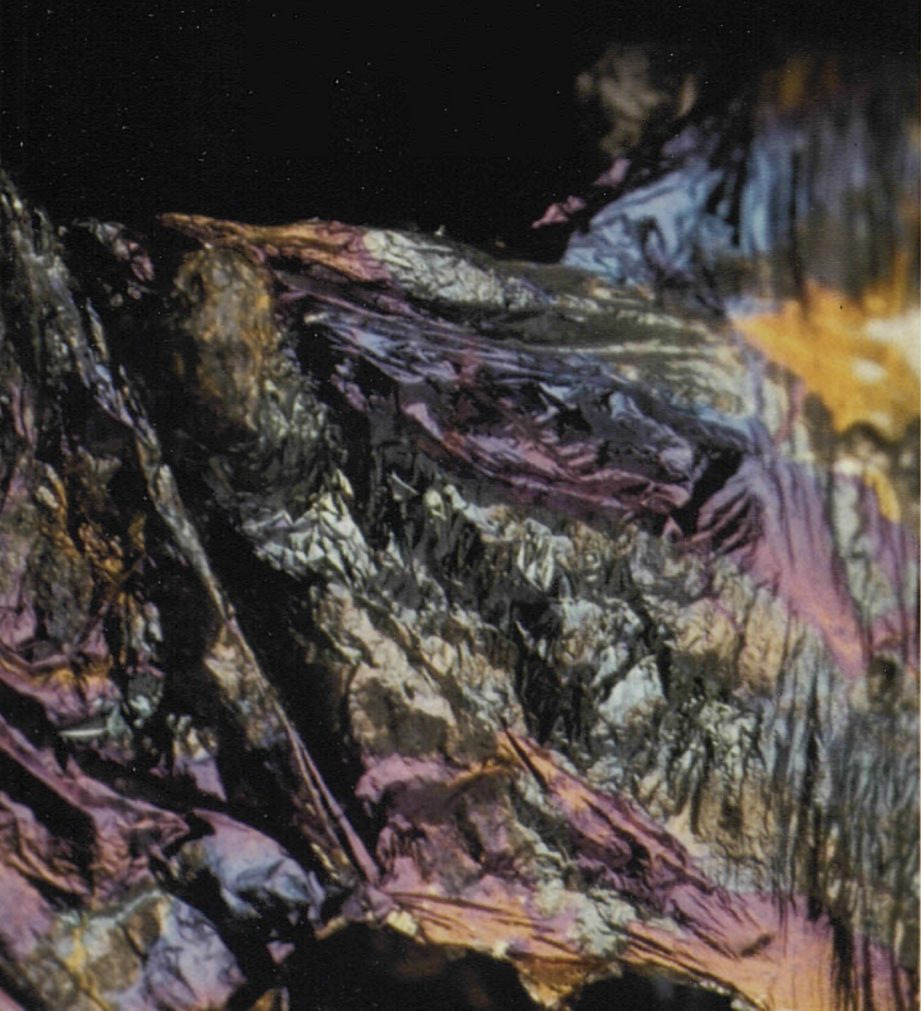




**Institute for Systems,
Informatics and Safety**



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**Institute for Systems,
Informatics and Safety**

Annual Report 96



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In 1996, I set up the Institute for Systems, Informatics and Safety to be the European Commission's centre of expertise in

- the multidisciplinary analysis of industrial, socio-technical and environmental systems;
- the innovative application of information and communication technologies;
- the science and technology of safety management.

Its main task is to support policy initiatives of the European Union which require access to this neutral and independent technical expertise.

Today, the role of scientists and engineers in constructing solutions for complex societal issues is increasingly important. The ISIS annual report highlights examples ranging from fraud prevention by electronic animal identification to the definition of standards for the earthquake proof design of buildings. The chapter on cultural heritage protection presents a combination of technologies applied to find solutions in a field which is particularly important for the promotion of many European regions.

I encourage readers who find subjects of interest amongst the themes presented in this annual report to contact the Institute for any further information they may require.

Edith CRESSON

Member of the Commission

responsible for research, innovation, education, training and youth

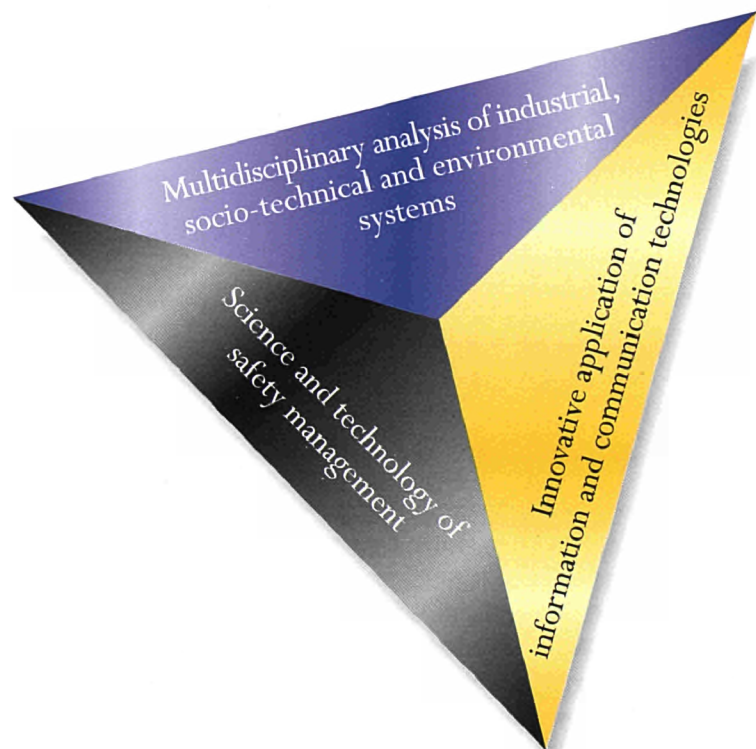
Mission

The Institute for Systems, Informatics and Safety (ISIS) is the JRC impartial centre of expertise in:

- the multidisciplinary analysis of industrial, socio-technical and environmental systems;
- the innovative application of information and communication technologies;
- the science and technology of safety management.

ISIS develops and applies its expertise and unique test facilities in a range of fields, including:

- Nuclear safety and safeguarding of nuclear materials
- Industrial and transport safety
- Seismic protection of buildings and civil engineering works
- Natural resource and environmental management
- Preservation of cultural heritage
- Fraud detection and countermeasures
- Security and reliability of information systems
- Medical imaging and health
- Pharmaceutical information and communication systems



Introduction

The Council Conclusion on the Role of the JRC, 26 April 1994, set goals for the competitive work of 22% for the non-nuclear framework programme and 10% for the nuclear programme. Given the balance of activities in ISIS, this corresponds to an average of about 15%.

I am pleased to report that we have met this goal. The Institute was created on 6 March 1996 to integrate the activities for systems, information and safety technologies. With this combination we can respond faster to new applications and customer demands. The competitive activities performed in the Institute have more than doubled during the course of 1996, reaching 17% on average. New contracts signed confirm a continuation of the positive trend.

Competitive support to the Commission has shown the strongest increase. This is in line with the mission of the JRC. Main tasks are to provide scientific and technical support for legislative initiatives and for the implementation of policies. Our advantages in this market are strict neutrality and scientific know-how. In fact, the total proportion of support activities in the Institute is now about 45%. Apart from the competitive work, this also includes the institutional support, e.g. in nuclear safeguards, antifraud, animal identification, and major accident reporting. This evolution from our traditional research activities has required an increase in the attention to monitoring quality and performance indicators, and responsiveness to customer requirements.

The second largest increase of activity was in collaborative research. ISIS' scientists were involved in 39 shared-cost action projects, each with several partners in different Member States. These projects, together with projects supported by DG XIII for technology transfer, are an important means to interface with European industries. Shared-cost action research also helps to build our long term base of technical expertise. In this respect, it is important that several projects have started in completely new areas of application. Institutional research is also becoming increasingly collaborative in nature, with a large number of international networks. To support further growth of expertise, the Institute has put great care to select and support its projects for exploratory research.

In 1996, work for third parties has remained at a constant level as compared to 1995; but it will be given increased attention in 1997. This is part of a JRC wide initiative to improve intellectual property protection and to look for more opportunities to license technologies and transfer them to industry.

This annual report presents several themes with the results achieved. It shows how different expertises and skills contribute in each of these applications. A lower emphasis is given to the internal structure of the Institute and to the different program lines. We also refer to a list of competencies from the ISIS "who does what" guide. This is regularly updated and available on request.

The principal asset of the Institute is its 381 staff. I would like to take this opportunity of thanking each of them for their contributions in the Institute's successful first year of existence.

D.R. Wilkinson
Director
Institute for Systems, Informatics and Safety



Contents

Introduction	3
1. Decision support systems for environmental management	6
2. Detection of fraud and countermeasures	12
3. Information and telematics technologies	14
4. Safe and sustainable transport	20
5. Cultural heritage protection	26
6. Earthquake engineering and dynamics of structures	32
7. Industrial processes and clean technology	40
8. Nuclear safety (severe accidents)	50
9. Safeguards	60
10. Remote handling	72
11. Services to the Commission	74
12. Regional projects	78
Exploratory research	82
Technology transfer	86
Staff	89
Finances	90

1

Decision support systems for environmental management

author: P. Hastrup



Decision support systems (DSS) help policy-makers to take action. These systems exist in various forms and can be applied to a large number of decision situations.

Any decision support system requires access to data, models and tools such as geographical information systems (GIS) to perform an analysis of the possible decision options in a given situation. The topics presented in this section show how these systems can be applied to environmental management of coastal zones and wetlands.

Figure 1.1: Working with a networked decision support system for environmental management. The aim is to be able to actively work on the same project with partners in different geographical locations.

Decision Support Systems for Integrating Coastal Zone Management (ICZM)

authors: M. Parruccini, K. Fabbri

Coastal zones represent one of the most dynamic and complex natural environments in which human activity, ecology, economy and geomorphology interact. As coastal zones are particularly vulnerable areas in most parts of the world, a better understanding of the inter-relationships between natural and socio-economic variables is essential for efficient and sustainable coastal zone management. A DSS would help achieve this task. The development of such a tool requires a well-structured database design for ICZM and multi-criteria decision-making analysis (MCDA), the realistic development of scenarios and a multitude of primary and intermediate data layers. The availability of intermediate products is essential to make evaluations transparent and recursive, especially for re-evaluation of mitigation measures.

A model, called the "triple S", short for Screening, Scoping and Scanning, is being built around the DSS and represents an integrated methodology for the sustainable development of coastal zones. The SSS model uses a combination of policy and stakeholder analysis, spatial data modelling (GIS), multi-criteria and conflict analysis, and a graphical user interface. It is used as a tool for evaluating the best management strategies from an integrated systems approach (as opposed to a project approach). It attempts to motivate discussion and awareness amongst policy makers and coastal zone managers and promotes greater transparency in the decision-making process. In brief, the Screening module deals with the data, the Scoping module considers the stakeholders, and the Scanning module performs the evaluation of management strategies.

The Screening module consists of the knowledge base for the SSS Model. Once a study area is defined and relevant data collected, a database is designed that is suitable for geographic analysis in a GIS environment. The data and database structure is site-specific and therefore depends on the area and its prevailing problems. The data is then organised in general areas of economic activity (tourism, environment, industry, fishing, etc.), and represented graphically in a stock-and-flow dynamic simulation model.

This allows for a schematic representation of cause and effect relationships. The logical relationships in this highly interactive sub-model are constructed together with local experts in a multi-disciplinary context (part of the Scoping Module). The result is a knowledge base of linkages and interactions among variables (data) that are subsequently integrated (represented) in the GIS environment. These linkages are the basis for the selection of environmental indicators, and the understanding of cause and effect relationships pertaining to proposed development strategies for ICZM (Scanning module).

The Scoping module defines the stakeholders, the problems and lastly the objectives, policies and legislation related to the ICZM of the area under discussion. In addition to building the knowledge-base of the SSS model, each stakeholder (interest group) is asked to complete a questionnaire to determine their attitude towards environmental issues in general and more specifically to coastal zone management, as well as their relative influence in society and in the decision making process. Interaction with stakeholders leads to the definition of ICZM strategies (alternatives) which are then evaluated in the Scanning module. The Scoping module is vital for the definition of links between environmental and economic sectors. In recent years much work has been done in the area of public participation in ICZM.

The Scanning Module performs the evaluation of proposed development strategies. Once the strategies have been defined, socio-economic and environmental indicators are assessed for each alternative. Where relevant, indicators of a spatial nature are encouraged (i.e.: water quality distribution). Conflict analysis is also performed to assess the compatibility between stakeholders and their relative influence in their local setting. The results of the conflict analysis are then used to determine the actual feasibility of the best development strategies singled out by the spatial MCDA. The alternatives, along with their impacts are then displayed graphically.

In addition to the three core modules, a graphical user-interface allows the policy-maker to travel through the decisional process by linking the software components, the algorithms and the data in a comprehensive manner. An application to the Brest Bay (France) in the framework of the Eureka Project ADAGE (Aide à la Décision en Aménagement et Gestion de l'Environnement, a project for integrated environmental assessment) has started.

Modelling of Wetlands and Wetland Management

authors: I. Shepherd, D. Al-Khudhairi

The principal objective of the present research has been to develop systems that can both assist in the appraisal of ecosystem management options and study the impact on the environment of a range of human-induced actions. A major part of the research effort has concentrated on protected areas, in particular wetlands. These research efforts have been carried out in collaboration with local institutions - the Wetland Research Unit at University College London (UCL) in England and the Greek Biotope Wetland Centre (EKBY) in Greece and the Danish Hydraulic Institute. Two very different wetland systems in terms of climate, hydrological patterns and social-economic context were selected for investigation and for demonstrating the applicability of these methods: the North Kent Grazing Marshes and former Lake Karla.

The North Kent (Southeast) marshes had been subjected to extensive drainage during the period 1960-1982 in order to convert them into arable land. However as a result of drain failures and structural deterioration of soil surface during arable cropping, widespread ponding of water at the surface has occurred and with consequent crop failure. The present hydrological management project includes identifying the water levels and practices necessary to achieve the objectives of many interest groups including National Rivers Authority, English Nature, the Internal Drainage Board, National Nature Reserve and farmers.

The Karla (Thessaly, Greece) valley was once a lake that provided income for up to 1000 fishermen, grazing land for tens of thousands of animals, a breeding and international bird migration site. In spite of this, the lake was drained for agricultural purposes and the river Pinios was embanked preventing floodwaters flowing into the lake. Recent practices also pump groundwater for irrigation and allow effluents from local industries and fertilisers to pollute the drainage channels and consequently the Pagasilikos Gulf. An approach capable of modelling a variety of remedial solutions and to assist in developing appropriate management strategies for this natural resource is therefore required.

There are two challenges in producing a hydrological model of a wetland. Firstly because of their low

perceived commercial value little data has been collected and secondly it is the storage, rather than the flow, of water that dominates the water balance equation. The ISIS approach is based on the deterministic, physically based hydrological model, MikeShe, from the Danish Hydraulic Institute. In the case of the North Kent Grazing Marshes, a calibrated and validated model of an underdrained subcatchment, Bells Creek, has been produced. In addition, the hydrological consequences of hypothetically removing the existing underdrainage

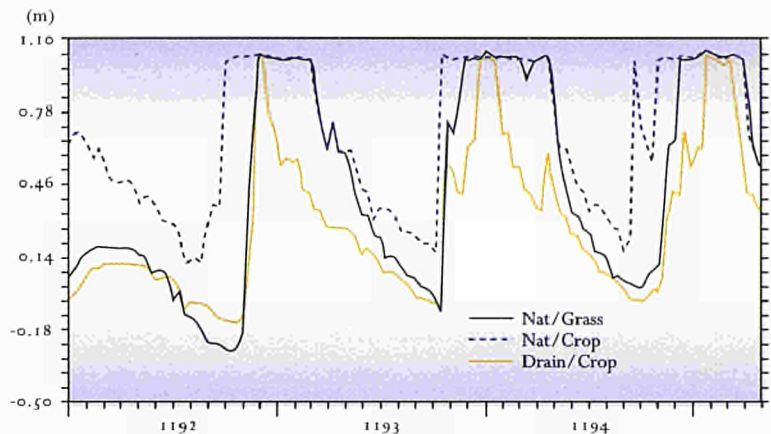


Figure 1.2: Head Elevations in a Lowland Section. The figure shows that removing the underdrainage system but maintaining the current land-use (crop) does not significantly effect the minimum (summer) nor the maximum (winter) watertable level. However, the soil remains saturated for longer periods during the wet winter months (November-March). Removing the underdrainage and introducing a different land-use (grass), reduces the soil-water buffer zone created by installing the drainage system.

and changing the land use from arable crop (Barley) to permanent pasture has been investigated. The results shown in Figure 1.2 indicate that removing the drainage system but maintaining the current land use may lead to reduced crop yield due to the problem of prolonged water-logging. By combining the removal of the drainage system with a change in land-use, from Barley to permanent pasture, the hydrological behaviour of the former undrained, natural, grasslands is successfully reproduced.

In the case of the Karla test site, much of the initial effort has been on gathering various types of data, ranging from meteorological to topography, and processing them in a format suitable for both the GIS and MikeShe. A Karla model has been set up and is now undergoing rigorous calibration; the simulated results compare well with observed ones. Other results such as simulated discharge flows and annual water balance indicate that the calibration process is proceeding well.

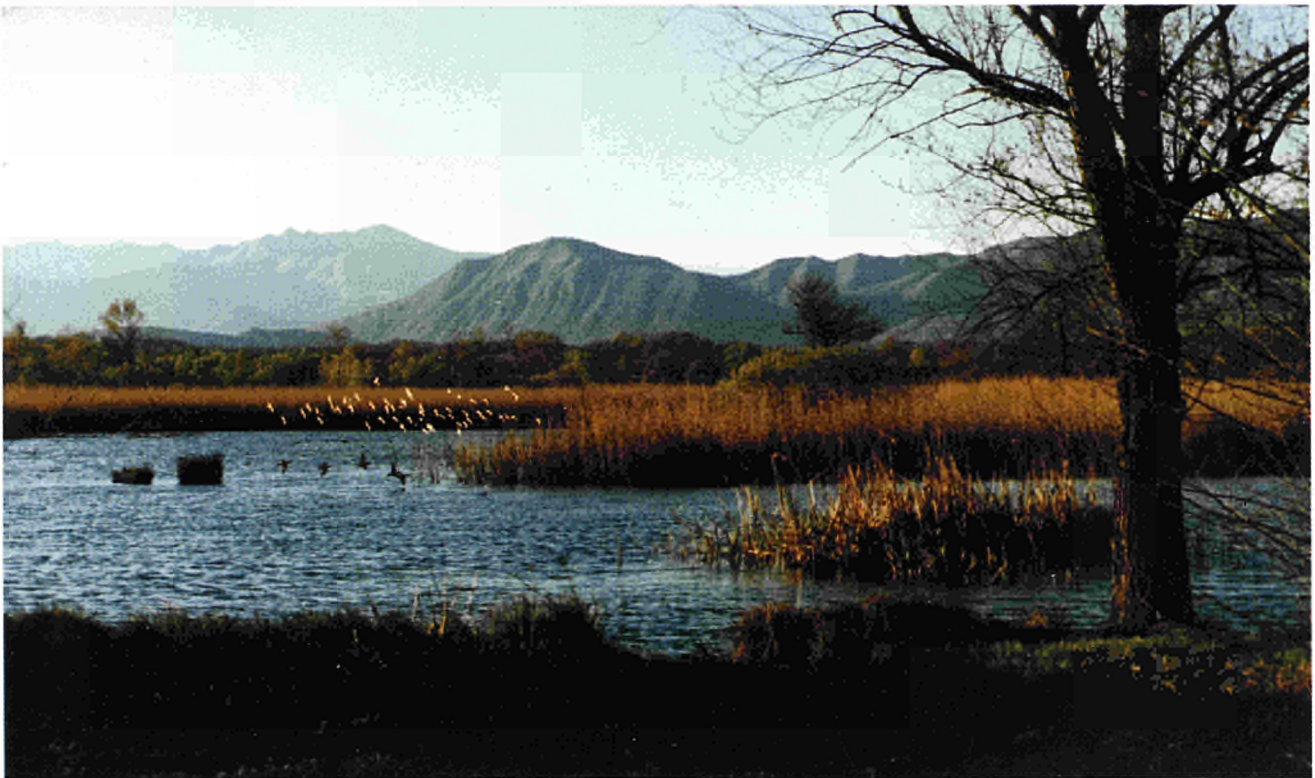


Figure 1.3: ISIS has been carrying out wetland modelling and management since 1994. The "Palude di Brabbia" is a protected wetland near the JRC (Ispra, Italy). Until recently wetlands were often equated with wastelands. However, this view is being overturned and there is a growing awareness of the important ecological and hydrological benefits. Throughout Europe the area covered by wetlands has decreased and this has led to their being protected by national, European and international legislation.

