of System Identification in Energy Saving in Buildings", /4/ was organised on specific problem areas in the application of this methodology. Preparations for a course book on the topic have begun and a course is planned for October 1994.

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/3/ BLOEM, J.J., DE GRAAF, M., WICHERS, H, - Application of the Performance Check on a Prediction Error Model, ORA 38042

/4/ "Workshop on Application of System Identification in Energy Savings in Buildings", EUR 15566 EN

5 INFORMATICS SERVICES

Corporate Informatics Services

Distributed Informatics and Communication Services

5 INFORMATICS SERVICES

Corporate Informatics Services

During the year a multi-annual plan for the modernisation of the existing information systems and the introduction of new services has been produced. In technical terms, such plan develops along the following major axes:

- the progressive migration of applications from the 'old-fashioned' central MVS mainframe towards distributed and specialised client/server platforms. The list of applications includes the financial & accounting systems SIBECA and MACS, the staff & payroll, the library, the building & accommodation, the inventory, the contracts, the health-insurance and the warehouse systems. This migration will produce an important reduction of running costs and solve the problem of the maintenance of obsolete software packages which is becoming critical.

- the creation of an information warehouse. This is the repository of all relevant alpha-numeric data about the organisation, its resources and its products. It allows managers and administrators to navigate into the corporate data and produce synthetic correlation and aggregation views. The key idea behind this project is the clear separation between the 'statutory' transaction systems which register and validate the operational acts according to the established procedures and the information warehouse itself that collects data and facts from those sectorial systems and provides a consistent view at the 'life' of the house. The information warehouse contains catalogues and references to other specific sources of information such as scientific publications, project progress reports, contracts, external relations and, in general, multi-media archives relevant to the unstructured query needs of managers and project leaders.

- the adoption of paperless procedures. The elimination of the paper from the offices is not just an environment-friendly measure but is also a prerequisite for enhanced performance, timeliness, accuracy and security of services. Having all work in progress stored electronically allows processes to include parallel tasks and to eliminate repetitive data entry, classification, search and transport practices and other dependencies on the 'physical' availability and manipulation of paper documents.

- with the inclusion of groupware and workflow management tools and methods both the productivity of teams and the performance of horizontal processes can be increased. In particular, the actual work content of the various steps in an administrative process becomes measurable, the priority of tasks can be controlled and an increased visibility and interaction is offered to the various actors, including the customer of the service. This allows changes to be introduced in the process and the progressive optimisation of the work is facilitated. Immediate snapshots of the status of the individual 'service products' can be obtained as well as a consistent view of the overall procedure that brings to their completion and delivery.

The most significant actions undertaken so far in the light of the above objectives and general technical guidelines are described in the following.

The Downsizing of the Mainframe Server

The central processor configuration has been downsized in order to match exactly the needs of the administrative applications i.e. the finance/accounting system, the staff management system and other ancillary corporate information systems. This downsizing exercise produces a 2.62 MECU/year reduction in running costs. The new bill for the administrative processor is 1.58 MECU/year. Further reductions of this expenditure can only be obtained through the migration of the existing application software towards cheaper platforms. This in turn requires important development efforts.

The Migration of Application Systems

Information systems such as the staff&payroll, the library, the building & accommodation, the telephone accounting & billing, the inventory, the contracts, the health-insurance and the warehouse were designed and implemented some 10-15 years ago and since then operated and upgraded with increasing difficulties due to the obsolescence of the supporting platforms and the rarefaction of the relevant competences.

A new version of the contracts system has been put into operation.

A modern hardware and network infrastructure has been installed to host the new health-insurance software under development by DG IX. The full operability of the new system is expected to occur early '94.

A similar migration initiative was activated as regards the staff & payroll and the inventory applications.

The building & accommodation system will be incorporated into the Geographical Information System presently under development. This GIS system is the kernel of a modern facility management system that allows the

graphic representation of the various service networks of the Ispra site (roads, water, energy, telephone, buildings) and associated thematic maps and data relevant to the operational interventions (maintenance, surveillance, waste storage&disposal, safety).

The migration of all information systems mentioned above is planned to be completed by the end '96. In most cases, such migration involves a substantial revision of the functionalities of the delivered product. In '93, up to 400 KECU were devoted to these purposes.

The Evolution of the JRC Finance & Accounting System (Sibeca)

The Sibeca system is by far the most important information system of the JRC. It represents about 40 man/year of development effort and requires 14 people devoted to its maintenance, operation and associated platforms. On the basis of many alternatives elaborated by a joint task-force, the 'Comité Directeurs Sibeca' with constituencies from DGXIX- Accounting, DGXX-Financial Control and the JRC, decided to address the problem of the future of Sibeca in the framework of the migration towards a newly designed SINCOM-2. This is a project that involves all Commission services. There are now hopes that Sibeca can be replaced by a cheaper product within the next 3-4 years. The operation of the new system will be fully integrated into modalities applicable to the whole Commission. The JRC development team has been asked to contribute to the specifications of the future system and to join a number of ad-hoc working groups.

The experience gained with Sibeca has inspired major design features of the new system that, substantially, will reproduce the same integrated functionalities.

The Re-engineering of Business Processes

Major administrative, managerial and infrastructure work- practices have been reconsidered in the light of the potentialities offered by advanced IT. This survey, carried out in collaboration with service providers and end-customers, identified some 41 'business problems' whose solution is expected to contribute to the overall improvement of the quality and performance of the administrative/logistics/infrastructure activities. Suggested remedies include the deployment of office systems, document management systems, electronic document interchange systems, decision support systems, geographical information systems, order/claim systems, billing/accounting systems.

The connective tissue across functional units, which at present is based on the sharing of some data bases and, more often, on the exchange of paper forms, should be revitalised through the adoption of shared electronic document archives, groupware and workflow management systems. The envisaged projects reflect a common architecture as regards, on the one hand, the supporting massaging and network arrangements and, on the other hand, the integration of sectorial activities into horizontal processes in order to provide the required fluidity and continuity of workflows.