The unsaturated zone in the selected test sites is important. In Karla it extends for 50 metres. In order to understand whether MikeShe's neglect of lateral flow in this region was justified, a two-dimensional finite element model, the WHATFEM computer code, has been developed. The model results showed excellent agreement with published results and the model is now capable of simulating flow in variably saturated soils in two dimensions. The model has been applied to the Karla site and compared to MikeShe. The results show that horizontal flow in the unsaturated zone even in poorly conducting soils can be too significant to ignore. An extension of the method to handle pollution transport in one dimension has also been made. The results obtained were stable numerically and showed good agreement with published results. An innovative technique, called SHYLOC (System

for HYdrology using Land Observation for model Calibration), allows historic monitoring of wetlands and uses remote sensing data for the determination of surface water. The method combines Landsat-TM images with ditch positions obtained from maps. It derives "Ditch Indices" and measures features (e.g. ditch width) that are much smaller than an image pixel size of 30 metres. The method has been designed to run with the minimum of manual intervention; the user only needs to import a raster image into a GIS containing the stream positions and delineate the boundary surrounding the area of interest. All the statistics are calculated automatically. The method has been applied to the North Kent Marshes test site. The results show that sub-pixel size ditches can be detected and the signals obtained from them can even be used in a feedback loop to improve the accuracy of the image geo-referencing

- 1.1 Al-Khudhairi D. - *Modelling the hydrology of an underdrained catchment in the North Kent Marshes: Validation calculations with the MikeShe code* - JRC Technical Note No. I.93.73, May, 1996.
- 1.2 Al-Khudhairi D., J. Thompson, I. Shepherd - *Modelling the hydrology of the North Kent Grazing Marshes using the Mike She Code* - Intecol's V International Wetlands Conference - Wetlands for the future, Perth, Australia, September 1996
- 1.3 Nguyen H. - *A Petrov-Galerkin finite element scheme for one-dimensional water flow and solute transport in the unsaturated zone* - Computational Methods in Water Resources XI. Ed. Aldama et al., Computational Mechanics Publications Southampton, Boston 1996.
- 1.4 Shepherd I. - *Measuring surface water storage in the North Kent Marshes with Landsat-TM images* - JRC Technical Note No. I.96.96, June 1996

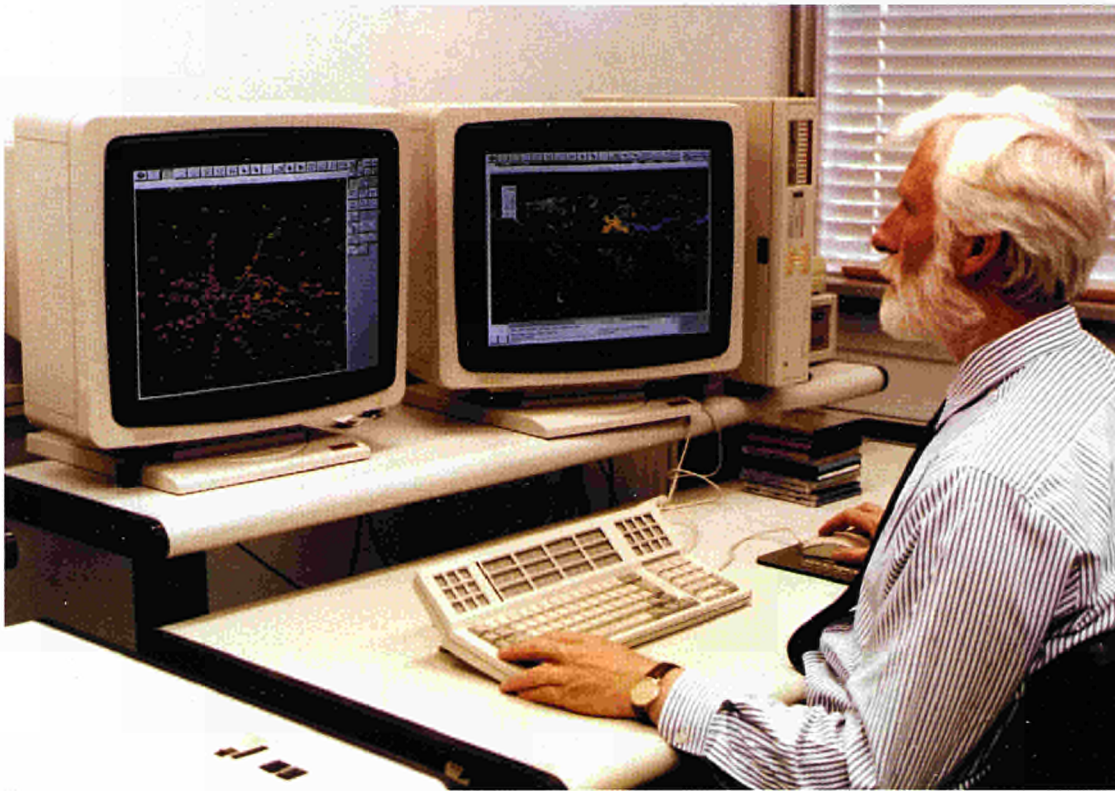


Figure 1.4: The geographic information system (GIS) is a very useful tool for general applications. In this case, for example, decision support systems are based on data fusion from different sources such as earthquake data, boundaries and urban areas GIS.

Geographic Information Systems on the WWW

authors: C. Boehner, R. Peckham

Geographical data are stored in a vast number of data servers all over the world, mainly structured by specific types of database software known as geographic information systems (GIS). The capture, treatment, storing, elaboration and interpretation of this kind of data is very cost intensive and requires specific expertise and technical equipment. To increase the use of geographical data by users who do not have access to sophisticated GIS systems, a gateway linking a number of different GIS systems to the WWW has been developed by this Institute. The query pages of the current version are still static and are generated using a scripting language. Future versions will be created using a Graphic User Interface (GUI), automatically interpreting a data set content module.

To date, three data sets have been implemented: (1) North Kent (Isle of Sheppey) on GRASS; (2) Florence Municipality data set on ARC/INFO™ Version 6.1 and (3) the European Soils database (Figure 1.5) on ARC/INFO™ Version 7.0 (made available for testing by the Space Applications

Institute of the JRC). The Intergraph data set implementation is still under construction. For each of these data sets there is one overlay query page available. The pages linked to limited access are generated on the flow after the relative access mode check.

The GIS-WWW Gateway is a valid method of approaching geographic information stored on GIS for data sharing, for comparing data from independent platforms and for enabling non-experts to use GIS data. It will therefore continue to be developed in coming years.

http://taws08.jrc.it/gis-gateway/gateway_main.html.

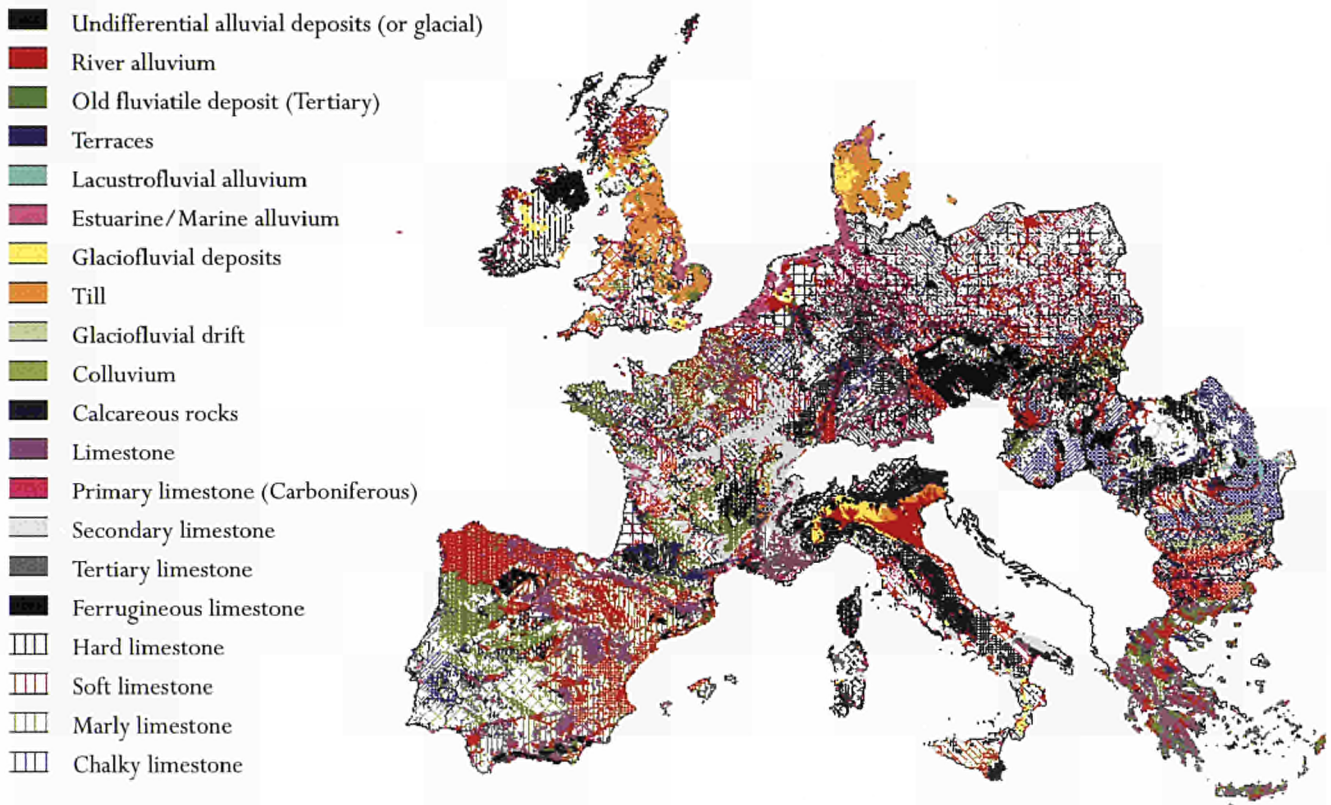


Figure 1.5: WWW interface to the European Soils' Database from JRC's Space Applications Institute. The GIS-WWW Gateway developed by ISIS allows access to remote GIS from any workstation or PC.

Complex System Modelling for Decision Support

author: D. Sarianni

In 1996, the development and validation of innovative modelling approaches of urban areas started. It is based on the analysis and forecasting of the far-from-equilibrium behaviour of interactive economic, environmental, energy, and transport systems. The output of this activity is an improved ability of predicting the catastrophe thresholds in the state space of each of these systems. This would lead to integrated assessment of innovative technological development and the consequent policy measures. This complex system-modelling tool is also being developed as a didactic instrument to support collective decision making and communication of ideas among urban actors, ranging from citizens to political representatives.

The key question to be answered by this modelling approach on a methodological level is how do the rules employed by individual agents to arrive at their decisions combine to generate large-scale,

global patterns in an urban environment. The main features characterising complex, adaptive systems such as the different organisational and behavioural aspects of a city (population dynamics, economic transactions, environmental quality, energy flow, transport) are:

- medium number of agents; traditional statistical techniques would fail to describe the behavioural patterns of the system;
- intelligent and adaptive agents; in general real-life agents decide based on specific set of rules, but they can modify these rules on the basis of new information, or even generate new rules;
- local information; at the most, an agent receives information from a relatively small subset of total population regarding their response to system dynamics.

A "virtual laboratory" is being built where simulation experiments are run in order to provide the intuitive understanding required to create a formal mathematical format for the comprehensive description of such phenomena. Only by seeing where interesting patterns emerge can we hope to invent appropriate mathematical frameworks that allow the description and possibly prediction of such patterns.

<http://stss-www.jrc.it/people/federico/index.html>

2 Detection of fraud and countermeasures

author: T. Barbas



ISIS provides scientific and technical support to UCLAF (the Commission's antifraud Directorate in the Secretariat General) and to DGVI (Agriculture) to detect fraud and countermeasures. For 1996, the Institute's activities in this area included:

- *data and risk analysis applied to irregularities and fraud cases reported to the Commission by member state authorities;*
- *the development of new information infrastructures to support UCLAF;*
- *animal tagging technology to help prevent several types of fraud related to live animals;*
- *olive oil tank measurement techniques to help provide national inspectors with a means of detecting fraud related to olive oil storage declarations.*

Figure 2.1: Mass and volume measurement inspection techniques, optimised in the TAME Laboratory have been applied to olive oil storage tanks. The methods were demonstrated in-field at an olive oil tank storage facility in Fasano, near Brindisi (Southern Italy). The dedicated system, which involved lowering a measurement probe in a controlled manner into the tank, showed that it was feasible to detect the difference between two olive oils via density difference. Aim of this activity, performed on behalf of DGVI, is to provide national inspectors with a means of detecting fraud in the case of claims for certain subsidies related to olive storage declarations. (author: B. Hunt)

Data and Risk Analysis

author: S. Arsenis

Work in data and risk analysis focused on estimating the proportion of claims defrauded and detecting similarities among frauds communicated to the Commission by Member State authorities. The extent of fraud against payments by the Community is not measured in absolute terms but rather as the amount of fraudulent claims paid as a proportion of total claims paid for a given budget category - as defined by budget lines. A non-parametric procedure has been developed to highlight the fraudulent transactions executed against budget lines that are particularly costly.

New Information Infrastructures

author: T. Barbas

Work on new information infrastructures for UCLAF included a study for an integrated fraud case information system, a data mining software survey and an inventory of fraud-related communications between the Member States and the Commission.

A feasibility study for the new, integrated fraud case information system of UCLAF was completed. A survey of techniques and software for investigations and analysis was also completed. The final report discusses data mining techniques and their main objective (information extraction from large amounts of raw data), describes a number of commercial software products in this area, and recommends further actions. The report also includes the findings of two case studies involving the use of data sources, data mining methods, database software for pre-processing data and network analysis software for visualisation and analysis. An inventory of information flows between the Commission and Member State authorities, of potential interest to antifraud, was completed. The study identified information that is exchanged between Member States and the Commission, as well as the networks used to communicate the information. The report includes an annotated list of relevant systems and a description of information and communication infrastructures

of the DGs. The recommendations include ways to harmonise the fraud report communication traffic across different domains.

New studies included: i) a preliminary study of design and implementation issues associated with the introduction of data warehousing technology to serve the UCLAF community of users; and ii) a project to facilitate access to relevant information resources external to UCLAF (project IIIMS: Integrated Intelligence and Information Management System). Work is underway to build a prototype application that indexes a set of databases with respect to a detailed thematic classification of the antifraud domain.

Animal Tagging

author: C. Korn

The IDEA project (Identification Electronique des Animaux) is a pilot demonstration project for DG VI (Agriculture) to prevent fraud and to respond



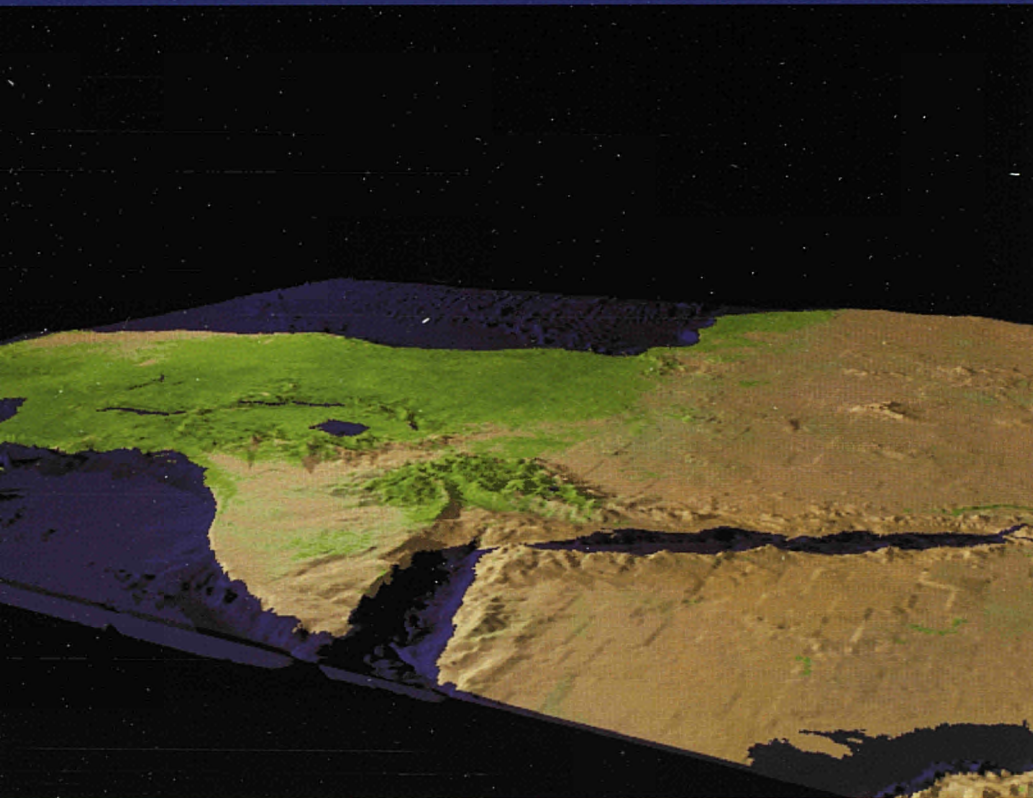
to specific problems having to do with the registration, identification and management of individual livestock. IDEA will demonstrate the electronic identification of one million farm animals (bovines, sheep, and goats) in different EU countries using passive transponders. The role of ISIS is to qualify the various electronic tagging techniques and to operate the database. In addition, ISIS provides the accounting methodologies developed for safeguarding accountancy.

In July 1996, the project was presented to representatives of all 15 EU Member States. Eight companies sent their components and systems to ISIS for testing in the TEMPEST facility (Thermal, Mechanical and Physical Equipment Stress Testing). The database information system was designed; it will include data acquisition, transmission, and storage and evaluation.

3

Information and telematics technologies

author: M. Wilkens



The impact on society of increasing the applications of IT imposes demands on dependability of security and products. Efficient access to and processing of information is enhanced by means of High Performance Computing and Networking technologies, WWW-based visualisation and navigation software and GIS (see Chapter 1). ISIS' role in 1996 in these themes was oriented towards the provision of scientific and technical support to the EU services and initiatives. This includes support for the IT R&D programme of DG III/F (Industry/Information Technologies) and support to the Centre for Earth Observation. Additional research was performed in collaborative projects.

Figure 3.1: Computer simulation combines satellite Earth observation data with a 3D image and allows a virtual aeroplane flight over the terrain. The example shows a 3D rendered image of vegetation growth in Africa. The normalised vegetation index was calculated by JRC's Space Applications Institute and has been draped over an accurate topographic dataset and ray traced.

Information Exchange Systems: European Wide Service Exchange (EWSE)

author: C. Best

ISIS has developed a new type of Internet server for information exchange between a community of users. This work was carried out on behalf of the Centre for Earth Observation (CEO) hosted by the Space Applications Institute, and in the frame of the G7 Environment and Natural Resource Monitoring (ENRM) Project.

The special feature of this type of server is that users world-wide can submit and modify entries in the database, while other users can search and retrieve data. For CEO the objective is to help customers and providers of EO data and services find each other, and to attract new users and applications of EO derived data. It has some unique features, which overcome previous limitations of WWW interfaces to on-line databases. The system handles user logons and profiles, which allows the user interface to be customised. Unlike other Web servers that are maintained by a single Webmaster, the European Wide Service Exchange (EWSE) is a dynamic system that belongs to all its users (Figure 3.2). Specialised search engines have been built to locate information. The system includes a "Virtual Tradeshow" for browsing, context sensitive help and a "guided tour". EWSE users can submit remote searches to NASA, ESA and international data catalogues. JAVA applets enhance the user interface for geographic searching and for navigation purposes. To date, there are about 2000

users and 300 organisations registered and who have entered data on the system.

The ENRM system was developed by request of the G7 Information Society Pilot Project. It addresses information on Climate Change, Biodiversity and Environmental Resources. The ENRM system is linked to large databases in the US and elsewhere. There are over 1300 registered users on ENRM from over 50 different countries.

Currently a generic information exchange system is under development. This will allow a community of users from any discipline to set up a server and define their user interface and database objects. This potentially addresses a wide application base.

<http://ewse.ceo.org> and <http://enrm.ceo.org>

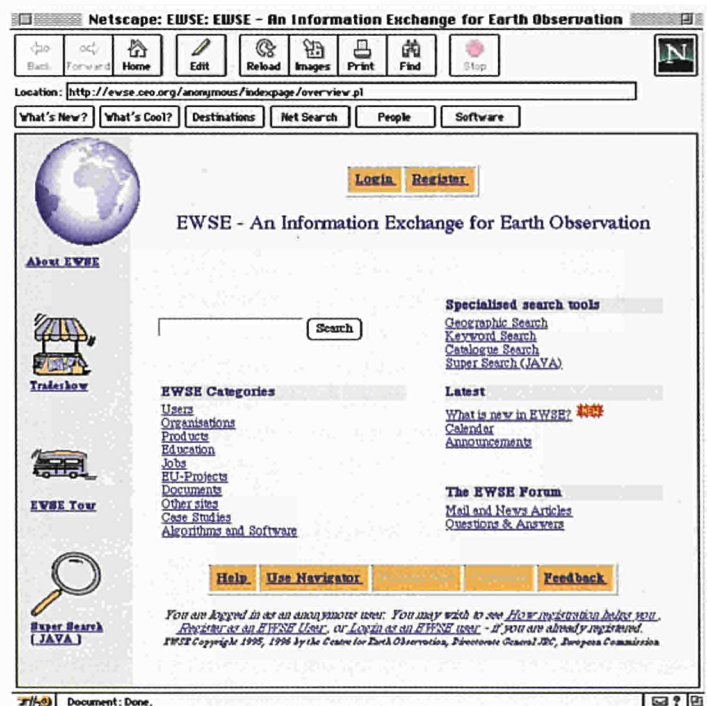


Figure 3.2: The European Wide Service Exchange (EWSE) home page. It is used for Earth observation data and images coming from over 1700 providers world-wide and it allows new data providers to make their data available to the users' community. It was developed by ISIS as a test-bed information system for Earth observation data and services for JRC's Space Applications Institute

- 3.1 Best C. - *EWSE: An information exchange for Earth Observation* - in: Proceedings of the 7th SIEKIN Symposium, Global Environmental Monitoring from Space, University of Tokyo, Japan, 1996
- 3.2 Best C. - *The EWSE Information System* - in: Proceedings of the 1996 IEEE International Conference on Systems, Man and Cybernetics; Information Intelligence and Systems, Beijing, China, 1996

Software Dependability

author: M. Wilikens

The Dependable Software Applications laboratory undertakes research, development and R&D policy support in the field of dependability engineering of systems that are safety, mission, security critical, or whose failure could lead to large economic losses. The activities included:

- Requirement Engineering (RE) Projects and Industrial Uptake: As a follow-up of the first RE workshop, an industrial workshop aimed at understanding and articulating industrial views on R&D projects on RE and their relationship to industrial relevance was organised.
- Dependability of Extensively-Deployed Products with embedded IT: this subject focuses on these products which are deployed extensively on the market place and, for this reason, require appropriate approaches for managing dependability. A study was initiated followed by a workshop to identify the anticipated engineering challenges and regulatory framework.
- Work has begun on understanding opportunities for information technology in the field of Intelligent Systems for Emergency Management. In a first phase, a study screened results of relevant projects; end-user groups; user needs; available IT technologies.
- Exploratory study in the usability and possible adaptation of safety analysis methods and tools during the early phases of the development life cycle of software intensive systems. In 1996, the study focused on the integration aspects of safety analysis methods and their results into formal requirements specification approaches. A case study is being performed on an existing formal methods prototype tool, the VSE (Verification Support Environment) applied to a robot control software.