Addressing the Market of Informatics Services

In order to identify the optimum organisational and technical solutions for the 41 'business problems' mentioned above, a world-wide call for tender was issued. Basically, the JRC is interested in the assistance from those companies that are experienced in the penetration of advanced IT in large organisations and in the procurement of higher level products/methodologies that proved to be effective in other businesses and would require a limited customisation effort in order to support our work. The adoption of mass-produced application software, which represents the accumulated experience gained by many sources, is expected to turn out cheaper than in-house developments and, more importantly, to facilitate the maintenance/upgrading practices.

A New Procurement Policy for IT Platforms

Every year the JRC negotiates discount contracts with various vendors of IT platforms. Despite the dramatic competition in force, there are further margins for savings. The possibility is being explored for 'package' deals with vendors that cover the whole lifecycle of products including maintenance, support and re-cycling of obsolete equipment. The idea is to avoid the avalanche of independent commercial and technical interventions through a more structured long-term service agreement. The reduction in overhead costs could be devoted to the enhancement of end-user services. The above mentioned call for tender includes some projects of this nature.

Under the assumption that service organisations spend on average 2-3 KECU/year/man for desk and network platforms, even a 5% reduction in mark-up costs would produce considerable enhancements in terms of service quality.

The CIS Unit has activated a limited experiment of this new approach by 'outsourcing' its PC network. The

gained experience will be instrumental to the launch of more pervasive services, once both the JRC and the suppliers have learned how to deal with the commercial, operational and management conditions of this innovative service.

The Information Warehouse

This new relational data base collects data from various statutory and operational sources in order to offer a consistent view at the 'corporate' level. The prototype version of the product was demonstrated to managers and administrators from the Institutes and obtained enthusiastic comments. The final product is expected to support in various forms the majority of management and reporting practices through a comprehensive aggregation of all relevant data about staff, projects, activities, services, finance, costs and scientific production.

The architecture of the system is based on an advanced client/server approach that sees desk-top decision support systems, provided with powerful query and presentation tools, translate user requests into SQL commands addressed to the server data base. The data base is made by a multitude of normalised relations with standardised domains extracted from the various source information systems. Major implementation problems come from the heterogeneity of the original data, their different updating rates, and from the complexity of the pattern of 'Chinese walls' that need to be constructed around data for reasons of confidentiality.

Distributed Informatics and Communication Services

The services provided in 1993 were those that had been negotiated with our customers during 1992. Moreover, these services and the activities of the DICS Unit were evaluated during 1993 by a "Visiting Group" of international experts. The negotiation process was continued during 1993 in order to define the services and resources for 1994.

Members of the unit participated in a large Call for Tender exercise in order to provide services and applications development for the JRC Administration.

Network Services

At the beginning of the year, the 64 Kbps connection of Geel to the IXI network was installed and activated.

This was connected to the Megapac node that had been sent from Ispra some months earlier and put into service. Once the necessary addressing modifications had been performed, the new connection was used to provide all of the data communications connections between Geel and the rest of the JRC. The most noticeable improvement was the response times for SIBECA users, although the connection also improved the speed of Xerox communications. Negotiations have also begun in order to connect the Karlsruhe establishment to the WIN network in Germany at 64Kbps (which interfaces to EuropaNet), thereby completing the "JRCNet" connections at 64Kbps.

A contract was signed with the Swiss research network SWITCH in order to use the 64Kbps line to Manno not only for accessing the Super computer at Manno, but also for IP access to the World-wide Internet. The 64Kbps line was installed by SIP in May, and the Internet service was moved from the IUNet connection to SWITCH in June, with a large increase in the speed of the connections.

A new round of extensions to the Ispra FDDI backbone network has taken place, with the installation of an additional FDDI node in building 44. This node not only serves building 44, but also connects building 50 (the Cyclotron). Buildings 20M, 53, and 64, were also connected to the backbone during this period.

A new software version of the FDDI Network Management product was installed. This runs on a Sun Unix platform (the previous version ran on a PC), and contains much more functionality than the previous version. Its use, however, is limited to the FDDI nodes themselves, and a decision has been taken on how this can be extended in 1994.

An FDDI concentrator has been installed that makes available a set of 10MB ports for the connection of servers onto the network. This gives each of them a full ethernet bandwidth into the FDDI backbone without any changes to the server's hardware or software.

Distributed Systems Management (DSM)

During this period some presentations have been made to Institute representatives on the DSM service and progress made in 1993, in an attempt to give more publicity to what is available through this service. Also individual contacts with some user groups have been made for the same purposes. These have increased the amount of use that is made of the DSM facilities.

There have been substantial changes in the hardware components of the DSM service. First the "dicscs1" SUN Sparc 10 has been put into operation as the principal DSM service machine. It has 6GB of disc available that is fully backed-up on a regular basis. It is currently connected to the FDDI concentrator that gives it a full 10MB access onto the backbone network. This has separated the service components from the infrastructure servers of DICS and SAD Units which previously were used for part of the service provision. The Hewlett Packard machine "hpdb" is now allocated totally to the Data Pool project of CIS.

The DSM services machines (the new system "dicscs1", the Cisco router "dicscs2", and "dicscs3" previously called "is") are now into "operations mode", which means they are guaranteed to be up-and-running, and monitored against possible "outside" attacks, etc.

A new algorithm has been put into operation, which makes it possible to add aliases to the DNS (Domain Name Server) dynamically, controlled by the LSA's. (Perl-scripts).

An evaluation of the Novell Networking software (Netware 3.11) for the PC environment was completed. The conclusions were very positive, particularly in relation to its use in the administrative environment where some units had already decided on an implementation. A limited number of scientific groups had also decided to use Novell, and DICS has coordinated these various implementations and provided some support during the installation phases.