- Industrial case studies for the application of IEC 1508 (draft) standard applied to safety critical control systems (SCCS) in the transport and energy domains.

- Development of an information system available on WWW containing a directory of SCCS standardisation activities.

<http://stss-www.jrc.it/dsa/sccs-dir/index.htm>

- In addition, the laboratory participates in collaborative networks like ENCRESS (ESPRIT, Information Technologies), COTCOS (Training and Mobility Research), EWICSTC7 and OLOS (Human Capital and Mobility Programme).

Activities in 1997 are devoted to the strengthening of the support activity mainly in the areas of *requirements engineering* and *dependability aspects of consumer goods*. A new line in the field of *survivability of complex information and communication infrastructures* will be addressed to pave the way for Framework Programme V. Also, collaborations within European R&D projects will be started.

Multimedia Techniques, Data Acquisition and Visualisation

author: P. Loekkemyhr

An automatic data-acquisition and distribution system has been developed for the Indoortron laboratory of JRC's Environment Institute (Figure 3.3 a and b). The system is used to monitor and log measurement data during experiments. Real-time data are made available on the WWW.

In 1997, the research group will further exploit its experience in the fields of 3D data visualisation, computer graphics and animation. This, combined with Internet interfaces, is now opening opportunities in the field of networked virtual reality and networked multimedia.

- 3.3 Scheer S., Maier T.- *A Knowledge Based Approach to Safety and Reliability Assessment of Safety Critical Software Intensive Systems* - ESA 1996, Product Assurance Symposium, ESTEC 19-21 March 1996; ESA S.P.-355, May 1996.
- 3.4 Morris P., Masera M., Wilikens M. - *Industrial Workshop on Requirements for R&D in Requirements Engineering* - in: Proceedings of the Third IEEE International Symposium on Requirements Engineering, Annapolis, USA, 6-10 January 1997; IEEE Computer Society Press.

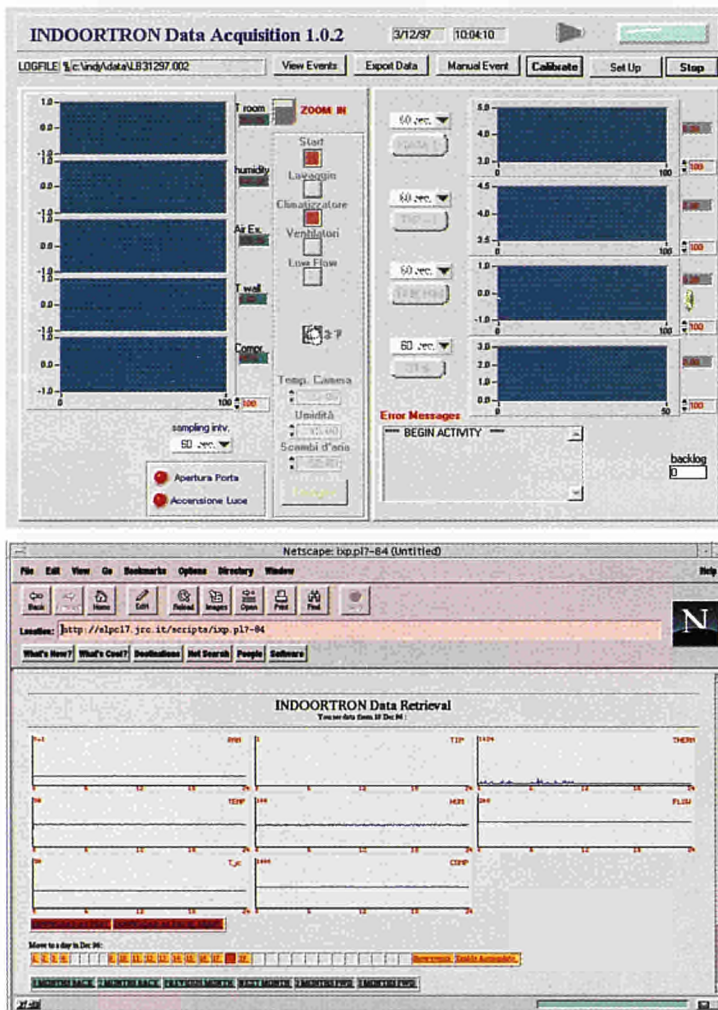


Figure 3.3: ISIS provides technical support for experimental facility operations in the form of electronic data acquisition systems. 3.3(a) shows the specific application to the Indoortron laboratory of the JRC's Environment Institute; it controls the laboratory and acquires data continuously. It is possible for scientists to view the real-time data via WWW (b).

High Performance Computing and Networking

author: M. Amsellem

The High Performance Computing and Networking laboratory is operated on behalf of DG III/F4 (Software and Advanced Information Processing) to promote high performance computing applications. It makes available computing capacity and related user-support on TELEMAT (the laboratory for Teleoperations and Robotics), medical image processing, holography and parallel computers with a total computations capacity of 5.5 Gflops. Our customers and activities are:

- DGIII/F4 institutional support for the promotion of European high performance computing;
- support in the frame of the bench marking of European Parallel Processor Systems for Real Time Image Processing in Remote Sensing and Medical Applications project;
- support in the frame of the bench marking of European Neural Network Systems on Remote Sensing Applications project;
- partner of the innovative remote sensing measurement of volcanic emission (VULCANO) project for DG XII (Science, Research and Development) which includes the University of Messina (IT), ARIA Technologies (FR), Automation Philips (IT), the Fraunhofer Institut Atmosphärische Umweltforschung (IFU Garmish, DE) and the International Institute of Volcanology (Catania, IT).

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- 3.5 Sequeira V., Gonçalves J.G.M., Ribeiro M.I.- *3D Reconstruction of Indoor Environments* – in: Proceedings of the IEEE International Conference on Image Processing (ICIP'96): Special Session on Range Image Analysis, pp. 405-408, Lausanne, Switzerland, Sept. 16-19, 1996
 - 3.6 Sequeira V., Gonçalves J.G.M., Ribeiro M.I.- *ActiveView Selection for Efficient 3D Scene Reconstruction* – in: Proceedings of the 13th International Conference on Pattern Recognition (ICPR'96); Track 1: Computer Vision, pp. 815-819, Vienna, Austria - August 25-30, 1996
 - 3.7 Sequeira V., Gonçalves J.G.M., Ribeiro M.I.- *Construction of a 3D Model of an Unknown Environment using Range Data* - in Modelling and Graphics in Science and Technology, Teixeira J.C. and Rix J. (Eds.), pp.164-172, Springer-Verlag, 1996

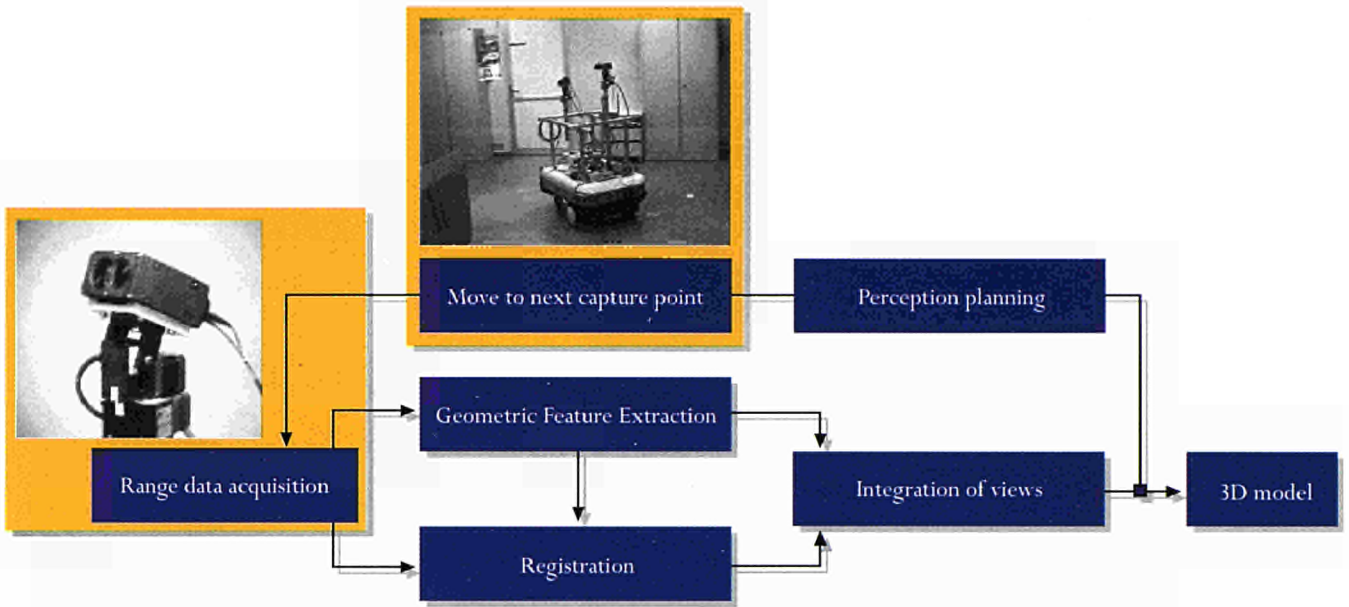
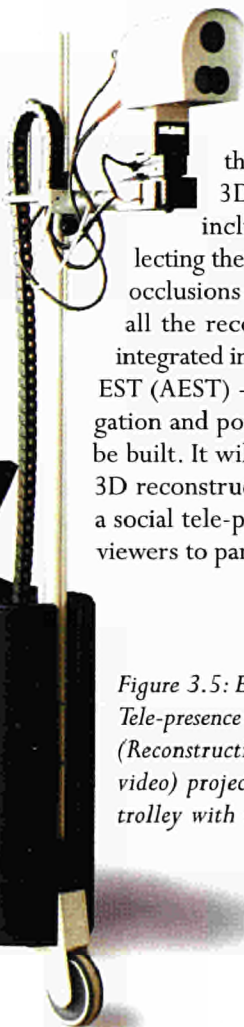


Figure 3.4: Paradigm for 3D Reconstruction of real scenes developed by ISIS using a scanned laser. When occlusions are found, the new data are integrated into the already existing model. As a final step, the video data is used to texture the 3D model.

3D Reconstruction

authors: V. Sequeira, J. Gonçalves

ISIS is a partner of the ACTS (Advanced Communication Technologies and Services) project: RESOLV (REconStructiOn using scanned Laser and Video). The ultimate goal is the 3D reconstruction of real scenes necessary for the construction industry but which can also be used as support to social tele-presence [3.5-3.7]. The 3D models are based on 3D data acquired with a laser range-finder and textured using video grabbed from a TV (or digital) camera as shown in Figure 3.4. The main achievement of the project has been the construction of the Environment Sensor for Tele-presence (EST), a trolley with an on-board computer for controlling range and video data acquisition (Figure 3.5) and which creates the 3D models.



The work during 1996 focused on setting the hardware and software for the EST as well as developing the 3D Reconstruction paradigm, including the algorithms for selecting the next capture points whenever occlusions need to be resolved. In 1997 all the reconstruction software will be integrated in the EST and the Autonomous EST (AEST) - a mobile platform with navigation and position localisation tools - will be built. It will be used for fully automated 3D reconstruction of environments and as a social tele-presence tool enabling remote viewers to participate at meetings.

Figure 3.5: EST - Environment Sensor for Tele-presence developed under the RESOLV (Reconstruction using scanned laser and video) project. The EST is made up of a trolley with an onboard computer and a laser head for 3D acquisition and reconstruction



Figure 3.6: The 3D Image Laboratory has improved the signal and image compression technologies which are based on wavelet fast transforms and on lossless compression techniques. Fast transforms include Fourier, Hadamard, Walsh Paley, Haar, wavelet packets and fractal transforms. The implementation demonstrated that image compression can be achieved by a factor of 10 up to 500 without significant loss of information.

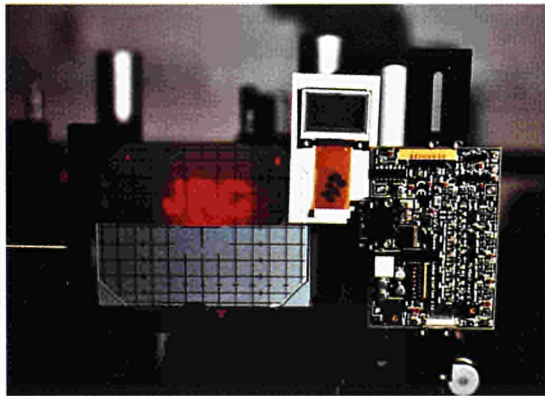


Figure 3.7: The 3D Image Laboratory has created a complete pre-industrial 3D holographic flat screen based on liquid crystal technology and spatial light modulator. The main objectives are to develop improved and up-to-date true real colour hologram synthesis for realistic 3D scene reconstruction. Activities concentrate on new technologies needed for 3D holographic display as well as on holographic optical elements that are required in advanced integrated electrophotonic devices.



Figure 3.8: The data set of the visible human has been implemented by ISIS in the 3D Image Laboratory. The first step was to test visualisation algorithms. The next objective is to study and implement specific constitutive laws to understand the thermo-mechanical behaviour of the human body as well as the diffusion processes and the exchange systems involved in human behaviour.

3D Image Processing and Synthesis Laboratory

author: J.C. Grossetie

The 3D Image Processing and Synthesis Laboratory has for a long time been specialised in European parallel computers and in image and holographic synthesis. The major activities carried out during the year were:

- Interactive image processing and synthesis;
- Advanced image compression and compaction techniques;
- Holographic processing and synthesis;
- Stereo-photogrammetry;
- Real-time image and holographic data acquisition.

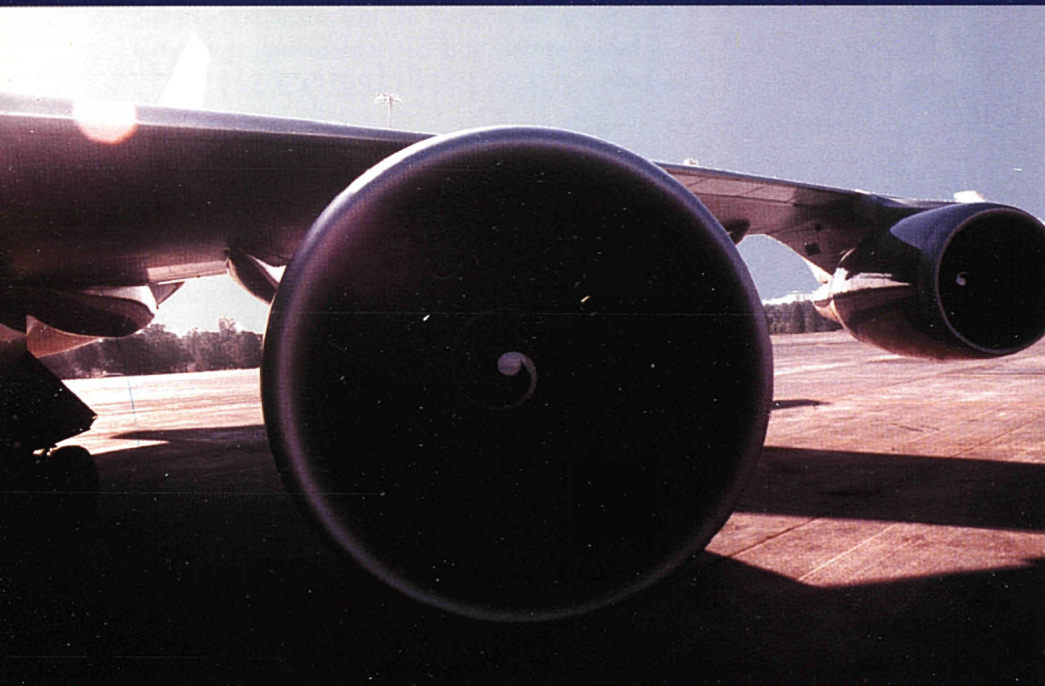
The laboratory also has considerable experience and expertise in the areas of 3D image and holographic synthesis, optical and fast transforms, and signal analysis.

4

Safe and sustainable

transport

author: C. Cacciabue



Technological development and needs of the society have strongly enhanced all means of transportation (surface, air and water) and this trend will continue to enlarge. The vast amount of work and persons involved in the transport domain and the impact that transport has in the social life of modern society means that safety becomes one of the crucial goals of future transport development.

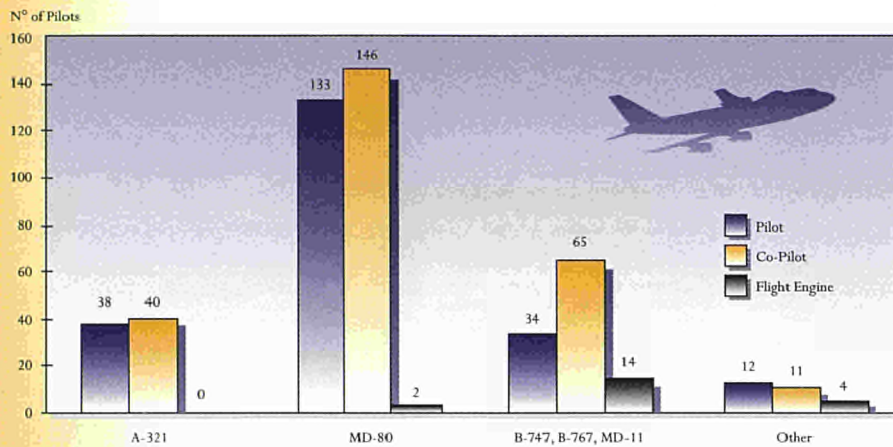


Figure 4.1: Distribution of the ALITALIA pilots who replied to NASA's Flight Management Attitude Questionnaire, subdivided into their role within the cockpit versus their aeroplane sector (Airbus A-321, McDonnell Douglas MD-80, B-747, B-767, MD-11 and others)

The safety levels reached today are very high. The low rates of accidents resulting in casualties and environmental damages are generally acceptable both to the public and to the regulatory bodies. However, these rates have reached a plateau value, which needs to be carefully examined. Indeed, if these records are not improved further, the increased speed and capacity of the transport means and the increase of traffic density would result in unacceptable catastrophic consequences with much larger environmental and social impacts. Hence the safety issue of future transport systems needs to be tackled and fulfilled both at regulatory and technical levels. Moreover, as this subject spreads throughout the whole of Europe (and the world), safety becomes a trans-national concern, demanding the use of internationally accepted means and methods. ISIS has contributed to transport safety studies by fostering a number of research actions with strong commonalities and interfaces with transport. In particular, a number of competitive actions have been initiated in support to DG VII (Transport), to the industrial world and to other European research institutions, both at national and international level.

Crew Resource Management

author: C. Cacciabue

The CRM (Crew Resource Management) is a training course dedicated to developing an understanding and awareness of the Human Factor

problems arising amongst airliner pilots [4.1, 4.2]. This type of training will become compulsory in 1998 and is already widely spread within many Airline companies. The course, developed by ISIS, has been used by Alitalia airlines and is available in a prototype version for pilots. The Computer Based Training (CBT) module contains the pre-course material, self-paced and based on advanced multi-media technology using video/audio, integrated with user controlled interaction. A specific part of the course, based on the "Safety Culture" of the Company is being

developed. In collaboration with NASA and the University of Texas (Austin, USA), NASA's Flight Management Attitude Questionnaire (FMAQ) has been applied within Alitalia to analyse its Safety Culture. All the Company's cockpit crew members (about 1600) were given a questionnaire and 517 answers were collected (Figure 4.1). Each questionnaire had 147 questions totalling 76,000 data inputs; the pilots' replies were subdivided into their role within the cockpit (Captain, First Officer and Flight engineer) and into their sector of membership, i.e. Airbus A-321, McDonnell Douglas MD-80, B-747, B-767, MD-11, and other types of aeroplanes.

Air Traffic Control Computer Based Training

author: C. Cacciabue

Human factor issues are now included in air traffic control training programmes to improve safety and prevent accidents. In particular, as recommended and supported by different institutions, such as the Eurocontrol, the Federal Aviation Administration (FAA), the Joint Aviation Authority (JAA) and the International Civil Aviation Organisation (ICAO), further studies and research on the use of specific tools supporting human factors training in Air Traffic Control are needed [4.3]. ISIS has been commissioned by the Italian Agency for Air Navigation Services (ENAV) to develop a human factors CBT and integrate it with an existing,

- 4.1 Cacciabue P.C. - *Organisational Factors in Prevention and Investigation of Aviation Safety* - 3rd ICAO Global Flight Safety and Human Factors Symposium. April 9-12, 1996, Auckland, New Zealand. ICAO Human Factors Digest 13. CIRC 266-AN/158
- 4.2 Lie A. M., Kjaer-Hansen J., Cacciabue P.C. - *Organisational Factors and Culture in Human Factors Training* - 3rd ICAO Global Flight Safety and Human Factors Symposium. April 9-12, 1996, Auckland, New Zealand. ICAO Human Factors Digest 13. CIRC 266-AN/158
- 4.3 Bellorini, A. - *Task-related factors of stress: the analysis of conflict resolution in Air Traffic Control* - in: Proceedings of the 1st International Conference on Applied Ergonomics (ICAE). May 21-24, 1996, Istanbul, Turkey.

technical training for air traffic controllers. The project is split-up into four phases; by the end of 1996, the first phase ended and the second one began.

During Phase 1 the following tasks have been accomplished:

- the constitution of a working group with people from ENAV;
- the definition of human factors contents and safety (syllabus);
- the definition of the teaching method based on the use and role of the CBT;
- the definition of the "story board" and of the supporting materials (video, audio and texts).

In Phase 2 various examples of graphical interfaces (Figure 4.2) will be implemented. Some video sequences are digitised and a draft version of the supporting material (questionnaire and test) is being prepared. Another questionnaire will also be developed to test the prototype. Phase 3 and 4 will involve the installation of this tool at ENAV's training school and the completion of the material after a testing phase has been completed.

ADAMS: Human Factors in Aircraft Dispatch and Maintenance Safety

author: C. Cacciabue

The ADAMS Project, a BRITE Project on Human Factors in Aircraft Dispatch and Maintenance Safety, began in February 1996. It is carried out in collaboration with: the Defence Evaluation and Research Agency (GB), the Netherlands' National Aerospace Laboratory (NL), Trinity College of Dublin (IE), British Airways Engineering (GB), Sabena (BE), Scandinavian Airlines System, and Air Lingus-TEAM (IE). A review is being made of some of the major systems used in the aviation and/or maintenance field for accident/incident analysis and safety assessment; lessons learnt from their failure and/or success are addressed. Particular attention has been given to some of the most sophisticated methodologies currently in use in aviation maintenance. The final objectives are: (1) to disseminate relevant information within the maintenance environment and (2) to establish a

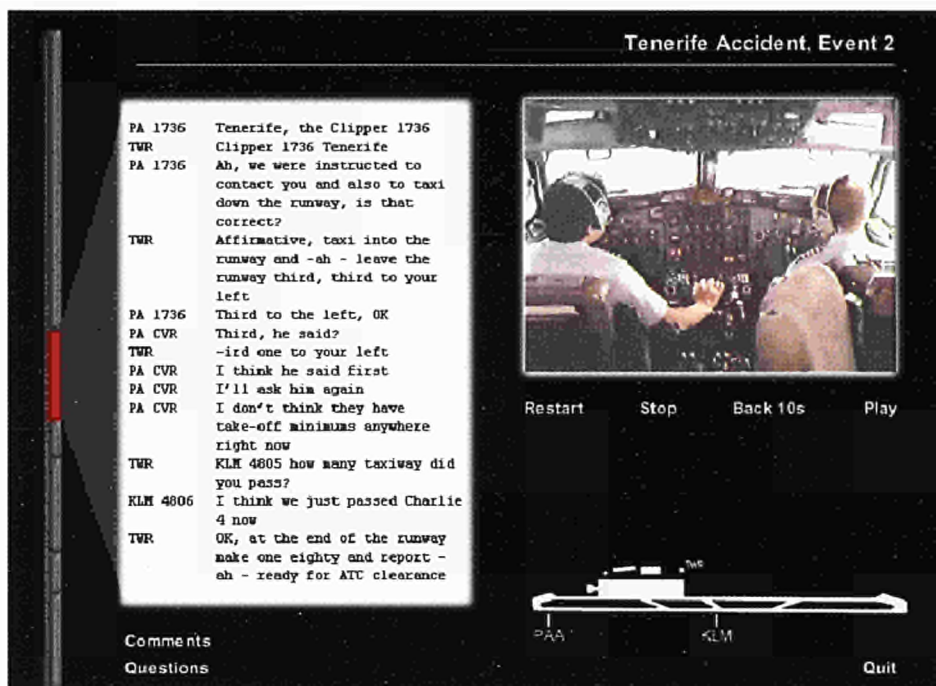


Figure 4.2: Computer Based Training allows Air Traffic Controllers to review emergency situations and to draw conclusions. In this particular example, the Tenerife accident is re-enacted on the screen and the communication from the cockpit voice recorder (CVR) are shown on the left side of the computer. The Tenerife runway is on the lower right of the screen and shows the Pan American Airline (PAA) landing site and the KLM take off position.

common background among maintenance personnel and to encourage a uniform approach to human factors accident/incident investigation and safety assessment.

The contribution of ISIS to this first year's task has been focused on the review of:

- confidential incident reporting systems - Aviation Safety Reporting System (ASRS) and Confidential Human Factors Incident Reporting Program (CHIRP);
- incident data-bases - British Airways Safety Information System (BASIS) and European Co-ordination Centre for Aircraft Incident Reporting Systems (ECC-AIRS);
- systems developed and specifically tailored for use in the aviation maintenance domain - Maintenance Error Investigation (MEI) and Managing Engineering Safety Health (MESH).

Much attention was dedicated to the analysis of the sophisticated reactive and proactive methodologies specifically developed for use in the maintenance fields: MESH and MEI. These have been shown to be both excellent from the theoretical point of view, while some difficulties have been identified for their practical implementation. Possible improvements have been discussed [4.4]. The outcome of this review will lead to specifications for reactive and proactive methodologies. These will be integrated with the activity results conducted within the

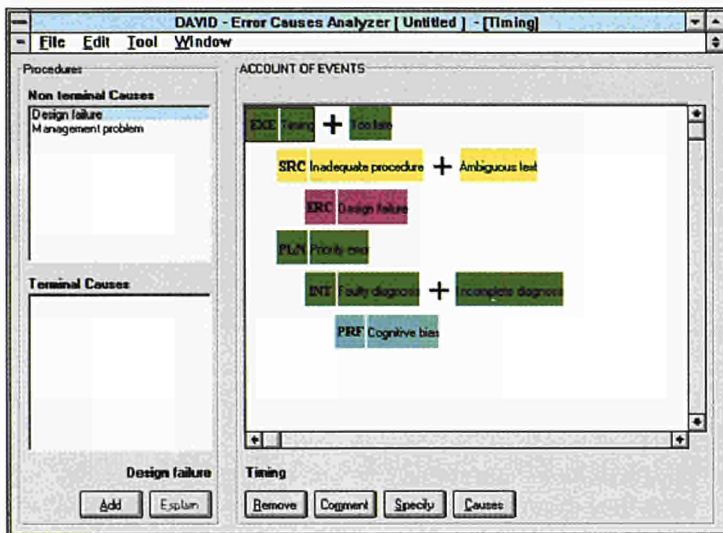


Figure 4.3: This is a typical video-display of DAVID developed by ISIS to support the search for root cause analysis of human errors. In this figure a causal structure outlines the sequential error chain, from the error manifestation (execution) to its root causes. The boxes indicate the causes selected by the analysis. These are automatically displayed according to their level of meaning: from general to detailed description. As an example, the error manifested itself through an "execution failure" (EXE) due to "wrong timing", i.e. a late performance. The different colours are used to distinguish between errors related to cognitive functions (Execution-EXE, Planning-PLN and Interpretation-INT), external (System Related Causes-SRC and Environment Related Causes-ERC) and internal (Personal Related Functions-PRF) factors.

ADAMS project. The specifications for reactive and proactive methodologies and a human error taxonomy, specifically tailored for aircraft maintenance and dispatch operation, will eventually support the end-user organisations in incident investigation and safety assessment.

Accident Analysis and Safety Assessment

author: C. Cacciabue

Research in Air Traffic Control and Cockpit (Pilots) behaviour has fostered the development of methodologies for root-cause analysis and for modelling cognition and human behaviour. The results of these actions are briefly reported below and will generate further activity in the course of the forthcoming year in collaboration with European air-carriers for Civil Aviation (AirEurope, Italy) and the European Association of Aviation Psychology (EAAP).

1. Root cause analysis of human errors

The dynamic human reliability methodology HERMES (Human Error Reliability Method for Event Sequences) has been developed for the

classification and identification of human errors in accidents [4.5] and both the prospective and retrospective uses of HERMES are covered. Applications have been made to hypothetical study cases as well as to true accidents such as the Zurich and the Mount Saint Odile crashes [4.6]. Moreover, the methodology has been implemented within a software tool for video analysis of human errors (Figure 4.3). This tool, called DAVID (Dynamic Analysis of Video in Incident studies) is a prototype of a software tool implementing the main principles of HERMES and has been integrated in a multimedia environment, imbedding a relational database and a desktop for linear video editing [4.7].

2. Modelling Cognition and Human Behaviour

This project is on research carried out within Human Capital and Mobility networks dedicated to the study of Human Factors in complex working environments and to the Design of Robust Human-Machine interfaces. The project focuses on generating a model of cognitive and behavioural performances which goes beyond the existing model already developed at JRC. The model is specifically dedicated to the simulation of a pilot's situation awareness, decision-making and action processes during specific phases of the flight. The integration with the Air Traffic Management system has been considered as a key aspect for the connections between the different human operators involved namely, the pilots, the tower controllers, the en-route and the approach controllers [4.8].

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

author: W. Post

The ECC-AIRS system is designed to serve as a EU collection point, as well as a national occurrence reporting system, of air traffic incidents in Member States. At the start of the '90s, a number of studies in the field of accident investigation and incident reporting systems were carried out on behalf of the DG VII (Transport). In a study entitled "Community Air Safety Information System" it was proposed to bring together the knowledge of the mandatory incident reports in various Member States. The study recommended to set-up a European Co-ordination Centre for the mandatory Aircraft Incident Reporting Systems (ECC-AIRS). ISIS was to present a proposal

and to include a functioning prototype solution for a system able of logically connecting the various systems related to aircraft incident reporting in the different Member States.

In the period 1993-1995 the ECC-AIRS pilot system was designed, built and evaluated. In October 1995 the ECC-AIRS Steering Committee assessed the feasibility of an integrated European aircraft incident/accident database. They agreed that the ECC-AIRS pilot system could be the foundation for a production version of an integrated European incident/accident database. Furthermore they regard the ECC-AIRS system as an essential building block in the development of advanced analysis techniques, since it has the capability to bring together vast amounts of data from several sources. The system can also serve as an ICAO (International Civil Aviation Organisation) compatible, automated aircraft incident/accident reporting system for countries that do not yet have automated facilities. During 1996 a second, significantly improved, CD-ROM release of the software was developed. This release includes most of the suggestions resulting from the evaluation, solutions for problems that were found and new additional functionality. This second release has been sent to the members of the Steering Committee and other interested organisations. The follow-up project, called ECCAIRS-3, began in December 1996 and will be completed at the end of 1997.

Car safety

author: C. Albertini

The increased severity of international crash safety standards and the use of crash safety performance of vehicles as a potent advertising argument present the automotive industry with the urgent task of optimising crash safety performance. The attainment of optimised crash safety at competitive cost is further complicated by environmental protection policies which demand the reduction of fuel consumption and the introduction of new less polluting fuels, obtained by the reduction of vehicle body weight. Thus the problem of designing automotive bodies with improved crashworthiness but weighing less is one of the most challenging and critical engineering problems that the automotive

industry must tackle. The main research carried out at ISIS on car safety and in support of developments from the automotive industry and the European transport safety authorities are:

- advanced automotive material testing and modelling which takes into account the extremely severe conditions arising from high strain rate effects;
- precision impact testing and modelling of automotive components of increasing complexity including the whole car body.

Special specimens have been developed for tests at high strain rate in tension, compression and shear starting from the thin metal sheet (1 mm thick) used in the automotive industry. These specimens have been tested at high strain rate up to 1000 s^{-1} using the tensile Hopkinson bar devices developed at JRC [4.10]. A carbon steel and an aluminium alloy have been investigated [4.11]; the carbon steel shows a pronounced strain rate sensitivity while the aluminium alloy shows practically none.

Precision Impact Testing of Automotive Body Components and Subassemblies

A benchmark exercise between 14 European laboratories on dynamic crash tests on aluminium longitudinal beams has demonstrated that the Large Dynamic Testing Facility at ISIS equipped with a large Hopkinson bar system (Figure 6.5) can be considered a reference precision crash test for automotive components dedicated to absorb energy during a collision as shown in Figures 4.4 and 4.5 [4.12, 4.13]. During 1996 a precision dynamic crash testing method has been developed. This test method, sketched in Figure 4.5 and with a patent pending,



Figure 4.4: The Large Dynamic Test Facility (LDTF) method is the only method available which can measure the complete deformation/energy absorption history during a fast dynamic event. Configuration for compression tests serves to measure longitudinal elements as used in cars during a collision as shown in the photograph. The LDTF facility is shown in Figure 6.5

- 4.4 Bacchi M., Cacciabue P.C., O'Connor S. - *Reactive and proactive methods for human factors studies in Aviation Maintenance* - in: Proceedings of 9th International Symposium on Aviation Psychology. April 27 - May 1, 1997, Columbus, Ohio.
- 4.5 Bacchi M., Cacciabue P.C. - *Human factors methods and data for reactive and proactive safety* - in: Proceedings of ESREL'96 - PSAM III International Conference on Probabilistic Safety Assessment and Management; P.C. Cacciabue, I.A. Papazoglou (Eds.). pp. 769-775. Crete, Greece, 24-28 June, 1996, ISBN 3-540-76051-2 Springer-Verlag, London, UK.
- 4.6 Pedrali M. - *Vers un environnement multimédia pour l'analyse video des causes d'erreurs humaines. Application dans les simulateurs d'avions* - Doctorate Thesis (1996) University of Toulouse 1, (F).

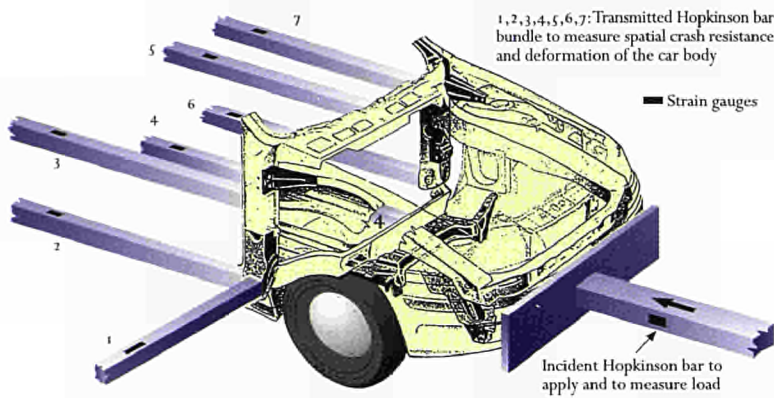


Figure 4.5: Precision crash testing of car body by Hopkinson bar bundle. The method will allow modifications to test the front end of cars (patent pending)

is based on Hopkinson bar transducers which can be applied in each point along any space direction of body structure cross sections. This allows the 3D tomographic measurement of load and displacement and therefore of the energy flow through the car body structures [4.14]. The application of this method will open completely new perspectives for the optimisation of car body crash-worthiness and for its numerical simulation which are indispensable in the construction of future car bodies characterised by less weight and increased safety standards. The folding mechanism of longitudinal beams is not very effective in energy absorption because only very restricted zone of the fold is strongly deformed [4.15]

The efficiency of crash energy absorption by folding of automotive longitudinal beams in case of oblique collision has been also numerically calculated using the code ABAQUS [4.16]. It resulted that a deviation of $\sim 10^\circ$ from frontal collision is sufficient to drastically reduce the energy absorption capability of longitudinal beams. Some solutions have been suggested in order to avoid such inconveniences. An approach is to give a conical shape to the longitudinal beams to avoid bending [4.16]. Another solution is

to use the crash energy absorption mechanism for the formation of a high speed (~ 200 m/s) jet of a low viscosity liquid encapsulated in the front part of the car; this solution has been patented [4.17] and a research prototype has been submitted for crash tests.

Energy-environment decision support (STEEDS)

author: D. Bain

The aim of STEEDS (Scenario-based framework for modelling Transport technology deployment: Energy-Environment Decision Support), which comes within DG XII's JOULE-THERMIE programme (Non-nuclear Energy), is to build and validate a decision support tool comprising an integrated framework of scenarios and transport-energy-environment modelling techniques. Where appropriate, this tool will incorporate existing models and thus be capable of (a) identifying which transport technologies are likely to achieve significant market uptake and (b) quantifying the energy and environmental impacts of different technology mixes. The project began in 1996 and is being conducted by a consortium from industry, universities and national research laboratories. The ISIS Technology Assessment sector has lead responsibility for the central task of software development and validation for the Decision Support System. ISIS also hosted the first mid-term review meeting and associated workshops in November 1996.

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- 4.7 Pedrali M., Bastide R., Cacciabue, P.C. - *A Multimedia Environment for Retrospective Analysis of Accidents and Incidents Involving Human Factors* - 3rd ICAO Global Flight Safety and Human Factors Symposium. April 9-12, 1996, Auckland, New Zealand. ICAO Human Factors Digest 13. CIRC 266-AN/158
 - 4.8 Amat, A. L., Bellorini, A. - *The issue of ground/cockpit integration: results from field studies* - in: Proceedings of the 8th European Conference on Cognitive Ergonomics (ECCE-8). September 10-13, 1996, Granada, Spain.
 - 4.9 Post W. - *European Co-ordination Centre for Aircraft Incident Reporting Systems: ECCAIRS-2* - Completion of the ECCAIRS Technical Note No. I.97.17, January 1997
 - 4.10 Albertini C., Montagnani M. - *Dynamic Mechanical Properties of Several Steels for Fast Breeder Reactor Safety Analysis* - EUR report 5787 EN
 - 4.11 Albertini C., Cadoni E., Labibes K. - *Precise Measurements of Crashworthiness of Automotive Longitudinals in Aluminium* - in: Proceedings of 29th International Symposium on Automotive Technology & Automation (ISATA), Florence, Italy, June 1996
 - 4.12 Haneft E.H., Wierzibicki T., Albertini C. - *Calibration of Impact Rigs for Dynamic Crash Testing* - Report EUR 16347 EN
 - 4.13 Albertini C., Cadoni E., Labibes K. - *Anisotropy and Strain Rate Effects on Dynamic Testing of Thin Sheet Boxes used as Automotive Crash Energy Absorbers* - 2nd ISIE, International Symposium on Impact Engineering, Beijing, China, September 1996.
 - 4.14 Albertini C., Labibes K., Solomos G. - *Precision Measurements of Crash Energy Absorption: from Material Specimens to whole Vehicle Body* - EUR Report 17293EN, 1997
 - 4.15 Mogilevski M. - *Some Investigations on Problems of Crash Impact and Hopkinson Bar Measurements* - EUR report 17294 EN, 1997
 - 4.16 Crutzen Y.R., Inzaghi A., Mogilevski M., Albertini C. - *Computer Modelling of the Energy Absorption Process in Box-Type Structures under Oblique Impact* - 29th ISATA Conference, Florence, Italy, June 1996
 - 4.17 Albertini C., Mogilevski M. - *A Device with a Liquid for Energy Absorption* - European patent 95 307 927.4

5

Cultural heritage protection

author: A.C. Lucia



ISIS has developed a number of technologies suitable for the protection of cultural heritage. A major contract in which the Institute contributed in the preservation of Palazzo Geraci in Sicily (Italy) has been completed .

Figure 5.1: Photogrammetric field measurements at the Steri building complex in Palermo, Sicily (Italy)



The technologies developed and applied by ISIS Laboratories were:

- Photogrammetry for high resolution 3-D documentation of the state of the monument. This includes 3-D CAD drawings.
- 3-D finite element modelling to study structural behaviour under various load conditions conditions. Results are presented graphically.
- Computer simulation of earthquake motion and the damage evolution to identify consolidation points.
- Experimental earthquake simulation on large scale model of the critical part of the monument.
- Computer simulation and experimental verification of damage repair techniques.
- Electronic Speckle Pattern Interferometry (ESPI) methods for damage assessment and affrescos, violin, wooden paintings, etc. for mechanical characterisation of stone materials.
- Multimedia archives for storage dissemination and use of results on information on cultural heritage.
- Decision support tools for identifying and prioritising objects for intervention.

Palazzo Geraci

Palazzo Geraci is a late 17th Century building in the historic centre of Palermo with neoclassical sculptures by I. Marabitti (Figure 5.2). The central part was severely damaged during World War 2 bombings; on the sides of the Palazzo are shops and on the floor above there are apartments. The Region of Sicily, together with support from DG XVI (Regional Development), requested and funded the intervention by the JRC with the collaboration of the Sicilian universities.

http://tintin.jrc.it/htdocs/e10/e10_jen.html

Photogrammetry for Field Measurements and Digital Model

author: M. Zürn

Data retrieval was accomplished mainly by stereo-photogrammetry. It was possible to reconstruct a 3-D image of the Palazzo Geraci using the Institute's high resolution numerical photogrammetry method. In particular:

- Topographic survey of the building and the surrounding area.
- Outline drawing of the entire front facade in a scaled 3D drawing.



Figure 5.2: The front wall of Palazzo Geraci in Palermo (Sicily, Italy) which was remodelled in the ELSA laboratory (see Figure 5.3)

- Detailed 3D outline drawing of both facades of the 'region of interest' in the central part of the building.
- Mathematical models were produced on the basis of the measured data to build networks of 3D points with a density of 400 points/sqm on the object. The model was represented graphically.
- The front gate of the Palazzo Geraci was elaborated to complete a 3D CAD Detail drawing. This re-affirmed that photogrammetry can yield output products at virtually any level of detail.

Photogrammetry

author: M. Zürn

The demonstration project at Palazzo Geraci showed the validity of high resolution photogrammetry. It is an efficient method to interpret photographs metrically. The concept is simple, the field work consists in little more than taking photographs and the measurements are taken directly on the photograph. It would be possible to archive the photographs and to perform the evaluation step also after the object has been destroyed.