Electronic Mail

The most important event was the nomination of a single individual as responsible for this service, who was allocated full time to the activity, something that had not been possible previously. One of their first tasks was to begin the process of replacing the Bull DPX systems that are used to provide the mail service and which are nearing obsolescence. The technical analysis has been completed, and the actions to procure the replacement systems has been carried out.

The X.400 and SMTP mail services with the outside world continued throughout this period without any modification.

The process of identifying an X.400 mail product for the PC and Unix environments was carried out with the installation and testing of a series of products. These products included :
- an X.400 user agent for MS-Windows on PCs;
- a compatible FAX gateway and
- a Remote access server and user agent that can be used by portable PCs through the telephone network.

The tests were sufficiently positive for DICS to adopt these products for their own use, and for some user groups and Institutes to decide to adopt these products as part of their "common base platform". DICS has given support to users of these products.

Office Automation

The activity of upgrading all Xerox workstations to Global View 3.2 was carried out, and a limited number of installations of Global View on the PC platform (using O/S 2 vers. 2.0) were made, as well as pilot installations of the products for X-Windows and MS-Windows. These evaluations will continue into 1994.

Computer Aided Design

Steps were taken to extend the migration of this service from a central one to a distributed one, in that additional workstations were ordered so that by the end of 1993 only 50% of the original users are still using the central system. These remaining users will migrate during the first half of 1994 so that the central system can finally be closed down.

Other Developments

In May, a demonstration was given of the work that had been done on developing a prototype for an electronic "bon de commande" using Electronic Data Interchange (EDI) technology. Coupled with a presentation by DGXIII on the Commission's initiatives as regards EDI, the creation, transfer and reception of an electronic form was shown. The security related to such a form, in terms of the signature, was solved by using smart cards with public key encryption algorithms to guarantee authenticity.

6 OTHER PROJECTS

The Euro-Quebec Hydro-Hydrogen Pilot Project (EQHHPP)

The Ispra ECOCENTRE Project

6 OTHER PROJECTS

THE EURO-QUEBEC HYDRO-HYDROGEN PILOT PROJECT (EQHHPP)

Following the evaluation of hydrogen production, handling, transportation and distribution technologies, the EQHHPP continued in the current Phase which is oriented towards the various technologies related to the use of hydrogen. The objective is to demonstrate that the different types of hydrogen utilisation considered present no problems in terms of feasibility and safety.
The project is to be carried out in four Phases:

- Phase I
  assessment; completed by March 1987
- Phase II
  detailed system definition, 1989 - 1991
- Phase III.0
  1. investigation for Phase III & IV
  2. hydrogen applications demonstration projects, 1992-1993/94
  3. operation of the demonstration projects 1993 - 1997
- Phase III
  detailed engineering & specifications; planned to last 1-2 years
- Phase IV
  construction; planned to last 4-5 years

Present Status of the Projects

The Phase III-0-2 on demonstration project was continued. The activities involved three groups of projects and studies: Specific European Projects, Joint Projects (Europe and Québec), Specific Québec Studies.

Specific European Projects
- Storage and Transport
- Deloment and scale test of large liquid hydrogen containers, development of the design of barges for a liquid hydrogen ship
- Urban Transportation
  - City bus with a converted diesel internal combustion engine; liquid hydrogen storage (Belgium); the first test with hydrogen gas (~1 hour and ~10 km, max speed 60 km/h) was successfully made on December 1993
  - City bus with a converted natural gas internal combustion engine; liquid hydrogen storage (Germany)
  - City bus with a fuel cell; liquid hydrogen storage (Italy)

- City bus with a Stirling engine; gaseous hydrogen storage (Ireland)
- Steel Production
  - Utilisation of hydrogen to reduce CO_2 emissions in steelmaking
- Fuel Cell Cogeneration Plant
- Piston Engine Cogeneration Plant

Joint Projects
- Aviation
  - Design of a minimum No_x aviation turbine
- Urban Bus
  - Integration of the Montréal/Brussels urban bus projects
- Automotive Reservoirs
  - Liquid hydrogen storage in thermoplastic reservoirs
- Socio-Economic Studies
  - Comparison of social and environmental costs of hydrogen and conventional fuels
- Studies on Safety Rules and Acceptability
  - Safety measures and rules definition

Specific Québec Study
- Urban Transportation
  - City bus for Montréal operating with hythane

Concerning Phase III-0-3, contracting has been undertaken viewing the operation of the apparatuses built within Phase III-0-2.
In addition the construction of a hydrogen fuel cell driven passenger boat for inland navigation (Italy) and studies concerning hydrogen liquefaction optimisation, methanolisation of hydrogen, transatlantic power beaming and Shannon (Ireland) as a European Centre for the reception of clean energy have been contracted.
All the activities have progressed regularly, with the exception of the Irish city bus which sees considerable delays.

In addition to the coordination activities, papers were presented at various conferences, symposiums and workshops various.

- Conference on Using Energy in an Intelligent Way, EPS, Trassenheide, May 1993;
- Workshop "Hydrogen and other Alternative Fuels for Air and Ground Transportation" DG XII - F, Brussels, June 1993;

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- Sommet Solaire Mondial. "Le Soleil au Service de l'Humanité", UNESCO, Paris, July 1993;
- Workshop on "Material Science and Physics of Non- Conventional Energy Sources" International Centre for Theoretical Physics, Trieste, August-September 1993;
- Workshop "Hydrogen as a Means of Energy Storing", Politecnico di Milano, Milano, November 1993.

THE ISPRA ECOCENTRE PROJECT

Present Status of the Project

In 1993, the European Parliament allocated 5 million ECU to the Ispra Establishment of the Joint Research Centre for the modernisation of its site and buildings. It was stipulated that this was to be both ECOlogical and ECOnomic and results were intended to be transferable to other ageing research centres. Although responsibility for this project was given to the Director of the Environment Institute, the working group set up to carry it out contained a number of specialists from ISEI's Non-Nuclear Energies Unit.