Computer Aided Diagrams (CAD)

author: V. Renda

Three-dimensional structural modelling and analysis have been performed, starting from the available data provided by stereo-photogrammetry. 3D numerical models based on CAD and finite element methodology, allowed the global stability to be investigated statically/dynamically. Particular interest was on material stresses, structural deformations and vibrations under heavy traffic conditions.

The consistency check for the photogrammetry - CAD/3D - Computer Graphics chain has been performed on Palazzo Geraci's main façade and front gate. From the application of such a methodology, two complementary research lines have been highlighted:

- the Architectural Description based on Virtual Re-Building
- the Engineering Survey Oriented to Cultural Heritage Preservation.

Simulations of Earthquake Motion

author: A. Anthoine

Earthquakes may cause important damage to historic buildings. Often in the past, the earthquake was not recognised as the cause of this because the visible signs usually appeared several hundred years after the earthquake.

In a preliminary study, the entire façade of the Palazzo Geraci has been modeled elastically and subjected to a distributed lateral earthquake loading (the so called "equivalent seismic loading"). Trial and error computations have enabled the geometry of the central part of the facade to be tested as well as determining the best boundary conditions to be provided by the testing apparatus.

To further improve the testing set-up and to evaluate the levels of force and displacement that could be reached during the tests, refined non-linear numerical analyses have then been performed. The stone blocks have been modeled separately (elastic material checked a posteriori against failure) and the mortar joints were represented by frictional interface elements (Figure 5.4). Such a choice was based on the hypothesis that the mortar joints were the weak links of the structure, but this turned out not to be case. Therefore, the numerical results

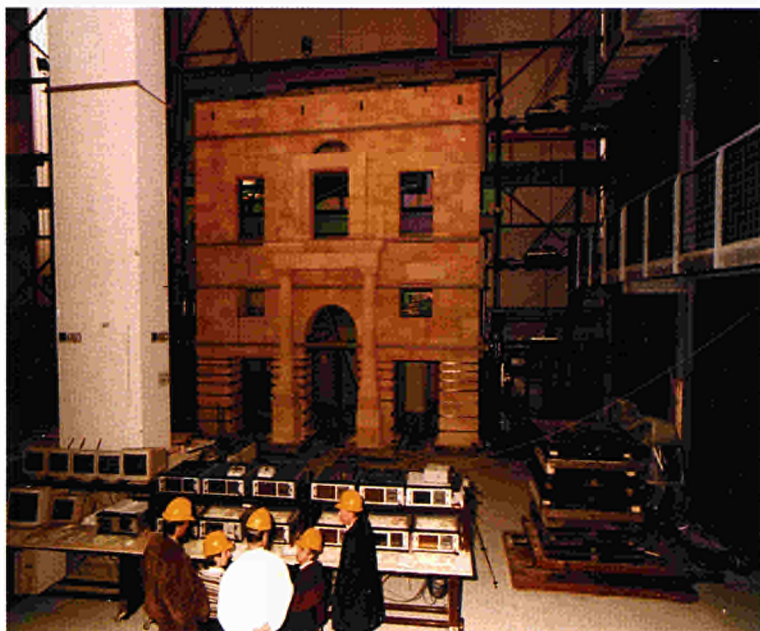


Figure 5.3: Large scale model of the front wall of Palazzo Geraci built at ELSA before submitting it to earthquake tests



Figure 5.4: Computer simulation (displacement and damage patterns) expected during a seismic event on the Palazzo Geraci allowed to set up the test parameters. It is hoped that computer simulations will help predict earthquake behaviour of similar historical buildings

agreed with the experimental ones only for a low level of damage.

ELSA Tests

author: V. Renda

Tests on the entrance portion of the Palazzo Geraci have been performed at the European Laboratory for Structural Assessment (ELSA) on a half-scale model (Figure 5.3). Great care was taken to the original reconstruction, which included bringing



Figure 5.5: Steri building complex: Jail building orthophoto. An orthophoto is a map-like photograph that has a constant magnification scale. It is an orthogonal projection of the scaled original object

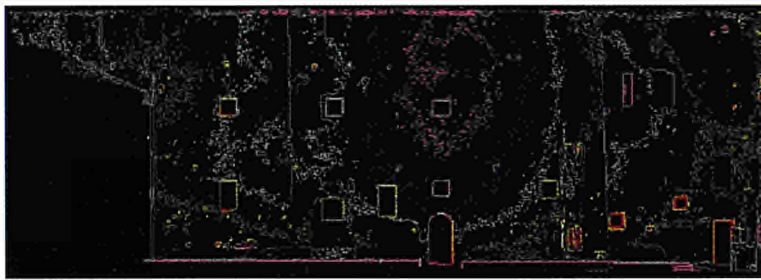


Figure 5.6: Steri Building Complex: Contour map of the 50 metre-long jail building showing the lines of equal depth. Each colour represents a depth of 5 centimetres.

bricks from the original quarry of Sicily; the original construction techniques were applied. The main objectives of the tests were:

- to investigate the capability of numerical models and software to assess the vulnerability Palazzo Geraci as an example;
- to repair the model after the simulated earthquake and to verify the validity of the repair in a second test.

The main results showed that there was good agreement between the tests and the numerical analyses only for a low level of damage. Thus, the numerical analyses can be considered a good tool for relative assessments of the potential damage of different structures. This however, is not the case for earthquakes strong enough to induce large damages to the building.

Structure Surveying using SAR Interferometry

author: E. Ohlmer

SAR (Synthetic Aperture Radar) interferometric measurements were performed on the Palazzo Geraci model at ELSA at different deformation stages. It is expected that the imaging of this remote sensing method can monitor the deformation of large structures with an accuracy of fractions of a

millimetre. The method was developed in the Space Applications Institute at Ispra, within the European Microwave Signature Laboratory (EMSL).

Steri Building Complex

author: M. Zürn

The 14th century Steri building complex offered a particular opportunity to demonstrate the potential of the stereo-photogrammetry method (Figure 5.1). It is located near the well-known Piazza Marina in Palermo surrounded by beautiful gardens and at one time the residence of the Sicilian king. East of the main palace the so-called "penance-jail" can be found, built during the Spanish Inquisition era. Unlike the main palace, the jail has not yet been restored (Figure 5.5). Almost the entire outer part of the building has been measured by a topographic survey and a detailed stereo-photogrammetric analysis (Figure 5.6). This included the use of temporary construction scaffolds to have access to certain camera positions and to ensure reliable source photographs. The output products were:

- several sets of outline drawings in 3D CAD
- comprehensive surface calculations (i.e. measuring wall surfaces, window areas, door area surfaces) to help estimate the costs of restoration;
- comprehensive set of mathematical models, 100-400 surface points per square meter with absolute 3D co-ordinates on the object;
- on some of the inner walls of the jail building, very interesting wall paintings can still be found. One of those paintings was subject to a photogrammetric evaluation, too, leading to an analysis to the relief shape of the painting ground and to corresponding source photographs.

http://tintin.jrc.it/htdocs/e11/e11_3it.html

Pretoria Fountain

author: M. Zürn

The Pretoria Fountain is a beautiful 16th Century Florentine fountain located in front of the Mayor's office in Palermo. It consists of dozens of detailed objects (for a total of 644 pieces) of which three were picked for topographic and stereo-photogrammetric analysis. Vibrometric studies gave an indication on the influence of inner city traffic on marble statues. One of these, in the shape of a human figure (Figure 5.7), was chosen for a precise profilometry based on 14 source photographs. The resulting 7 photogrammetric right/left models were

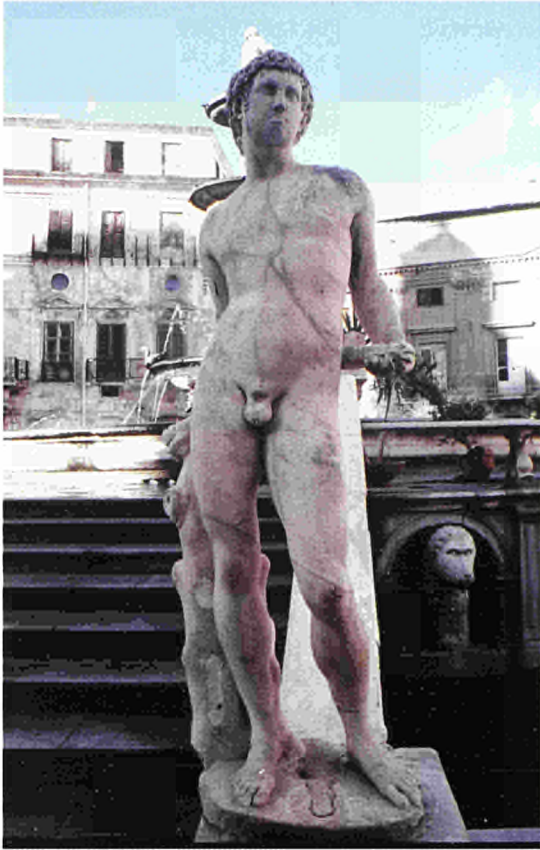


Figure 5.7: Part of the Pretoria Fountain in Palermo (Sicily, Italy); one of the 644 objects of this fountain

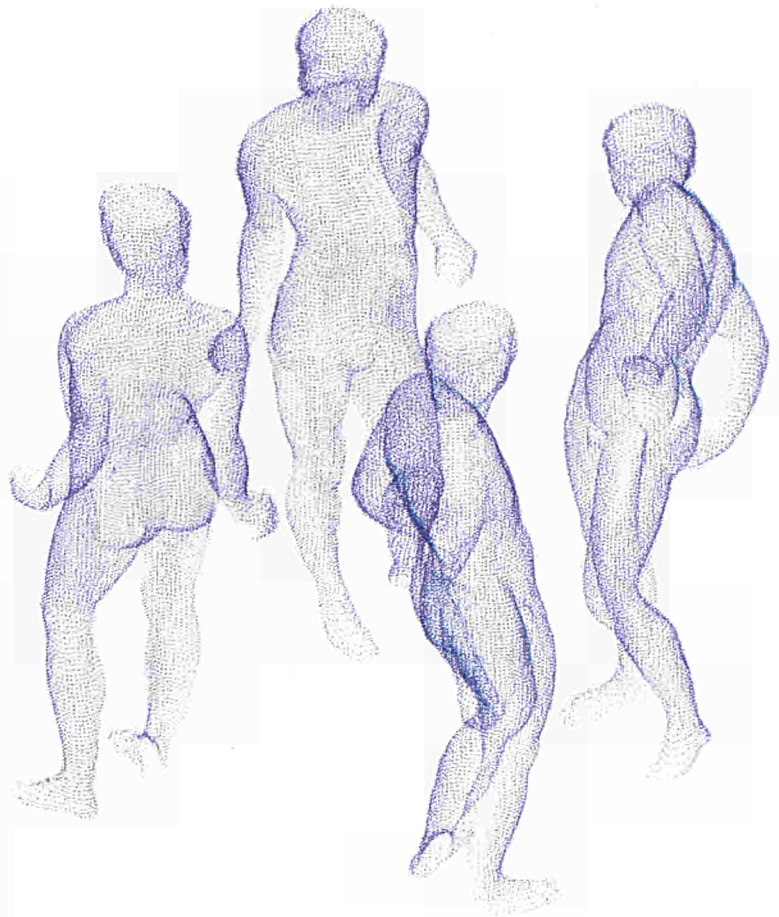


Figure 5.8: The mathematical model of the statue in Figure 5.7 representing 26.000 measured points. This is built on a network of 3D points (mesh width of 1 cm) on the object. With this model it is possible to create copies that are identical to the original.

put together to form a mathematical model that exceeds the standard properties of digital models in the sense that each x-y pair of model points is allowed to have more than a single corresponding z-value. The resulting object point density was more than 1000 3D points per square meter (Figure 5.8).

http://tintin.jrc.it/htdocs/e11/e11_2it.html

Interferometric Methods

author: M. Whelan

Recently, a portable Electronic Speckle Pattern Interferometry (ESPI) system was designed and tests built in-house. It has proven to be a powerful tool for studying the heterogeneous mechanical properties of antique violins [5.1]. Typically, a restorer wishes to identify weak areas on the panels of the violin which may require reinforcement. This ensures

that the instrument is protected from further deterioration and helps to restore it to its original shape and stiffness. Static micro-deformation studies on the instrument using ESPI can map critical areas easily, without any actual contact with the violin surface. A violin from the Amati workshop (from around the year 1650) was examined with the ESPI system. An example of the recorded fringe plot for the out-of-plane deformation of the back panel of this violin when the string loading was increased slightly was shown in Figure 5.9 (a). Standard image processing techniques can be used to obtain a false colour plot of the deformation field to help interpretation of the results (Figure 5.9 b).

The ESPI has the advantage of taking full-field, highly sensitive, non-contact measurements. In particular, attention has focused on the creation of compact portable ESPI systems that allow comprehensive testing to be carried out on objects in situ. This has allowed the routine application of interferometric based tools to a broad range of

problems originating in fields such as civil engineering, non-destructive testing of composites, vibration analysis and the restoration of works of art. Other techniques available include: holographic interferometry, white light interferometry (coherence radar), contouring holography and fringe projection.

Mechanical characterisation of masonry materials

authors: *M. Facchini, M. Tatti*

ESPI techniques were also used for the quantitative evaluation of the mechanical properties of various materials. It consisted in a mechanical compression test machine used in conjunction with an optical, bi-directional ESPI set-up. The aim of the tests was to catalogue different materials, to determine their mechanical properties and their behaviour under different conditions. The materials, supplied by the University of Messina (Sicily) and tested at ISIS, were:

SMRED: Red marble S. Marco
 BASET: Mt. Etna basalt of Maniace
 COMIS: Comiso stones
 ARESI: Grey Sicilian sand stones,
 Sinagra sand stones
 MISTR: Mistretta sand stones.

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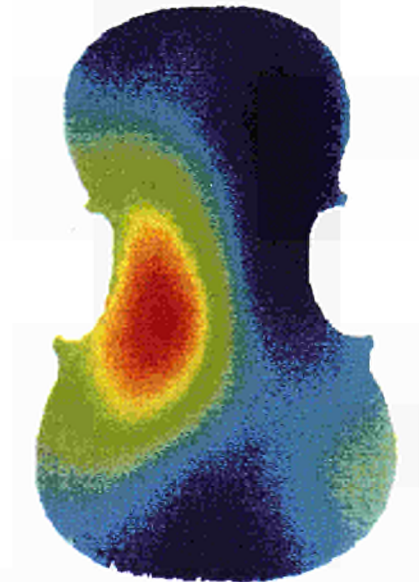
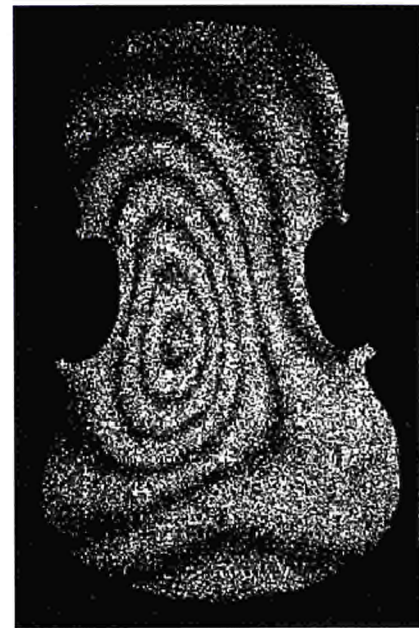


Figure 5.9 (a): ESPI fringe plot and (b) associated false colour map of out-of-plane deformation field of violin back panel (maximum deflection <math>< 2</math> microns; red zone)

- 5.1 Lucia A.C., Langhoff A. – *Prospective of Holographic Techniques Applied to Cultural and Historical Objects – Optics within Life Sciences (OWLS-III)* Munster, Germany, July 1996

6

Earthquake engineering and dynamics of structures

author: V. Renda



ISIS performs its experimental activities on earthquake engineering and dynamics of structures in the European Laboratory for Structural Assessment (ELSA) and the Large Dynamic Test Facility (LDTF); both are unique tools in Europe. The first is a Reaction Wall facility for seismic testing of full or large-scale models of civil engineering structures; the second allows impulsive or high strain rate testing of materials and mechanical components for the transient dynamic response. The applied research activities deal with the pre-normative research on construction norms in seismic areas (Eurocodes) and with the development of new technologies for strengthening vulnerable structures. Additional projects have been carried out for applications such as historic monuments, buildings, engineering of structures, etc.

Work in Support of Earthquake Construction Standards

author: A. Pinto

The prenormative research in support of the earthquake construction standards in Eurocode 8 (EC8) covered four major priority topics: i) reinforced concrete frames and walls, ii) infilled frames, iii) bridges, iv) foundations and retaining walls. The research was performed jointly by 18 research organisations in the European Union grouped together in the Pre-normative research in support of Eurocode-8 (PREC8) network under the European Commission's programme on Human Capital and Mobility (HCM). Details on the research programme and on future activities in support of Eurocode-8 may be found elsewhere [6.1]. The research programme on bridges, under the PREC8-HCM project, included the pseudo-dynamic testing of six (1:2.5) scaled bridges in the ELSA laboratory at ISIS. These tests included a quasi-static cyclic test on a squat pier [6.2], the pseudo-dynamic testing of three irregular bridges and a regular one described in [6.3] and three special tests, namely: two bridges with isolation/dissipation devices and a bridge with asynchronous input motion described in reference [6.4]. Those issues were of major concern in the recent Kobe earthquake [6.5].

The experimental programme was conceived to investigate several aspects of the seismic design of bridges such as: the regularity issue, alternative design methods including seismic isolation and asynchronous earthquake motions. A complete data set was required for the calibration and/or development of analytical models able to represent the earthquake non-linear response of such structures [6.4]. Subsequent parametric studies, foreseen in the above mentioned research programme on bridges, will lead to the accomplishment of the scientific objectives of the PREC8 research network, which are the upgrading and further development of Eurocode 8 - Part 2.

The results obtained from these seismic tests confirm that safety against collapse of the regular bridge is much higher than the safety of the irregular bridges. In fact, despite the comparable demands obtained for the design earthquake, the regular bridge was



Figure 6.1: Isolated bridge columns tested at ELSA. The pseudodynamic earthquake simulation test was possible due to the substructuring technique, where the bridge-deck behaviour is simulated by the computer. The digital controllers developed at the JRC proved essential in this application.

able to withstand twice the design loads without loss of capacity and with homogenous damage pattern. On the other hand, the irregular bridges, tested with an input signal 1.2 times the design earthquake, suffered quite important damage concentrated in the short central pier.

Tests on the isolated bridges (Figure 6.1) showed that isolation is an effective approach to earthquake protection of bridges. In particular, isolation can be considered as a rational alternative solution for highly irregular bridges. Both isolation schemes (partial and full isolation) have shown very good seismic performance, reducing the seismic response of the bridges to levels at which the piers were kept in the elastic range.

An irregular bridge was also tested with asynchronous input motion. The results demonstrate that the asynchronous earthquake motions do not lead to higher demands compared to the synchronous ones (Figure 6.2). However, the bridge damage pattern can be altered with respect to the one resulting from the synchronous motion.

- REFERENCES
- 6.1 Pinto A.V., - *The Kobe Earthquake (January 17th, 1995) - Damage to R/C Structures* - in: Earthquake Performance of Civil Engineering Structures. Special Publication No. I.96.56.SMU, ISIS, JRC, Ispra, Italy, 1996
 - 6.2 Pinto A.V., Verzeletti G., Negro P., Guedes J. - *Cyclic Testing of a Squat Bridge-pier* - Report EUR 16247 EN, EC, JRC, Ispra, Italy
 - 6.3 Pinto A.V., Verzeletti G., Pegon P., Magonette G., Negro P. - *Pseudo-Dynamic Testing of Large-Scale R/C Bridges* - Report EUR 16378 EN, EC, JRC, Ispra, Italy.

Buildings

authors: P. Negro and I. Papadopoulos

The infills often control the global seismic performance of framed buildings. Although masonry infills are non-engineered and considered as non-structural, they can dramatically change the stiffness and strength of the structure. The presence of the infills is generally regarded as beneficial because they increase the global resistance and energy dissipation capacity. However, the experience from recent strong earthquakes [6.7, 6.8] demonstrated that irregular distributions of infills, in particular in-height, can cause the premature failure of buildings, even of those designed according to recent codes. This was also confirmed by the tests recently performed at ELSA. A four-storey building designed as a ductility-class “High” frame -without specific provisions for infills- was tested pseudodynamically as a bare frame [6.7] as well as with differing patterns of masonry infills [6.8]. The results demonstrated that the presence of an in-height irregular configuration of infills could lead to unacceptably large concentration of ductility in the frame. In spite of the importance of the problem, seismic codes usually neglect or take into very limited account the presence of non-structural infills. Although some provisions do exist in Eurocode 8, they are considered to be too broad and often unduly penalising infilled structures. New design rules, to be eventually proposed for possible inclusion in Eurocode 8, have been formulated based on the findings of non-linear numerical analyses. ELSA is currently active to produce the necessary confirmation experimental results.

The experimental programme is addressing the problems of in-plan and in-height irregularities separately. In-plan irregularities have been studied by means of shaking table tests, conducted at the Istituto Sperimentale Modelli e Strutture (ISMES, Italy) on two identical one-bay by one-bay two-storey frames, one bare and the other equipped with infills at two adjacent sides. The results seem to confirm that in-plan irregularities cause much lesser problems than in-height irregularities. The latter are being studied at ELSA by means of pseudodynamic tests on a two-bay by one-bay three-storey building. The frames of the building have been designed according to two different sets of design rules, and the building is being tested in three different irregular configurations of infills.