The first step in the ECOCENTRE project was actually an energy and environmental audit of the Ispra site financed by the German Government and completed in 1992. On the energy side, this report /1/ concluded that there was considerable potential for reducing the heating and cooling loads of the buildings and proposed that, once this was achieved, a cogeneration plant (CHP) should be installed. Replacing the present, ageing, centralised heating and cooling plant, this would produce most of the site's heating and cooling requirements together with a substantial quantity of electricity.

Before investing in a CHP plant, the working group decided to begin with the energy retrofitting of a number of permanent buildings. Although the JRC's staff could have devised retrofits for these buildings, it was felt that more interesting proposals might be obtained by organising an international competition.

The competition attracted a total of 70 proposals from some of Europe's leading architectural and engineering consultancies. Winning entries were selected by a panel of experts appointed by the JRC and contracts were signed before the end of the year, for the retrofitting of 5 buildings. The winning designs proposed solutions which should greatly reduce the need for artificial heating, cooling and lighting by improving natural ventilation and daylighting. Improved envelope insulation was combined with passive solar measures in a manner which should improve both the internal environment and the external appearance of the buildings. One of the winning designs is shown in fig. 6.1.

ISEI Contribution

In addition to the competition and in order to check the site's energy balance, the ISEI organised investigations into the heat losses from the district heating network (aerial infra-red survey: see fig. 6.2) and of ventilation heat losses from the buildings. A study was also made of the choice between centralised and decentralised CHP and the UK Building Research Centre was invited to carry out their BREEAM environmental assessment of a new building which was being constructed to an
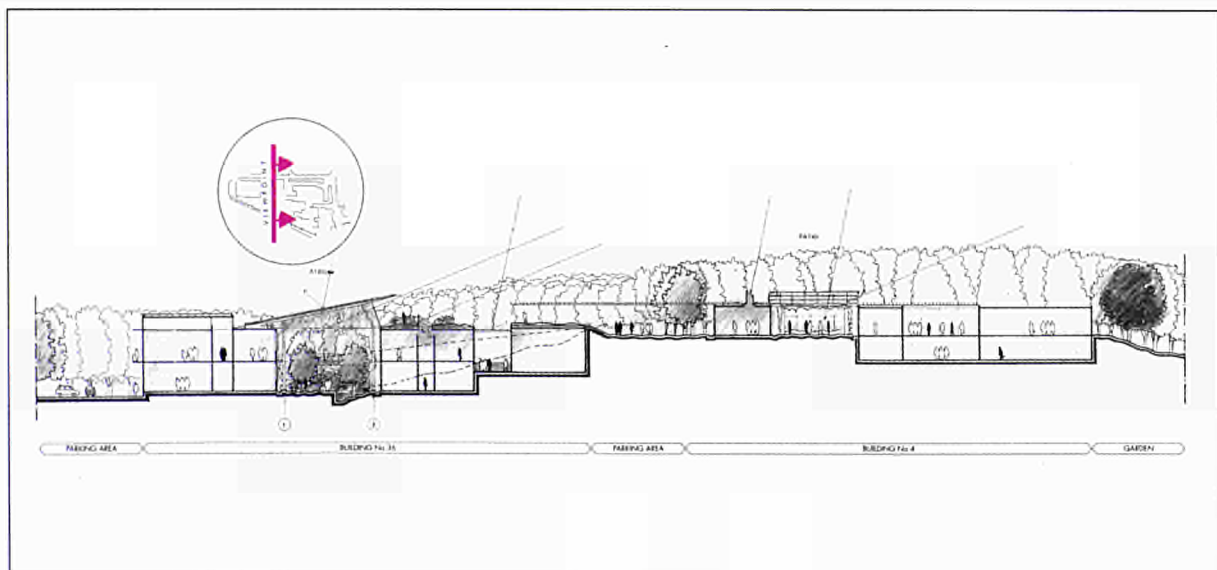
Fig. 6.1. A Winning Design for the Retrofitting of a Building

norms. These, it must be emphasised, are already very much better than those that were in force when most of the other buildings on the site were constructed. Much of this work is reviewed in reference /2/ and was also reported at a workshop on the environmental assessment of buildings /3/.

A Geographical Information System (GIS) is being set up to assist with the planning and analysis of the actions within the ECOCENTRE Ispra Project. In the GIS a number of thematic maps of the site, covering structural and ecological aspects are registered to the same coordinate system, and in some cases linked to databases of alphanumeric attribute data, e.g. buildings are linked to information on their construction characteristics, dimensions, energy use and occupancy. This facility can be

Fig. 6.2. Areal infra-red images of a part of the Ispra site.
The smaller image shows the result of fitting the original scan to the site plan using a Geographic Information System (GIS) currently under development for the Centre. Much of the original distortion is removed and the outlines of the plan are superimposed on the thermographic image.

improved ECOCENTRE standard. This was the first time that the BREEAM method had been applied outside Britain. *Fig. 6.3* shows how the estimated energy consumption of the building was progressively reduced, by the ECOCENTRE team, to under half of that which would be obtained by constructing to current Italian

used for the preparation of new thematic maps, planning, evaluation and monitoring of changes over time. The system developed so far includes two-dimensional information on roads, car-parks, buildings, planning zones, lakes and wooded areas. Infra-red photographs from an aerial survey of the site, carried out within the ECOCENTRE project, were obtained and digitised by scanning. The scanned images were imported to the GIS GRASS (Geographical Resources Analysis Support System) where it was possible to rectify them to coincide with the existing vector map of the site. The rectified images were then patched together to form a single raster image covering the whole site.

This has proved useful in the interpretation of the infra-red survey, and also for obtaining outlines of lakes and woods to update existing maps. A 3D model of the whole JRC site has also been developed for use in visualising the site and the impact of new construction.

Fig. 6.3. Bar Chart of Effect of Improved Conservation Measures on Predicted Energy Consumption of Building Under Construction

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7 WORK FOR THIRD PARTIES

Work under payment was carried-out for various European and non-European industrial and public Organisations. In the following are outlined the areas where this type of work has been addressed.