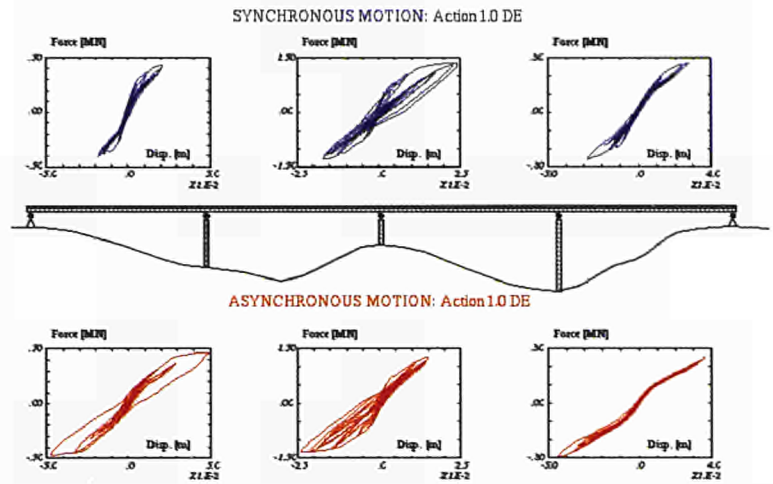


Figure 6.2: ISIS is contributing to the calibration of the Eurocode 8 by carrying out reference tests on bridges. An example is this comparison of force-displacement diagrams between synchronous and asynchronous motion for an irregular bridge (i.e. with a short pier in the middle)

A further experimental programme deals with the energy dissipation capacity of composite steel-concrete structures. The research on steel-concrete structures along with the research on infilled frames mentioned above, make part of a Competitive Support to the Commission project concerning the Stability of Civil Engineering works and in particular the Design in Seismic Regions. The steel-concrete experimental programme aims to provide a classification of various design configurations of the beam-to-column connections, regarding their energy dissipation capacity under varying external loads. To this end cyclic and pseudodynamic tests will be performed at ELSA on a full scale, three-storey, three-by-three bay composite steel/concrete bare frame, Figure 6.3. This frame includes various design patterns of its numerous beam to column connections. The moment-rotation behaviour of each particular beam to column connection, will be assessed through numerous displacement measurements at selected points of the structure and with the help of a System Identification numerical tool. This research programme will allow the formulation of design recommendations to be included to Eurocode 8.

- 6.4 Pinto, A.V. (Ed.) - *Pseudo-dynamic and Shaking Table Tests on RC Bridges* - ECOEST/PREC8 Report. LNEC, Lisbon (in print)
- 6.5 Pinto A.V., Calvi G.M. - *Ongoing and Future Research in Support of Eurocode-8* - in: Proceedings of the 11th World Conference on Earthquake Engineering, Acapulco, Elsevier Science Inc., New York, 1996
- 6.6 Guedes, J., Pinto A.V. - *A Fibre/Timoshenko Beam Element for the Cyclic Bending and Shear Behaviours of R/C Structural Elements* - Special Publication, EC, JRC, Ispra, Italy (in print)



Figure 6.3: A typical three-storey steel frame construction was tested in ELSA. The scope was to verify the Eurocode 8 on earthquakes

Innovative Technologies for Earthquake Engineering

author: V. Renda

ELSA is involved in the support of the development and diffusion of innovative technologies for earthquake engineering. These technologies allow an efficient protection of buildings of relevant importance against the actions of strong earthquakes. The technologies include the base isolation of the structures and the energy dissipation. Base isolation decreases the free frequencies of the system reducing the resonance with the spectrum, while the energy dissipation moves part of the seismic energy on specific damageable components limiting the effects on the structural parts of the building. Base isolation apply mainly to new buildings while energy dissipation can be easily applicable also to existing ones. The effectiveness of these mechanisms, in particular as concern base isolation, has been proved by the behaviour of protected buildings in recent earthquake, but the diffusion of this technology is

strongly limited by the difficulty to validate the design of such systems. The contribution of ELSA, though its capability of testing large scale models of protected systems, can be very important for the validation of designs which include these innovative technologies.

Computer Simulations

In the field of dynamics of structures, computer simulation is essential for sensible and workable test results. In fact the precise understanding of both the underlying phenomena and the global structural behaviour heavily rely on detailed finite element analyses. A large number of such analyses using various models and oriented towards earthquake engineering issues (buildings submitted to seismic action) were carried out during 1996, among which:

- the development and calibration of an innovative semi-global model for shear dominated bridge piers;
- the improvement of a flexibility-based global model for reinforced concrete girders including distributed vertical loading;
- non-linear studies of the Geraci Palace in Palermo (IT) presented in Chapter 5 and of the S. Vicente de Fora Monastery in Lisbon (PT) to define an optimal experimental set-up and obtain pre-test estimates;
- the generalisation of sub-structuring techniques for extended PSD testing, for instance in the case of bridges only the piers are tested while the deck is entirely computed;
- the refinement of time integration schemes (implicit non-iterative);
- the development of new/improved material models in particular for masonry and concrete also including reinforcement; multi-scale approach.

- 6.7 Bonacina G., Indirli M., Negro P. - *The January 17, 1994 Northridge Earthquake* - Report to the Sponsor: Earthquake Engineering Field Investigation Team - Special publication N° I.94.14, 1994, Ispra (VA), Italy
- 6.8 Inukai M., Hiraishi H., Fukuta T., Nakata S., Negro P. - *Investigation of Damage to Buildings following the Hyogoken Nambu Earthquake* - 7° Convegno Nazionale "L'Ingegneria Sismica in Italia, September 25-28 1995, Siena, Italy
- 6.9 Negro P., Pinto A.V., Verzeletti G., Magonette G.E. - *PsD Test on a Four-Storey R/C Building Designed According to Eurocodes* - Journal of Structural Engineering - ASCE, Vol. 122, No. 11, 1409-1417, 1996.
- 6.10 Negro P., Verzeletti G. - *Earthquake Engineering and Structural Dynamics*, Vol. 25, 753-773, 1996.

Joining Techniques for Fibre-reinforced-composite Space-frame Structures

author: E. Gutiérrez

The objective of the research is to produce an efficient, and relatively cheap, beam-column joint for fibre-reinforced-composite (FRC) space-frame structures. These joints are one of the key elements in the construction industry, particularly when used in portal frame structures.

A typical FRC construction practice is to take beam and column profiles and join them using a variety of connectors, rather like angle brackets. The connectors may be cumbersome to mount and increase the number of parts required, and hence the cost of the final structure. Also, it is often the case that the joint as a whole is inefficient. There is a good reason for this: FRC's are strong in proportion to their weight, but, like wood, are orthotropic materials. In particular their, so-called, through-thickness properties are particularly poor; unfortunately, the loads produced in a beam-column joint are so that through-thickness stresses develop at critical areas of the joining jigs. The loads do not have to be particularly high to cause local failure, whereas the loads in the beam and column sections far from the joining area may be well below the maximum capacity. This makes for inefficient structures; too flexible and too weak in strength, i.e. their ability to withstand deformation. The technique of joining beams to columns that is being developed and tested at ELSA, tries to avoid some of the problems associated with assembling such systems by manufacturing a monolithic cruciform element and placing the joining connectors away from the bending stresses acting near the joint area. A cruciform joint, shown in Figure 6.4, manufactured using an autoclave moulding process would allow the designer to distribute the orientation of the fibres in the direction most suited to carry the working stresses.

The testing campaign consists of two stages. First, a selection through experimental testing, of the most favourable fibre alignment for the prototype, simply: design, test, design. This stage has already identified important design issues, which, in turn, have resulted in new specimen configurations. Ideally, this design process should be complemented with Finite Element pre-calculations.

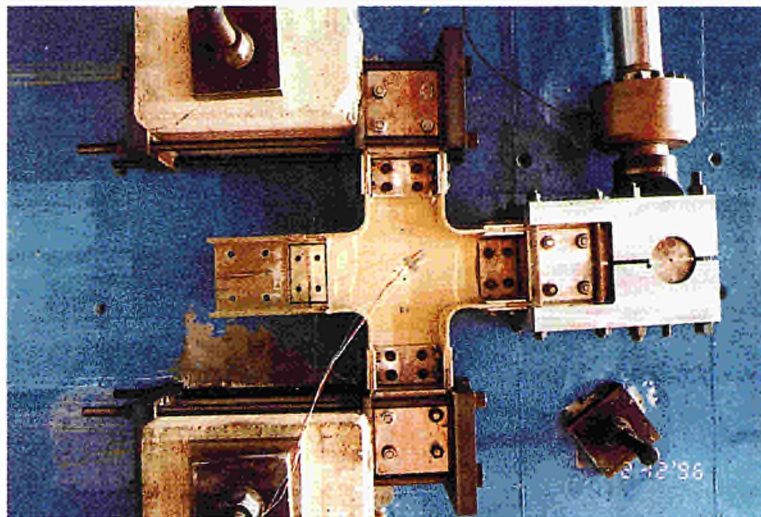


Figure 6.4: A cruciform sample measuring 0.85m by 0.85 m. The aim of the research is to produce an efficient and relatively cheap beam-column joint for fibre-reinforced-composite (FRC) space-frame structures.

The second stage will investigate the performance of the selected system within a simple, but representative, structure: a single bay portal frame will be constructed from pultruded beams and columns and the moulded cruciform joints.

Fast Dynamics of Concrete

author: C. Albertini

A precise description of the fracture process and the mechanical properties of plain concrete with real size aggregates under high loading rate are of basic importance for the assessment of engineering structures under severe accidental loadings like

- 6.11 Gutiérrez E., Verzeletti G., Galiotis C. - *Application of Composites to Civil Engineering Structures: Shear and Bending of Beam-to-column Composite Sections* - Advanced Composite Letters, Vol. 6, No 2, 1997
- 6.12 Bruneau M., Walker D. - *Cyclic Testing of Pultruded Fiber-reinforced Plastic Beam-column Rigid Connection* - J. of Structural Eng, Vol. 120, N°9, 1994
- 6.13 Mosallam A.S., Abdelhamid M.K., Conway J.H - *Performance of Pultruded FRP Connections under Static and Dynamic Loads* - J. of Reinforced Plastics and Composites, Vol. 13, May 1994

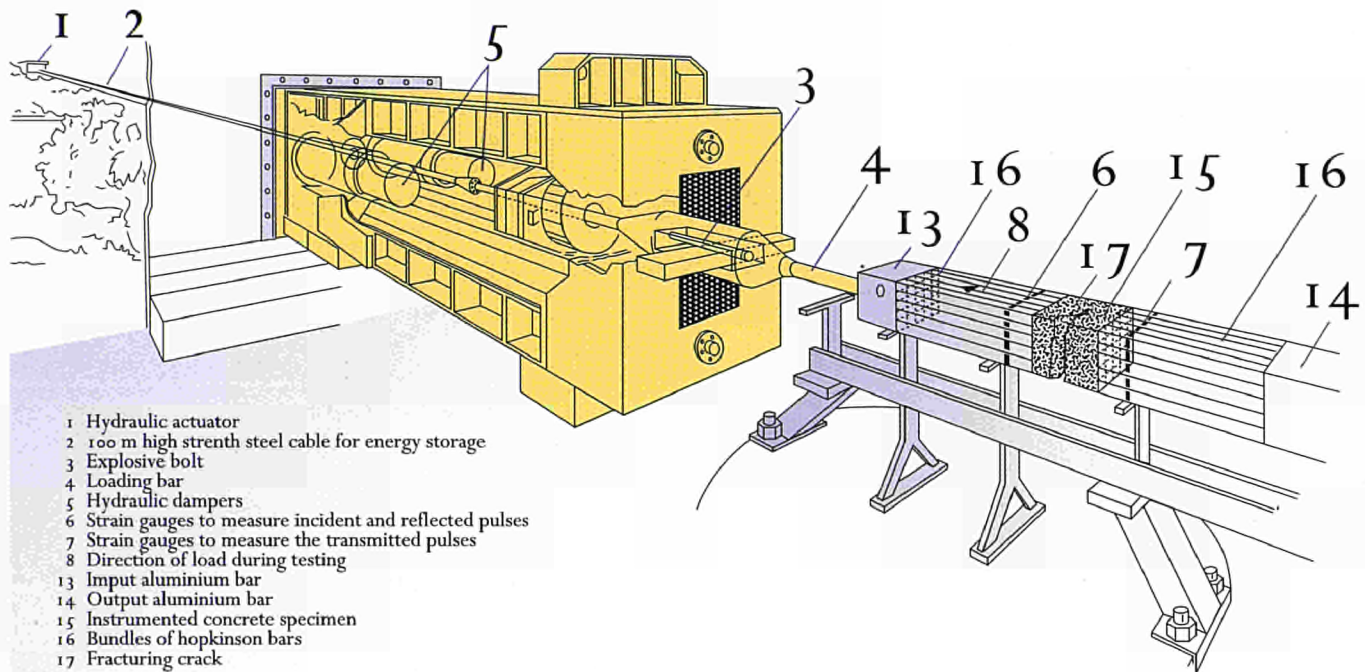


Figure 6.5: Large Dynamic Testing Facility in configuration for tensile tests of large concrete specimens for crack propagation measurements

those occurring in impacts, explosions and strong earthquakes. Therefore, an experiment has been conceived which foresees the high loading rate tensile testing of plain concrete cubes of 200 mm side with real aggregate size in the Large Dynamic Test Facility (LDTF). This special set-up device consists of a bundle of 25 elementary Hopkinson bars working in parallel over the cross-section of the large specimen shown in Figure 6.5.

The LDTF enabled the correct characterisation of the fracture process and of the softening branch of the stress-strain diagram. This is important for the evaluation of the energy absorption capability of the real material used in civil engineering structures. The test set-up was constructed using two square aluminium bars subdivided into 25 pairs of specular bars [6.14, 6.15]. Each bundle is individually instrumented with strain gauges. During the fracturing process phase, each pair of specular bars of the two bundles measures the incident, reflected and transmitted pulse I, R, T, concerning only the portion of the specimen cross-section facing the cross-sections of this particular pair.

A large programme of tension and compression

testing in a range of strain rate extended from 10⁻⁶ to 10 s⁻¹ was performed with the support of industry; this study includes the investigation of aggregate size (up to 25 mm), specimen size and of relative humidity. Figure 6.6 is an example of the important strain rate effects that have been observed in this research programme [6.16].

Material Behaviour of Reactor Confinement Structures

author: G. Solomos

The impact problems that occur as a consequence of hypothetical steam explosions in nuclear reactors require a correct knowledge of the material deformation and failure processes. Accompanying investigations are thus needed to make sure that the results are transferable to the real problem and that the essential effects are adequately simulated:

- 6.14 Albertini C., Montagnani M. - *Testing Technique in Dynamic Biaxial Loading* - Institute of Physics, London, 1979, Conf. Ser. No. 47, 25-34.
- 6.15 Albertini C., Montagnani M. - *Study of the True Tensile Stress-strain Diagram of Plain Concrete with Real Size Aggregate; Need for and Design of a Large Hopkinson Bar Bundle* - Journal de Physique IV, Colloque C8 Supplement an Journal de Physique III, Vol. 4, September 1994, pp. 113-118.
- 6.16 Economou S., Cadoni E., Labibes K., Albertini C. - *Strain Rate Effects on Plain Concrete in Tension* - AIAS International Conference on Material Engineering, Gallipoli, Italy, September 1996

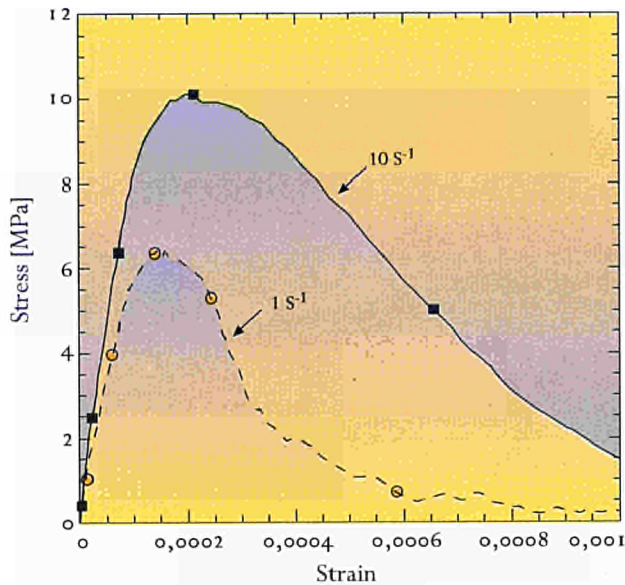


Figure 6.6: The strain-rate effect during tension loading of concrete shows the different stress measured in the material depending on the deformation speed.

(specimen) size effect, strain rate effect, temperature, and strain gradient effects. The particular underlying scenario is the impact of a slug of molten corium and debris on the upper head as well as the dynamic pressure loading in the lower part of the reactor vessel due to steam explosion.

Its maximum mass and kinetic energy are to be investigated as, should the upper head fail, missiles could be generated able to penetrate the containment shell, and thus cause severe environmental consequences immediately. Theoretical investigations and modelling have produced strongly differing and unreliable results, and therefore, experiments with detailed structural mock-ups have been deemed necessary (BERDA and FLIPPER experiments of the Forschungszentrum Karlsruhe, FZK). The LDTF sector has been assigned in a shared-cost action project to carry out these dynamic tests for material characterisation of large specimens under well defined strain rates. Uniaxial and biaxial tension tests are foreseen of the materials used for the pressure vessel and its internal structures. These include: ferritic steel 20 Mn Mo Ni 55 (vessel head), austenitic steel X6 Cr Ni Nb 1810 (Upper Internal Structure), ferritic steel 26 Ni Cr Mo 146 (bolting), brass (simulation of UIS in BERDA). Specimens will be tested at room temperature and at 800°C, and at strain rates ranging from quasi-static (10^{-3} /sec) to dynamic (200/sec) conditions. The work at ISIS in 1996 has been mainly concentrated towards the preparation of the experiments.

Radar Tests Performed by SAI at ELSA

authors: E. Ohlmer, D. Tarchi

Interferometry is being studied at the Advanced Techniques Unit of Space Application Institute of the JRC as a technique able to monitor structural changes of building or similar man-made structures with a precision in the order of a fraction of millimetre and a spatial resolution of few centimetres. The technique is based on the comparison between a pair of complex radar image acquired before and after the event producing structural changes. The recorded phase difference between the image pair is directly related to the displacements of the visible portion of the imaged scene. The range of applicability, mainly in terms of structure characteristics and environmental conditions, seems to be very wide making the technique suitable for in situ measurements on large structures. Moreover, exploiting the capabilities of microwave to penetrate non-metallic materials such as concrete, the internal stress can be monitored below the surface.

Following the positive results of a first feasibility test performed at the European Microwave Signature Laboratory (EMSL) of JRC a new more realistic test has been performed at the ELSA facility on the in-scale model of the facade of Palazzo Geraci (see Chapter 5).

Measurements have been performed using the portable outdoor linear Synthetic Aperture Radar (SAR) system (LISA) of the Advanced Technology Unit. In order to better image the whole structure a new original 3 dimensional SAR geometry has been implemented allowing to produce a tomogram of the structure under test but also requiring the development of a new dedicated software program to process the data.

The validation of the software tool is currently under completion. A preliminary validation and analysis of the data collected at ELSA shows an overall good agreement with the expected deformation patterns. Further analysis, leading to more accurate results, is currently being performed.

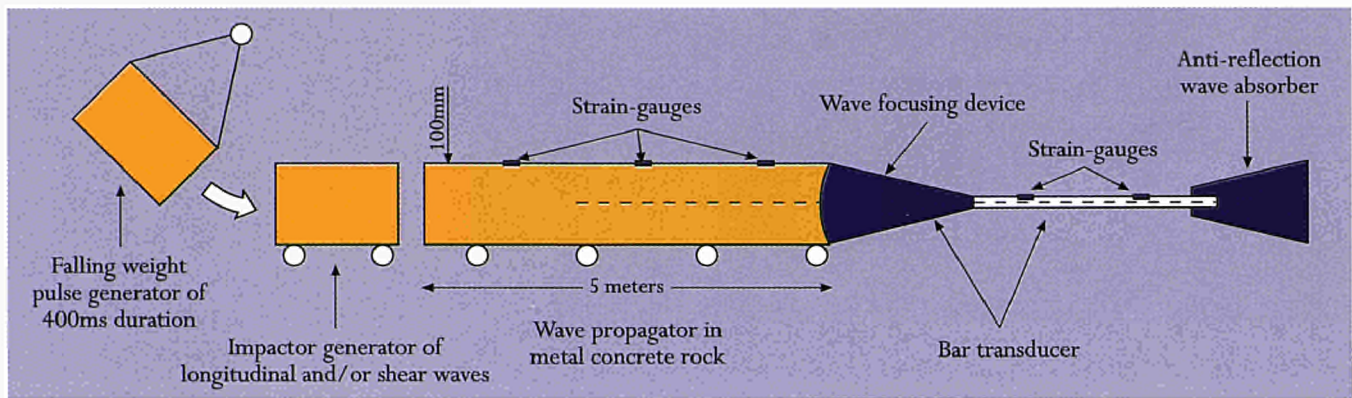


Figure 6.7: Sensor for seismic precursors; testing set-up

Smart Composite Materials

author: R.P. Kenny

Smart composite materials are composite materials with self-monitoring capabilities, primarily providing strain data and damage detection. Actuators may also be incorporated which control the form of the material as desired based on the monitor data. Monitoring is typically provided by embedding networks of fibre optic sensors within the material during fabrication. Two current projects in this field are the Characterisation and Testing of Pultruded Composite Beams for Structures and the Tomographic Shape Reconstruction of Composite Panels.

Sensor-based Earthquake Monitoring and Prediction

authors: C. Albertini, C. Coutsomitros

The present research proposal aims to achieve, as long term target, a substantial improvement in the monitoring and prediction of earthquakes and other natural phenomena like volcanoes, landslides. Intermediate targets of this research will be the optimisation and safety of important industrial activities such as mining and large civil engineering works.