Photovoltaics

During the year the European Solar Test Laboratory (ESTI) completed the work for various manufacturers of photovoltaic devices (fig. 7.1). No new requests for module qualification testing were accepted, as the reduced personnel resources were concentrated to eliminate the backlog in qualification testing tasks. Experts from external companies were hired at the end of 1993 in order to restart full operation in 1994. Some new contracts were established for device calibration and in sales of the ESTI-Sensor.

Computer Aided Design and Engineering (CAD/CAE)

Industrial product assurance by 3D CAD/CAE techniques has been promoted, involving European industries into joint operations in order to enable more competitiveness. Marketing and professional consultancy efforts were continuously addressed to identify and to solve problems of the industrial partners. Modern ways of CAD/CAE modelling and structural analysis have been applied and engineering services have been fulfilled. An example was the design optimisation and certification agreed with a European transport industry. Several structural analyses have been performed for complex 3D transmission pieces under severe loading conditions. The safety margin of gear box pieces under fatigue loading conditions has been investigated by full 3D models (see figure 7.2). All the numerical modelling approaches can be validated experimentally in order to satisfy and overcome the severe civil transport certification normative.

Statistical Analysis of Industrial Components

The performance of selectric motors from different companies as included in the Component Event Data Bank (CEDB) have been compared in the frame of a contract with an utility company. Component specific

and mean failure rates have been produced. The work is being extended to the use of operational experience for evaluating alternative component maintenance policies on the basis of system availability.

Human Capability and Dependability

An industrial study on the methodologies for the analysis of the root causes of human errors has been carried-out. The main existing approaches to the cognitive modelling of operators and the different taxonomies for human errors have also been reviewed. Finally an ideal methodology for the root cause analysis problem has been worked out.

Robotics

Support was given to a partner of the ESPRIT project "Behavioral Learning: Combining Sensing and Action". The main objective of this work was the enhancement of robot programming and autonomy by introducing learning capabilities to close the loop between sensing and action. Robust subsymbolic (i.e., neural networks) and symbolic learning strategies were studied and developed which are useful to enhance robot performance and reliability as well as to support the acquisition of behaviour and skills. These techniques are being applied to real assembly, machining and navigation tasks. The contribution was related to navigation tasks and concerned the definition of a robot learning architecture, the acquisition of efficient reactive strategies through neural networks, as well as the interface between subsymbolic and symbolic knowledge.

Decision Support Systems

Requests for work on decision support systems (DSS) for environment management came from national public administrations. Two projects were defined during the year based on development and implementation of DSS with Geographic Information Systems capability and decision techniques modelling. DSS are articulated so as to be applied to both to single level territorial planning as well as right interventions. Extensive training Courses for local administrations are foreseen in the same framework. The corresponding contract signature is expected by the period of 1994.
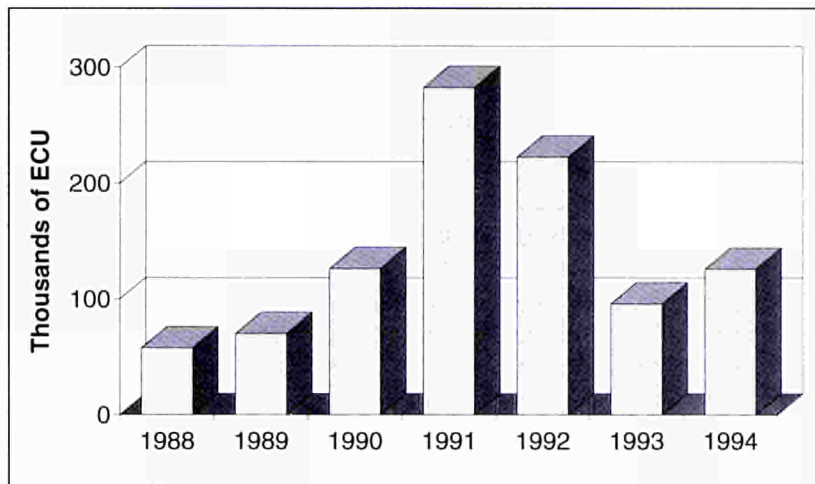
Fig. 7.1. Evolution of Third Party Work at ESTI

Reliability and Safety Analysis

The Computer System STARS (Software Tools for the Analysis of Reliability and Safety) methodology has been applied to two specific industrial cases.

In the first case, the objective of the contract was to develop a version for a power generating plant able to represent components and systems and to develop specific application modules for integration within STARS. In particular, a new modelling technique based on a functional decomposition of the industrial system has been developed. This functional model supports the automatic construction of the failure mode and effect analyses tables and it is at the basis of new algorithms for semi-automatic construction of event-trees.

In the second case, the STARS methodology, in particular the part related to the automatic construction of fault-trees, has been applied for the design of a car equipment. The contract-study, established with an industrial company, concentrated on the use of hierarchical description of functional specifications for qualitative risk assessment during the early stages of the design process.

Insurance Risk

A study is in progress to develop a model suitable for the evaluation of the insurance risk associated with the transport of dangerous goods. An report was issued containing a comparison on a world-wide scale of the risks from fixed installations and transport of the same type of substances.

Nuclear Safeguards and Fuel Cycle

A contract has been set-up between JRC-Ispra and a Japanese company, aiming at the development of a special sealing system for the PuO_2 casks used for transportation from France to Japan. This technique would be derived from the existing sealing-bolt technique. A feasibility study has been completed indicating a simple solution which could apply to close shock-absorbers (covers), without requesting any design modification.

An other contract has been established with a Canadian public Organisation in order to jointly develop the hardware and part of the software of a common reading system (called SIU "Seal Interface Unit") to be used in the near future by IAEA for inspection of both ARC Seals located on CANDU spent fuel stacks and MK4-r ultrasonic seals installed on BNFL spent fuel transport and storage containers.

Fig. 7.2. Gear box pieces under fatigue loading conditions (full 3D models)

8 TEST FACILITIES

ESTI, European Solar Test Installation

Passive Solar Test Cells

TELEMAC Laboratory

Computer Aided Engineering Laboratory

TESLA Laboratory

STRIKE Labotatory

LASER andf Applied Optics Laboratory

LaSCO, Laboratory for Containment and Surveillance

8 TEST FACILITIES

ESTI, European Solar Test Installation

The European Solar Test Installation at the Joint Research Centre of the European Commission is a "centre of excellence" in the field of solar energy. The major part of ESTI relates to solar photovoltaics, the direct conversion of sunlight into electrical energy.

ESTI's objectives are as follows:
- Provide pre-normative research and development on advanced photovoltaic conversion devices.
- Contribute scientifically to the harmonisation of European norms and standards for the Internal market.
- Offer calibration and qualification expertise to industrial and standards bodies taking advantage of JRC's neutrality and independence.

The test facilities at ESTI have been built up since 1977 and are now the most advanced of their kind in Europe. A large volume of data and experience has been accumulated over the years. The services available at ESTI for testing photovoltaic devices and systems serve several purposes:

- Qualification testing of commercial modules according to the relevant standards
- Tests on prototype devices as part of the development process
- Calibration of reference cells and pyranometers
- Acceptance tests of complete systems in the field
- Development of methods and equipment for the experimental assessment of photovoltaic technology.

Equipment Available

WEISS Light Simulator + Climatic Test Chamber
BOSCH Steady State Large Area Solar Simulator
SPECTROLAB Large Area Pulsed Solar Simulator
GLOBAL PHOTOVOLTAIC SPECIALISTS Large Area Pulsed Solar Simulator
PASAN Large Area Pulsed Solar Simulator
Mechanical Load Simulation System
Hail Impact Simulation System
Ultraviolet Radiation Unit
High Temperature / High Humidity Climatic Chamber
Thermal Cycling / Humidity Freeze Climatic Chamber
High Voltage Test System

Laser-Scanning Facility
GER Spectroradiometer
Semiconductor Spectroradiometer
CIR PMO6 Absolute Cavity Radiometers
Field Array Testers up to 100 kW.

Passive Solar Test Cells

The JRC site is part of the European facility for outdoor testing of building components. Four test cells are maintained in operation for experimental work. Modifications to the test cells are being prepared which should make future experiments faster and more accurate.

TELEMAC Laboratory

The TELEMAC Laboratory is dedicated to the computer simulation and reliability analysis of remote handling equipments and operations and to the validation of numerical simulation results by experiments on mockups.

Equipment Available

Software

An Advanced Computer Simulation System supporting the design of remote handling equipments. The support provided by the system is based on Computer simulation techniques: kinematic, dynamic and visual simulation.

Test Facility (ROBERTINO)

ROBERTINO is a large gantry robot for Validation Tests with four movements axes: X, Y, Z and a rotating head (fig. 8.1). The mechanical data are the following:
- Axis travel lengths: 3000 mm(x), 2200 mm(y), 6500 mm(z).
- Rotation axis travel: unlimited.
- Payload: 5000 kg.
- Maximum error in the all workspace: 1 mm.
- Repeatability: 0.2 mm.

On the computer simulator installed in a workstation, a file can be produced following the step size required by the user. Translated into the appropriate format the

commands are then sent to the control cabinet of the robot.

At project mock-ups of vessel and of in-vessel components of a fusion reactor are mounted in the facility testing. The vessel-sector mock-up is installed on a trolley that can be moved under the gantry robot or taken away from it for maintenance and improvement. An upper trolley, with a storage rack, is installed at the ground level.

Computer Aided Engineering Laboratory

Equipment Available

Software

CATIA Computer Aided Design System

3-D Visual Simulation packages for Robotics, (The commercial package KISMET and ISPRA-Simulator, a new 3D simulation package under development at JRC which will include dynamic simulation, collision detection and avoidance, etc.)

Fig. 8.1. TELEMAC Laboratory - ROBERTINO Facility for Validation Tests

ABAQUS code for static and dynamic, thermal, mechanical and instability analysis (linear and nonlinear domains) of structures models generated by CAD, applying 2D and 3D finite elements computational methodologies which includes computer graphics techniques.

P-Thermal code for complex thermal/thermohydraulic calculations.

ADAMS (Automatic Dynamic Analysis of Mechanical Systems) Computer Simulation programme for rigid bodies Kinematic and Dynamic Analysis.

CARIDDI, ELEKTRA, SCILLA and TRIFOU packages for 3D electromagnetic computations of eddy current and electromagnetic forces, including coupled magneto-mechanical effects.

FISPACT - Activation Code.

Different interface tools for CAD modelling (CATIA-PATRAN and MEDUSA-PATRAN), finite elements input/output transfer and animated visualisation of the results.

Hardware

Three Workstations IBM RISC/6000 used for CAD-CAE activities.

A graphic standalone Workstation CDC-CYBER 910B-731 for Simulation in the field of Teleoperation, connected with video- recorder to animate the results on video-tape.

Three Workstations SGI R4000 for structural analysis in electro-magnetic and mechanics.

A Workstation SGI R4400 with EXTREME Graphic Board for RH Simulation.

Two TEKTRONIX Workstations.

A SUN SPARC 10 Workstation.

Various PCs. The above workstones and the PCs are connected with Ethernet Network.

TESLA Laboratory

The TESLA LABORATORY is dedicated to the Modelling, Analysis, Validation & Design in Transient Electro-magnetic & Thermomechanics, with the objective of structural integrity assessment in transient conditions during accidental events in fusion reactors.

Equipment Available

Software

The 3D transient electromagnetic codes (CARIDDI, ELEKTRA, SCILLA, TRIFOU) combined with nonlinear stress analysis programmes (ABAQUS, ADINA). Different interface tools for CAD modelling (CATIA, MEDUSA), finite element pre- and post- processing (PATRAN, TRINACRIA) and animated visualisation of the results (Computer Graphics) are included.