The research proposal is based on the scientific theory that the source of an earthquake is a fracture-like process in which a large rock mass fails across a thin region (i.e. the fault surface) which extends rapidly outward from the nucleation zone with a

sudden release of enormous amounts of energy propagation at long distances as seismic waves. From this approach two major problems should be considered in the research proposal:

- a continuous, precise and clean recording directly in the ground of propagation parameters of weak (precursors) and strong seismic waves;
- the development of a physical model correlating energy release (seismic wave history) with the state of the fault rupture (source).

The improvements in accuracy of recording seismic wave history are pursued by developing new field sensors based on stress wave mechanics principles, which capture pressure displacement and particle velocity caused by the seismic wave in direct physical contact with the ground material. Preliminary exploratory experiments with the new sensor (Figure 6.7) have shown the possibility of accurate measurements and resolution of normal and shear components of the incident complex wave. The development of the physical models of fault rupture are based on special laboratory tests of large rock specimen fracture instrumented with the same type of wave sensors under development for the use in the field in order to have comparability between field and laboratory records. Tests on large geological material specimens will be performed at the Laboratory, by means of special multiple Hopkinson bar wave sensors (Figure 6.5).

The development of the new sensors and of the physical model of fault rupture will be validated by experiments with small and large ground movements provoked in the LDTF Laboratory or by means of explosives in old mines. Finally, the installation of a network of the new sensors around an active geological fault and around an active volcano or landslide will be investigated.

Industrial processes and clean technologies

author: B.Worth



The work of ISIS in the area of industrial processes and clean technologies covers many diverse activities. Scientific support for the development and implementation of EU legislation is provided through the continuous monitoring of EC directives in fields such as biotechnology, the environment and major accident hazards. Safety and reliability in the process industry derives many benefits from the application of fault tree analysis to the probabilistic study of accident consequences, as well as from a better understanding of the deterministic behaviour of complex plant.

Figure 7.1: The Major Accident Hazard Bureau provides support to DG XI (Environment, Nuclear Safety and Civil Protection) for the implementation of the Directive on the Major Accident Hazards of Certain Industrial Activities (82/501/EEC) and its amendments and revisions.



Computational fluid dynamics is now widely used in ISIS for the numerical simulation of gas explosion phenomena, multiphase flow processes, the emergency venting of relief lines and for transient fluid-structure interactions. These techniques, supported by experimental research, provide the scientific basis for continued progress in the improved control and supervision of chemical plants that in turn leads to cleaner and safer process technologies in Europe.

Scientific and Technical Support for EU legislation

This activity within ISIS covers three broad technical domains: (1) Biotechnology and Environment, (2) Major Accident Hazards, and (3) Environmental Impact. In the first two of these domains, ISIS, in addition to offering scientific and technical support for the development and implementation of EU Directives, has specific responsibilities for the gathering of bibliographic information, for assessing its relevance, and for the receipt of notifications imposed by the Directives and their subsequent handling and analysis.

Biotechnology and Environment

author: *G. Van den Eede*

In the domain of Biotechnology and Environment, support is provided to DG XI (Environment, Nuclear Safety and Civil Protection) to monitor the following directives:

- 90/219/EEC on the contained use of genetically modified micro-organisms
- 90/220/EEC on the deliberate release and placement on the market of genetically modified organisms (GMOs)

Notifications are mandatory information submitted by member states to the JRC, which then redistributes it to all member states and to the Commission's competent General Directorate. A major effort in 1996 was devoted to the implementation of a system for exchange of information on planned field trials of GMOs. An electronic format has been developed at the JRC that allows for efficient data exchange and data handling, with each member state running a local database and transferring appropriate information

to and from the JRC. The data submitted to the Commission are then analysed, and the results of this analysis presented to DG XI and the member states. A total of 975 notifications have been circulated so far.

The BIOSAFE initiative is represented by the Community Documentation Centre on Biotechnology Safety and Regulations. This body collects and analyses all information relevant for the Commission with a view to the harmonisation of member states' legislation on the production and exploitation of GMOs. It focuses on general documents, scientific literature and inventions related to legislation and safety aspects.

In 1996 BIOSAFE published the third edition of its "Bulletin", with reviews of pertinent publications collected in the course of the year, together with abstracts and a document index. BIOSAFE has also prepared a "Guide for Users" to the information contained within the bulletins. A web site (<http://biosafe.jrc.it>) has been created that contains details on field trials in the European Community, on regulatory aspects of biotechnology and on the BIOSAFE activity.

On behalf of the Forward Studies Unit of the European Commission, a project on Quantitative Environmental Risk Assessment (ERA) was initiated to study whether it is feasible to carry out comparative risk assessments of product dossiers which come under the Directive 90/220/EEC.

In addition, a research project on Safety Assessment of a Biotechnology Pilot Scale Facility was carried out on behalf of the Italian Institute for Health at Work (ISPESL). The aim was to take a pharmaceutical pilot plant as a real case example to study risk assessment methodologies for contained use facilities.

Major Accident Hazards Bureau

author: *Neil Mitchison*

The Major Accident Hazards Bureau (MAHB) is the second major domain of activity in the area of EU legislation (Figure 7.1). Providing institutional support to DG XI, the MAHB monitors the following Directives:

- 82/501/EEC ("Seveso Directive") on Control of Major-Accident Hazards (current)
- 96/82/EC ("Seveso II Directive") on Control of Major-Accident Hazards (Dec. '96)

Much of MAHB's activities in 1996, particularly the

organisation of Technical Working Groups (TWGs), centred on the requirements of the new Seveso II Directive, passed in 1996 and due to be implemented throughout the EU by February 1999.

The Major Accident Reporting System (MARS) is an information exchange system for notifying major accidents. A new software tool has been developed in 1996 which comprises a distributed data logging system for use in member state authorities, a central data management system and advanced analysis tool for use at the JRC. Using MARS, member state authorities can quickly notify all accidents in electronic form, using either computer diskettes or e-mail. The software was distributed to member state authorities in late 1996 for testing and evaluation; the central system has been specified and is now being built.

The Community Documentation Centre on Industrial Risk (CDCIR) collects a wide variety of material, both published (e.g. books, articles, reviews, laws) and unpublished (codes of practice, recommendations, company reports, theses) relevant to the control of industrial risk and the prevention and mitigation of major accidents. It has currently over 2300 documents. The 10th edition of the CDCIR Bulletin was distributed in 1996. New CDCIR bibliographic software was finalised, and the key-word reference system was completely updated.

Five technical working groups currently provide "guidance" on the implementation of Directive requirements in areas such as Safety Reports, Safety Management Systems, and Major Hazards in Land Use Planning, on Substances Dangerous to the Environment, and on Harmonised Criteria for Derogations permitting the limiting of information in a safety report.

Environmental Impact

author: A. G. Colombo

The third major activity concerned with legislation covers Environmental Impact Assessment (EIA), analysis of environmental indicator models and investigation on natural disasters.

Support was given to DG XI (Environment, Nuclear Safety and Civil Protection) covering the Council Directive 85/337/EEC on the "assessment of the effect of certain public and private projects on the environment". A Comparative analysis of Environmental Impact Studies (EISs) of installations for the treatment and disposal of toxic and dangerous waste in the EU was carried out [7.12, 7.13, 7.14]. A study was also carried out to develop and implement an overall strategy for Environmental Impact Assessment and Strategic Environmental Assessment research (EIA/SEA) in the EU [7.15].

Support was given to the European Environment Agency. A preliminary analysis was made of types of environmental indicators and categories of environmental aspects [7.16, 7.17]. Schemes and diagrams used in various countries to illustrate linkage in environmental issues will be discussed in a report to be completed early 1997.

In support to the statistical office of the European Communities and in view of the implementation of the 'Communication from the Commission to the Council and the European Parliament - Directions for the EU on Environmental Indicators and Green National Accounting; COM (670) final, Brussels, 21 Dec. 1994', a study on the Modelling of Environmental Pressure Indicators was performed. The objective of this study is the identification of different modelling approaches used for generating environmental pressure indicators, the types of input/output data involved and data uncertainty considerations.

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 - 7.3 Besi A., Amendola F., Belloni V., Christou M., Smeder M., Amendola A., Poli U. - *La pianificazione dell'uso del territorio in relazione ai rischi d'incidente rilevante* - EUR 16412 IT, 1996
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 - 7.6 Smeder M., Christou S., Besi A. - *Land Use Planning in the Context of Major Accident Hazards - An Analysis of Procedures and Criteria in selected EU Member States* - EUR 16452 EN, 1996
 - 7.7 Cozzani V., Amendola A., Zanelli S. - *Hazardous Substances Formed as a Consequence of Industrial Fires* - 3rd seminar "European Research on Industrial Fires", Denmark, Sept. 1996
 - 7.8 Mitchison N. - *Major Accident Hazards; European Activities in Prevention, Mitigation, and Response* - 5th TIEMEC Conference, Montreal, May 1996
 - 7.9 Papadakis G., Amendola A. - *Learning from experience: the Major Accident Reporting System in the EU* - ESREL '96/PSAM-III Conference, Crete, June 1996
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 - 7.11 Perschke C., Kirchsteiger C. - *Community Documentation Centre on Industrial Risk* - Bulletin no. 10, 1996



Safety and Reliability in the Process Industries

author: S. Contini

The risk assessment of potentially dangerous processes is performed through the application of a well-defined procedure comprising hazard identification, accident frequency and consequence calculations, and risk estimation. Fault Tree Analysis is a widely used technique for accident frequency estimation through the identification and probabilistic quantification of plant failure modes, whereas mathematical models are applied for modelling the consequences of significant accidents.

Fault Tree Analysis with 'Ispra-FTA'

Fault Tree Analysis provides a formal procedure for the systematic description of the failure logic of a complex system and the quantification of the occurrence probability. A new fault tree analysis tool ISPRA-FTA/W (a Windows version of ISPRA-FTA) based on new powerful computational methods has been developed in the institute. Novel use is made of the 'binary decision diagram', which can be considered as the most efficient analysis approach [7.18], together with a revised version of the hybrid approach [7.19] implemented in previous Dos versions of ISPRA-FTA. Besides the common probabilistic and logical cut-offs, a new type of cut-off has been implemented based on the maximum number of significant 'minimal cut sets'. These technical solutions allow faster calculation times and the possibility to analyse several complex fault trees in an efficient way.

Depending on the input data, this new software is up to 50 times faster than the DOS version. A powerful on-line editor, allowing full syntactic analysis and completeness check on the input data, now facilitates input generation. A highly-interactive user interface has been developed to meet specific user needs and to ease the preparation of detailed technical documentation required for safety and availability studies.

Accident Consequences and Domino Effects

authors: S. Contini, J.P. Nordvik

The so-called 'domino effect' plays a fundamental role in the evolution of an incident scenario, where a certain event can suddenly trigger a cascade of 'knock on' events with possibly disastrous consequences. However, the development of relevant methodologies and software tools explicitly addressing this issue has been held back not only because of modelling difficulties but also because of the lack of legislation.

Many software packages for consequence assessment are available on the open market but, in ignoring 'domino effects', oblige the analyst to use a pre-defined set of consequence models and accident sequences. This severely restricts the consequence assessment where efforts are continuously needed to reduce uncertainties through the definition of new models and in the use of more reliable data. In this perspective, the in-house development of the software package DOMINO recognises the importance of these effects on consequence assessment, the most important design issue being to allow subsequent changes and additions to the original software framework [7.20].

The main application in this software system is the Stars Event Tree Editor (an object-oriented representation of plants for safety and reliability analysis). It allows the construction of event sequences where new models can be easily added by a user. In this way, the user can define his own taxonomies of models, components, or substances and thus maintain complete control over the information contained.

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 - 7.13 Colombo A.G., Artola A., Gervasi C., Haq G., Melaki I. - *Ispra Study on Methods used in EISs for Annex I.9 Installations* - in: EIA Newsletter 12, Lee N., Barker A.J., Wood C. and Jones C.E. (Eds.), University of Manchester, Summer 1996
 - 7.14 Colombo A.G. - *An EC Analysis of EISs of Treatment and Disposal Installations for Toxic and Dangerous Waste (in Italian)* - in: Notizie dal Centro V.I.A. Italia, n. 3, 1996, Chitotti O. (Ed.)
 - 7.15 Colombo A.G., Haq G., Melaki I. - *A Study to Develop and Implement an overall Strategy for EIA/SEA Research in the EU* - Report available from EC DG XI, Brussels.
 - 7.16 Colombo A.G., Chitotti O. C. - *Types of Environmental Indicators and Categories of Environmental Aspects in Environmental Analysis* - in: Chemical Industry and Environment II, 3rd Volume, Piccinini N. and Delorenzo R. (Eds.), Politecnico di Torino, 1996
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 - 7.18 Contini S., de Cola G. - *A Top Down Approach to Fault Tree Analysis Using Binary Decision Diagrams* - European Journal of Automation, Vol. 30, n. 8, 1996
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RELAP5-MF

authors: B. Worth, G. Franchello.

Many years of involvement with the reactor safety code RELAP5 (for thermohydraulic analysis of complex systems) has provided new opportunities for extending the code into non-nuclear application areas. RELAP5-MF is a 'multi-fluid' version of the code with enhanced capabilities to model complex cooling systems having working fluids other than water. Single-component pure substances (e.g. refrigerants, cryogenic fluids, propene, compressed gases) can now be represented as well as simplified multi-component 'pseudo-fluids' (liquified petroleum gases or LPGs, hydrocarbon fuels) opening up new fields of interest.

Feasibility studies have demonstrated the usefulness of the code in modelling refrigeration systems, liquid hydrogen cooled components, accidental releases from reservoirs, oil pipeline hydrodynamics, and process plant transients. Collaboration with partners in the petrochemical industry has provided the first experimental verification and assessment of the 'pseudo-fluid' approach in handling LPG mixtures. Plans to further develop the code for process design and for optimisation of industrially-relevant operating procedures are being discussed.

Although the code is able to represent only a 1-D flow field, its usefulness comes from being able to treat very complex systems comprised of interconnected pipes, vessels, pumps, heat exchangers and control system elements. A modular approach allows a whole plant to be built up from simple subsystems and components. The complete thermal-hydraulic transient behaviour of the plant can then be simulated for a range of initial and boundary conditions or accident initiating events.

Computational Fluid Dynamics

Computational Fluid Dynamics (CFD) activities during 1996 included the modelling of gas explosions, fluid-structure interactions and structural response, multiphase flow processes, emergency relief and transient flow in complex networks. The numerical simulation of gas cloud explosions calls

for sophisticated computing techniques in order to capture the correct thermophysical characteristics of high Mach number combustion processes. Equally important from an engineering point of view is the effect of such explosions on surrounding structures. These have been important activities at the JRC for many years culminating in the development of REACFLOW (REACTIVE gas-FLOW simulations' code) for the modelling of arbitrary gas explosions, and, jointly with the CEA, France, the fluid-structure finite element code PLEXIS-3C (transient fluid-structure interactions code). Web pages describing recent developments can be found at:

<http://poplar.sti.jrc.it> and <http://www.sti.jrc.it/ELSA>.

Explosion modelling

authors: H. Staedtke, T. Huld

The REACFLOW code, originally developed at the JRC within the Industrial Hazards programme, is used to simulate deflagration and detonation processes in an arbitrary mixture of gases. Using finite volume upwind discretisation methods, the code can predict fast combustion processes in confined spaces taking account of all relevant diffusion processes like heat conduction, compressibility and viscosity effects, and flow-induced turbulence. It provides a detailed description of the chemistry and reaction kinetics of the combustion process, with optional explicit or implicit time integration schemes. The use of unstructured grids and automatic grid adaptation allows the high resolution of these processes in complex geometries. Turbulence may be represented using a k- ϵ model or an eddy dissipation model.

In 1996, developments concentrated on extending the 2-D Cartesian unstructured grid code version to include a 2-D axisymmetric option and a preliminary code version for 3-D flow conditions. External co-operation through various shared cost action projects in the areas of Reactor Safety and Technology Transfer as well as in collaboration with industrial partners have helped in further development of the code. One of these projects includes application of REACFLOW to problems of hydrogen distribution and turbulent combustion in LWR (Light Water Reactor) containment structures in the case of severe accidents and will allow verification of such codes on the basis of data coming from small-scale and large-scale test facilities. Other projects include the study of containment behaviour in the unlikely event of core melt with

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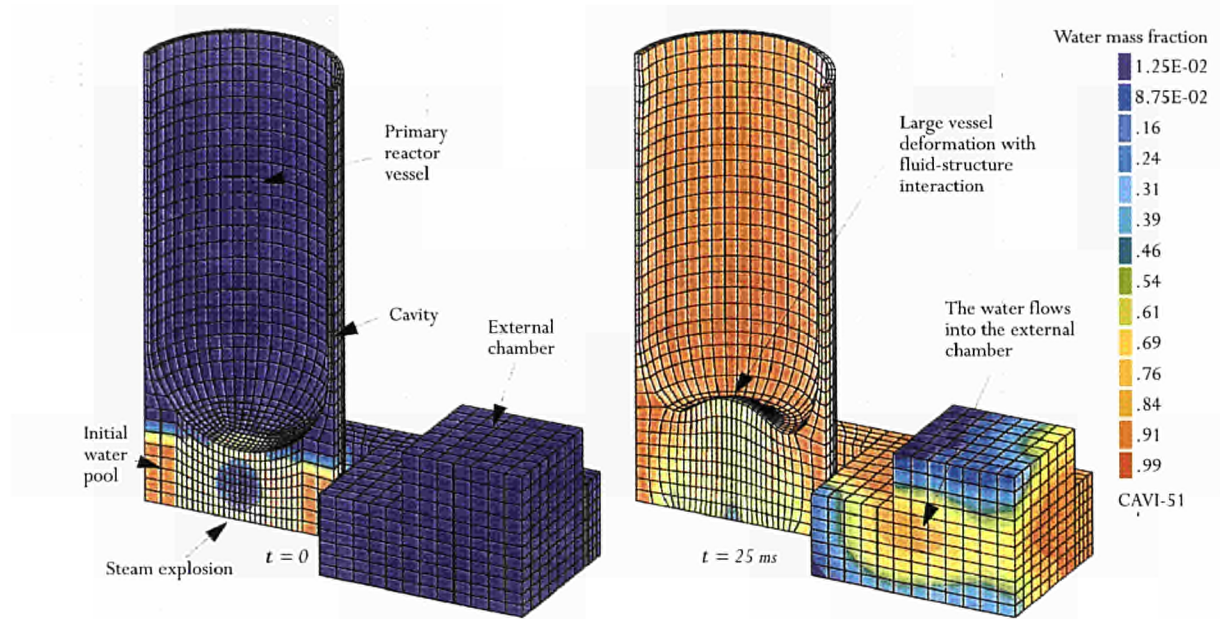


Figure 7.2: PLEXIS-3C: Simulation of a steam explosion in a 3D cavity (only half of the cavity is shown to highlight the internal section).

large gaseous releases, application of the 3-D code version to off-shore gas platforms, and more generic studies on the evaluation of computer models for predicting explosions and structural response.

PLEXIS-3C

author: F. Casadei

PLEXIS-3C is a general purpose computer code for the detailed non-linear analysis of fluid-structure systems subjected to fast transient dynamic loading. It can be used for a large class of problems involving impulsive / impact loading, and in particular for the study of explosion effects on structures of complex shape (Figure 7.2).

The generality and versatility of the computer code has been further extended in 1996 through a number of specific activities:

- 2-D spectral elements (with suitable loading patterns) and Cam-clay material models have been introduced in PLEXIS-3C in the framework of TRISEE, an 'Environment and Climate' shared-cost action dealing with 3-D soil-structure interaction in earthquake and vibration risk analysis.
- Earlier developments regarding multi-layer shell elements and a Drucker-Prager material model with visco-plastic regularisation have been completed.

- Graphical post-processing has been enhanced by the introduction of an AVS interface.
- Recent development efforts performed for the Ente Nazionale per l'Energia eLettrica (ENEL) were mainly devoted to fluid modelling and included a generalisation to multicomponent fluid flows (3-D), a refined corrected scheme for fluid-structure interaction in the presence of warped 3-D surfaces, an energy injection model, the treatment of rupture disks, and a review of the numerical integration of momentum transport.