Hardware

ELBA (Electromagnetic Basic Experimental) is an experimental test-rig reproducing transient conditions for the simulation of reference plasma disruption scenarios in fusion reactors (see *fig. 8.2*).
The instrumentation is based on laser measurement techniques able to investigate on the time dependent measurements and on the precision management in magnetic fields.

STRIKE   Laboratory

STRIKE (Structural Reliability Investigation by Knowledge Engineering) is a fully equipped laboratory constituted by two experimental facilities:

– Vessel test Rig where it is possible to perform fully automatic, unsupervised long running fatigue tests (pressure, vibrations, flexural) and burst tests.

– Thermal Shock where it is possible to perform fully automatic, unsupervised tests of repeated thermal shocks or thermal fatigue.

Equipment Available

– Data collecting unit

– Automatic scanning monitoring of critical regions by Ultrasonic method

– Continuous monitoring by multichannel Acoustic Emission system

– Laser holographic interferometric system for experimental strain analysis

• – System for residual stress measurement

– Systems for standard measurements: strain, temperature, pressure, water chemistry, water flow rate etc.

The experimentation can be supported by groups performing: FEM stress analysis, knowledge engineering application, development of mathematical models, reliability assessment, lifetime prediction, fracture mechanics.
The overall facility is particularly suited for standardisation, normalisation, comparison and benchmarking activities in the field of structure monitoring, structural reliability assessment and code validation.

LASER and Applied Optics Laboratory

This laboratory is specialised in the use and development of optical (both coherent and non coherent light) techniques for diagnostics. These techniques can be used for two kinds of measurement:

– Detection and measurement of microdeformations, both stationary (or slowly changing) and dynamic (even very fast); vibration and modal analysis of structures are included in this field; the resolution achieved is of the order of fraction of μm.
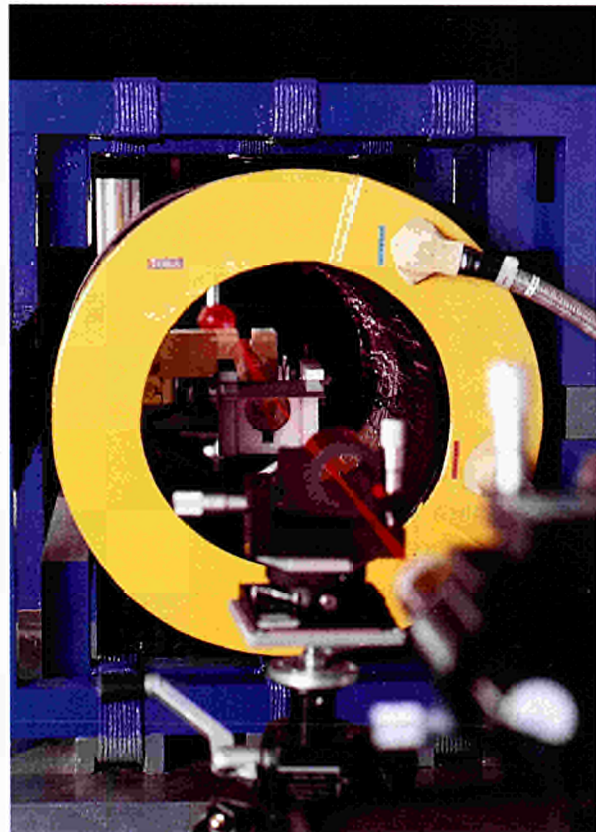
Fig. 8.2. TESLA Laboratory - ELBA Test-rig

– Contouring and surface profilometry, with resolution ranging from 10 μm to few mm, depending on the technique chosen.

The following techniques are available in the laboratory:
– double exposure laser holographic interferometry
– real time interferometry
– ESPI (Electronic Speckle Pattern Interferometry)
– endoscopic holography and interferometry (by optical fibres)
– optical correlation measurement for analysis of surface alterations
– line projection and fringe projection profilometry
– digital photogrammetry
– coherence radar

All these techniques are full field, non contact, remotely applied. They can be applied on any kind of materials and supply results in digital form stored on the mass memory of PCs or workstations for further elaboration by CAD codes, finite element analysis, graphical animation and so on.

Equipment Available

– continuous wave lasers of various power levels and different walve lengths
– pulse wave lasers
– holocamera system
– thermoplastic film recording system
– holographic plates recording system
– ESPI system
– optical fibres holographic endoscopes
– classical as well as CCD cameras
– video recorders
– digital photogrammetric system
– laser system for 3D scanning of objects
– image processing systems etc.

The application range is very high namely:
– structural integrity monitoring
– modal analysis
– defect detection in composite material plates
– detection of microdefects and discontinuities in works of art (frescoes, paintings, etc.)
– periodic inspection of aircraft
– stone material characterisation
– qualification on musical instruments.

LaSCo, Laboratory for Containment and Surveillance

The LaSCo laboratory has been established with the following objectives:
– performance assessment of Containment and Surveillance (S/C) devices and systems
– demonstration and development of effective procedures for proper use of C/S in specific applications
– training of users for the application of different C/S techniques.

Equipment Available

In order to qualify newly developed components or existing ones, to establish performance profiles and the fitness for the purpose, LaSCo has been equipped with several devices which are located in two zones: a Thermal Test Area (*figure 8.3*), and a Mechanical Test Area (*figure 8.4*).

Thermal Test Area

Two climatic chambers have been installed in LaSCo's Thermal Test Area:

– A small one with an inside volume of 30 litres operating in a regulated temperature range of -30°C to +150°C. This chamber is typically used for testing of small components such as seals, electronic cards, video cameras...
– A second larger chamber is also installed with an internal volume of 480 litres operating in the same temperature range but which is also able to perform humidity tests in a range of 20% to 98% RH, or to combine temperature and humidity complex cycles. This chamber permits testing of entire systems such as entire surveillance systems, acquisition units...

Both chambers are driven by a computer using a Lab Window software especially developed for the laboratory applications, which permits operation of the climatic chambers at fixed temperatures and conducting complex thermal cycles, in order to simulate real thermal and humidity conditions, occurring during storage, transportation and operation of equipment (when they are known), or thermal and humidity ones coming from standard testing procedures such as MIL std 810 E (when the real ones are unavailable).

For long term testing of components under real atmospheric conditions (hot, cold, rain, sand, dust, solar radiation...), two small boxes were installed outside LaSCo and equipped with various temperature and humidity sensors.

1- Climatic chamber for temperature tests (volume: 30 l, T ° range: -30°C to 150°C)
2- Climatic chamber for temperature and humidity tests (volume: 480 l, T ° range: -30°C to 150 °C, H % range: 20 to 98 %)
3- Furnace for high temperature tests (up to 250 °C)
4- Thermostatic bath for watertightness tests of small components
5- Main acquisition unit (for T °C and H % sensors)
6- Main control unit (PC 386/40 Mhz - 2 National Instruments I/O boards)
7- Sensor Interface unit
8- Modems
9- External box covered (for long term tests)
10- External box uncovered (for long term tests under real atmospheric conditions; rain, sun, snow...)
A-B-C-D-E-F-G : Temperature, humidity and atmospheric pressure sensors

Fig. 8.3. Thermal and humidity tests in LaSCo

1- Vibration pots (capacity = 35 Kgs at 10 g.).
2- Vibration pot (capacity = 2.5 Kgs at 19 g.).
3- Main power unit.
4- Main control unit for sine and random vibrations, and shock tests.
5- Free fall machine (for drops up to 3 m.).
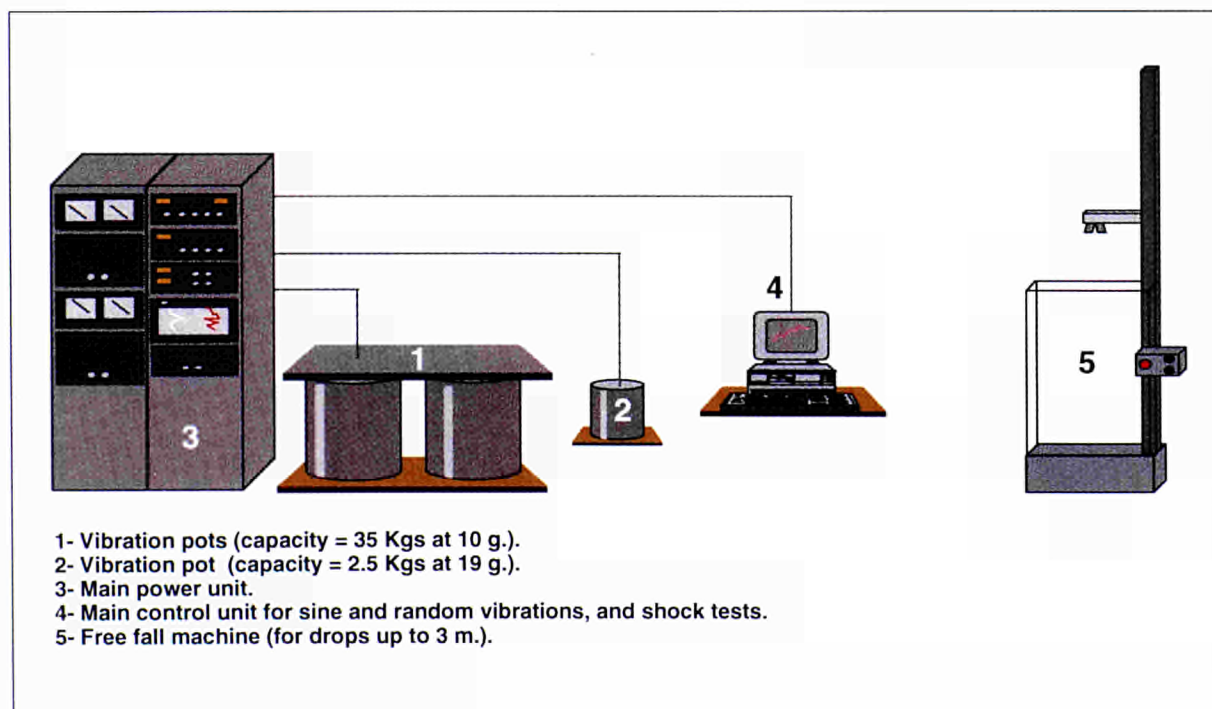
Fig. 8.4. Mechanical Tests in LaSCo

Mechanical Test Area

The various mechanical stresses which may appear during the life time of components are simulated on vibration pots and a free fall machine.

In order to test components under vibrations, generated for instance during transportation , LaSCo is equipped with a small vibration unit with a capacity of vibrating 2 Kg at 19 g's in a frequency range of 10 to 6000 Hz. This unit is used for testing components such as seals, electronic cards, video cameras.

A second vibration unit is also available, with a bigger capacity of about 30 Kg at 9 g's: entire systems may then be tested.

Both vibrations systems are driven by a Gen Rad calculator in order to generate classic (sinus) and complex vibration profiles (random), and also shock waves of different shapes, amplitudes and durations, which permits to be as close as possible to the real transport vibration and shock profiles or to the ones given by the various international standards.

In order to determine if the test item is capable of withstanding the transit drops normally induced by loading and unloading, LaSCo is equipped with a free fall machine which permits drops of components up to a height of 3 meters. The drop surface is made of plywood (according to standard MIL- std-810 E), but other surfaces are available, depending on the use of the component. (i.e. concrete, steel...).

9 ANNEX

List of Publications

List of Figures

LIST OF PUBLICATIONS

Industrial Hazards

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