Advanced Two-phase Flow Simulation

authors: H. Staedtke, G. Franchello, B.Worth

Many problems in the process industry involve inhomogeneous multiphase flow with chemical reactions. Serious difficulties arise in modelling such processes, firstly from the physical and mathematical complexities involved in trying to specify a sufficiently complete set of conservation laws and constitutive relationships, and secondly in formulating a numerical solution scheme that is not limited by the inevitable approximations being made. An advanced two-phase flow software being developed at the JRC offers a new approach to the

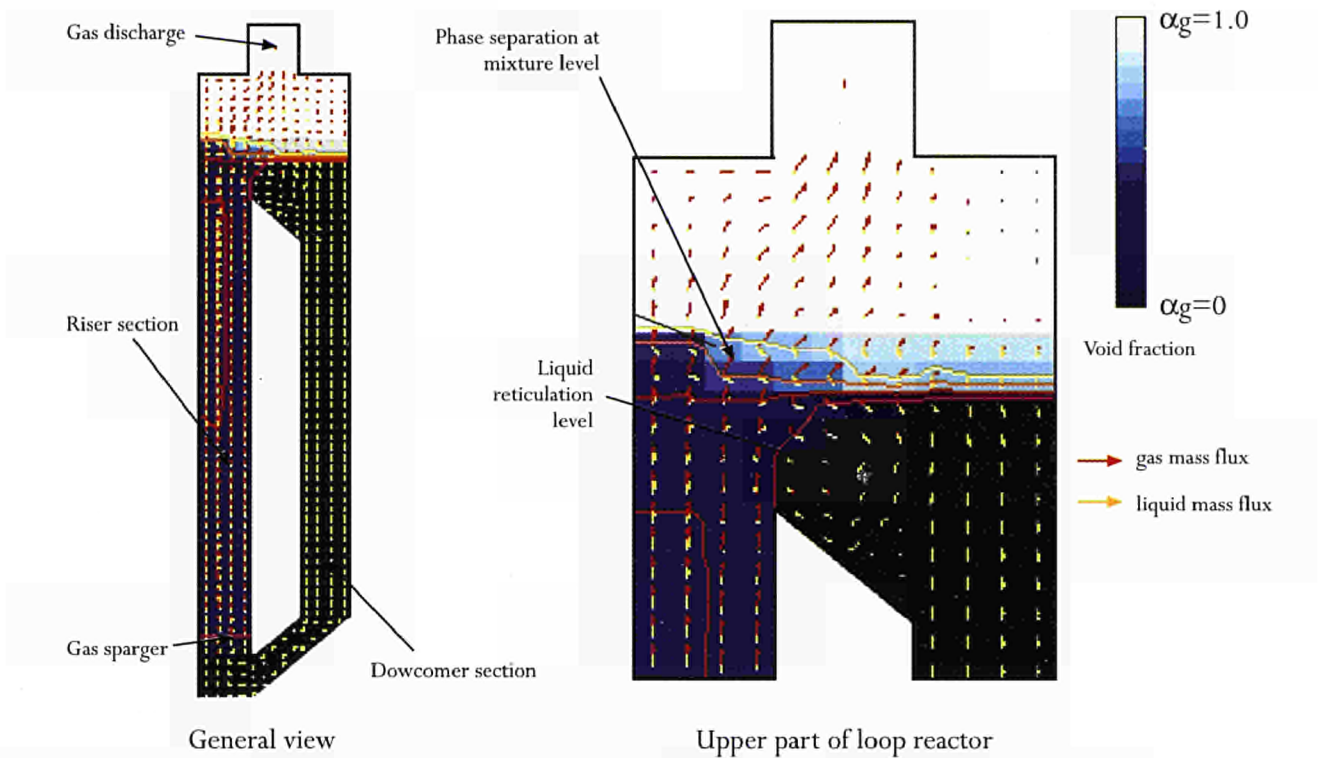


Figure 7.3: Numerical simulation of flow in a gas lift loop reactor. Gas lift loop reactors are widely used in the chemical industry for the production of industrial gases. The design and operation of these reactors will benefit from software that correctly simulates the flow field. Significant progress has been made in simulating the gas separation in the upper part and re-circulation within the reactor. Next steps will be to include a model for chemical reactions at the gas-liquid interface. The figures shows an overlay of calculated mass fluxes for gas and liquid with void fraction spectrum and iso-void fraction lines.

simulation of transient, multidimensional two-phase flow. It is based on a fully hyperbolic two-fluid model of two-phase flow using separated conservation equations for the two phases and includes a separate balance equation for the transport of interfacial area concentration - important for the modelling of chemical reactions. The numerical scheme makes particular use of the eigenstructure of the set of governing equations which allows an algebraic formulation of the major dependent flow parameters. A 2-D code version using polygonal unstructured space discretisation is fully operational. Fluxes at the cell-to-cell interfaces are calculated as a series of quasi one-dimensional Riemann problems normal to the specific boundary section of the computational cell. This facilitates the application of very low numerical diffusion techniques which combine signal propagation along characteristic lines with the conservation property with respect to mass, momentum and energy (Figure 7.3). Developments in 1996 tackled the difficult problem of including a separate field for arbitrary particle clouds to represent clusters of bubbles or droplets,

and having the potential to model flow regime transitions and chemical reactions at the moving particle interface. A preliminary code version for non-reacting monodispersed bubbly flow was successfully implemented in 1996 [7.22]. This will be extended in 1997 using a probability distribution function approach to couple particle number density to interfacial area concentration across a wide range of bubble (or droplet) sizes.

This work supports the 'ADMIRE Project' - a four-year multi-national research activity aimed at developing new design methodologies for the improved performance of gas-liquid chemical reactors. It is being carried out as a BRITE-EURAM project within the EU's 'Environment and Climate' section of the Fourth Framework Programme.

- 7.22 Blahak A., Staedtke H. - *Modelling of Transport of Interfacial Area Concentration in Two-phase Flow Systems* - European Two-phase Flow Group meeting, Grenoble, June 1996

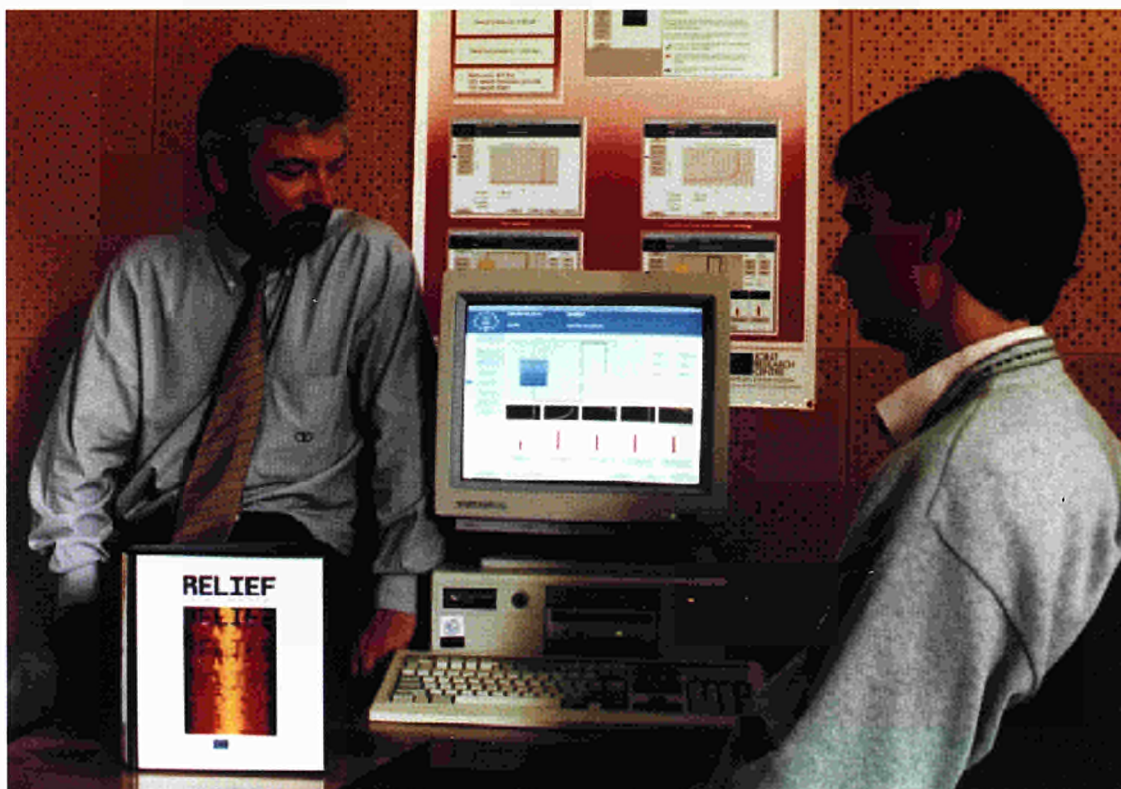


Figure 7.4: The RELIEF software which simulates emergency pressure relief scenarios for a safe design of chemical reactors.

Emergency Relief Systems (RELIEF)

author: S. Duffield

One of the major results from the Industrial Hazards Programme has been the development and commercialisation of the software package RELIEF (Figure 7.4). This software is concerned with modelling the emergency pressure relief of a chemical plant when an uncontrolled thermal runaway reaction occurs [7.23]. Its relevance is related to the EU directives 'Seveso' and 'Seveso II' (EU Directive 96/82/EC). Pressure relief and disposal systems are critical safety devices used to protect chemical and petrochemical installations from over-pressure. Incorrect design of relief systems has led to a large number of accidents which have resulted in significant loss of life and adverse impact on the environment.

Design and simulation calculations are complex and RELIEF provides a means by which this knowledge can be transferred to industry. Although the code is at an early stage of commercialisation, it is currently

used by European and Japanese industries. RELIEF plays an important role in the CHEERS (Chemical Hazard Evaluation and Emergency Relief Systems) shared-cost action. It has recently been transferred to the University of Palermo and is being further developed for widespread applicability.

Control and Supervision of Chemical Processes

author: M. Wilkens

Increased complexity of modern industrial plants is forcing operators to radically rethink the role of systems management and control. Many chemical processes can undergo rapid changes away from a controlled near-equilibrium or slow transient state, quickly developing into an off-normal 'runaway' event requiring immediate operator intervention and possible activation of the plant's shutdown systems. Due to the increasing level of control room automation, operators' tasks have shifted away from reactive low-level interventions to proactive supervisory functions. In such scenarios, the pressure on plant operators is often substantial because minor

mistakes in the interpretation of large amounts of data, and possible errors of judgement on the state of the plant, can have catastrophic consequences.

Two projects are running at the JRC to address these problems. The FORMENTOR project is a real-time plant analyser using knowledge-based on-line decision making for operator support and risk management. The FIRES project is an experimental facility specially designed to reproduce chemical runaway reactions and to study how these events can be managed using software-driven prognosis methods.

The FORMENTOR Project

One approach to risk management is to allow the emergency systems to shut down parts of the plant whenever any potentially dangerous problem is detected. This is far from ideal in terms of plant availability and often leads to unnecessary loss of production. Plant operators instead prefer greater control to reduce plant downtime, to increase safety and to improve product quality, which in turn requires improved assimilation of the information presented. This is the rationale behind the EUREKA project FORMENTOR - a real-time knowledge-based system to offer on-line decision support to operators of complex plant who are faced with unusual and potentially hazardous situations [7.24, 7.25]. During 1996, possibilities of extending FORMENTOR's functionality towards support of maintenance and safety management were investigated.

FIRES

author: H. Nieman

The Facility for Investigating Runaway Events Safely (FIRES) is a multi-purpose pilot plant (see Figure 7.5 a and b), with an extensive supporting calorimetric laboratory, for research into off-normal behaviour (e.g. failures, worst case scenarios) and

testing of shut-down systems of (semi)-batch chemical reactors at conditions close to those achieved in normal industrial practice [7.26]. Some experiments performed in 1996 included:

- The study of nitration of o-nitrochlorobenzene to dinitrochlorobenzene (in collaboration with the University of Stuttgart) was continued. The aim of this research is to validate a model which, in combination with a Kalman-filter, can be applied as a self-adapting algorithm for a model-based process control system. The experiments were carried out at lower acid strengths and thus with increased accumulation and runaway potential.
- The work for the safety evaluation of an existing production plant for styrene butadiene emulsion copolymerisation was published [7.27] with the partner company.
- Suspension polymerisation of methylmethacrylate is an industrial process for PMMA (e.g. perspex, plexiglas) production. Experiments were carried out both in the calorimetric laboratory and the 100 litre FIRES reactor. The aim of the research was to obtain experimental data for model development.

For a study of the application of parametric sensitivity analysis [7.28] for safe design of batch reactors experiments were carried out in the FIRES reactor. The well known esterification of propionic anhydride and 2-butanol was selected for this purpose. Different catalyst concentrations (sulphuric acid) were used to generate accumulation and subsequent runaway.

Volumetric Measurements

author: B. Hunt

Techniques for the Volumetric measurements and high-integrity sealing techniques are available for the process industry as they are for the safeguards processes (see Chapter 9)

- 7.24 Wilikens M., Burton C.J. - *FORMENTOR: Real-Time Operator Advisory System for Loss Control. Application to a Petrochemical Plant* - International Journal of Industrial Ergonomics Vol. 17, N^o. 4, April 1996. Elsevier Science Publishers. ISSN 0169-8141
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- 7.26 Nieman H., Ligthart J., Bassani C. - *'FIRES: European Runaway Research for Batch Reactor Safety* - presented at the 1996 Process Plant Safety Symposium Houston

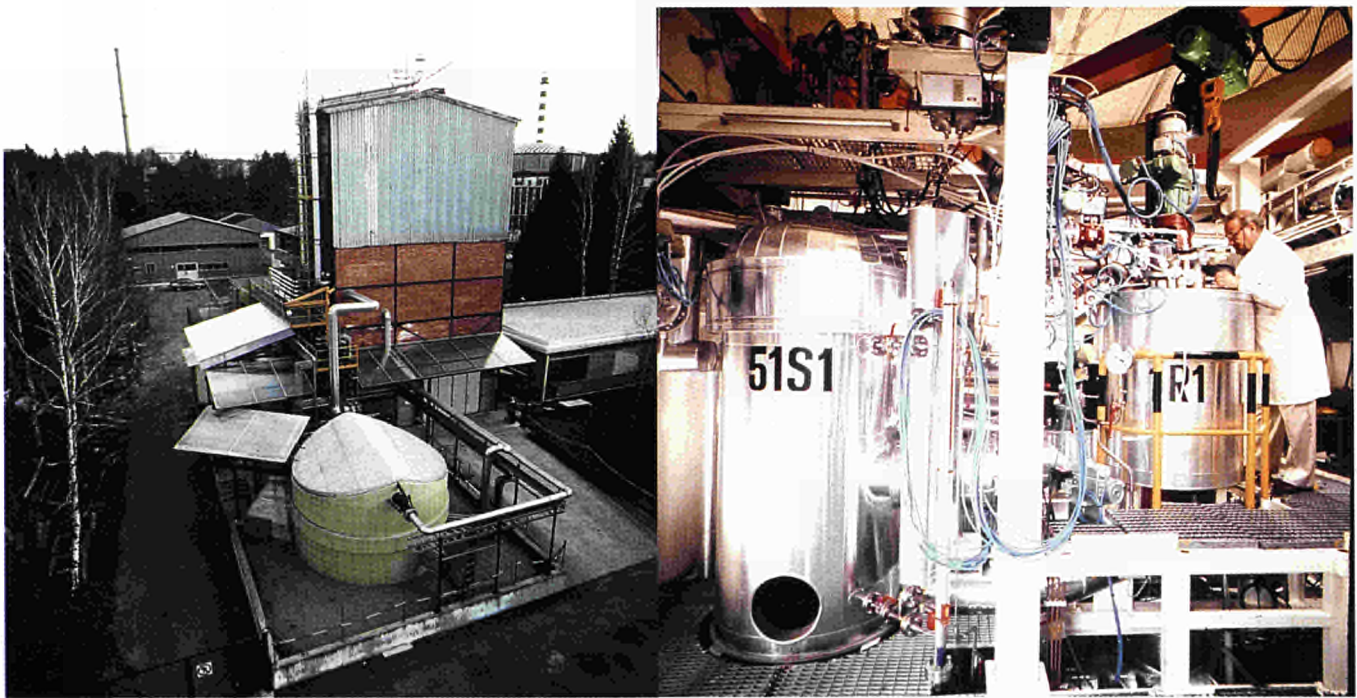


Figure 7.5: The FIRES experimental reactor (seen from the inside and outside) serves to simulate batch and semi-batch scenarios leading to chemical run-away reactions. Emphasis is on understanding the underlying mechanisms, on improving early detection and on studying new control algorithms.

Bio-energy Systems

author: D. Sarigiannis

The work of the JRC in bio-energy systems includes the development and implementation of comprehensive methodologies for:

- the assessment of the integrated potential of biomass for energy production in the European Union;
- the evaluation of safety, environmental and economic aspects of the state-of-the-art technologies for the conversion of biomass resources into liquid biofuel and high-added value chemicals;
- the assessment of the potential of other key renewable energy sources such as biological waste (including municipal solid and agro-industrial waste) and wind.

Advanced information technology systems are being used for the implementation of this integrated approach, including geographic information systems, object-oriented dynamic process system modelling, Petri nets and multi-criteria based decision support systems.

Four shared-cost action projects started in 1996: INSPIRE (Integrated Spatial Potential Initiative for Renewable Energy in Europe), AMOEBA, FLASH-PYRCON and AD-Nett. INSPIRE aims at developing an integrated methodology for the assessment of the biomass economic potential in the European Union. This methodology will then be tested in four test sites: United Kingdom, Sweden, Andalusia (ES), Piedmont (IT). In AMOEBA the goal is to produce a European Biomass Atlas. The objective of FLASH-PYRCON is to evaluate the penetrability of bio-oils derived via flash pyrolysis into existing and future markets of oils and high-added value chemicals. The JRC performs a system analysis of the technical and economic performance and of the environmental burden of the technology. Lastly, AD-Nett regards the development of an efficient information exchange thematic network on anaerobic digestion (AD) of agro-industrial waste and the completion of a comprehensive evaluation of the state-of-the-art in anaerobic digestion in the EU. The JRC is primarily responsible for the assessment of the safety aspects of AD.

<http://stss-www.jrc.it/people/federico/index.html>

- 7.27 Nieman H., Schipper A., Ligthart J., Duffield S. - *Experimental Worst Case Simulation of Styrene-Butadiene Emulsion Polymerisation for Safety Evaluation of a Production Plant* - presented at the 1996 Process Plant Safety Symposium, Houston
- 7.28 Alos M.A., Nomen R., Zaldivar J.M. - *Generalised Criteria for Assessing Thermal Stability of Discontinuous Reactors* - Report EUR 17275 EN, 1996
- 7.29 Sarigiannis D.A. - *Object-oriented Database Technology for Renewable Energy Information Processing* - in: Proceedings of the International Workshop on Renewable Energy Databases, CEC-DG XVII, Oxford, 1996
- 7.30 Sarigiannis D.A. - *The Implementation of LCA for Renewable Energy - the Case of Biomass to Energy Systems* - in: Proceedings International Seminar on Integration of Renewables, CEC- DG XII, Brussels, 1997

8

Nuclear safety (severe accidents)

author: A.V. Jones

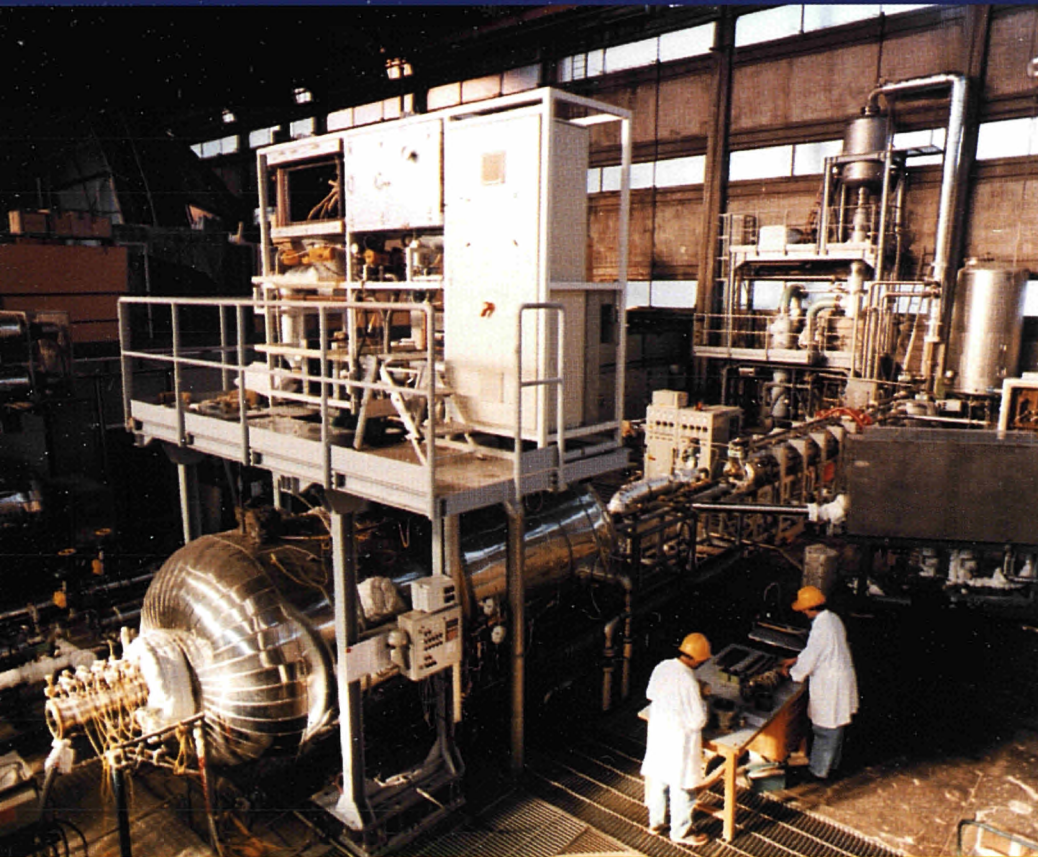


Figure 8.1: STORM experimental facility. In the foreground to the left is the aerosol generation system; in the background to the right, is the test pipe and the advanced instrumentation (sampling stations and radiation system). Within the Nuclear Safety research programme at ISIS, STORM is used to study the mechanisms of aerosol deposition and resuspension for an improved physical understanding on the subject.

ISIS' nuclear safety research is concerned with severe accident phenomena in light water reactors. Research activities include aspects of probabilistic safety assessment, experimental investigation of steam explosions and of core debris quenching and spreading, experimental studies of aerosol deposition and resuspension in the reactor cooling circuit, and a wide range of studies and technical support work associated with the in-pile severe accident experiments Phebus.

The overall objective is to improve understanding and modelling capabilities for the more accurate estimation of accident consequences, the development of new reactor designs, and improved techniques for the management of severe accidents by operators. Highlights of 1996 include:

- the launch of the first phase of a benchmark exercise on expert judgement based on a FARO test;
- the performance of two FARO tests with pressures down to 0.5 MPa, the first observation of a propagating corium/water interaction event in KROTOS (small-scale steam explosion facility);
- new information on aerosol resuspension from STORM (Simplified Tests On Resuspension Mechanism);
- the execution of the second Phebus experiment involving extensive degradation of irradiated fuel and control rods;
- the interpretation of important features of the first Phebus test such as early degradation as well as silver/iodine interaction.

For each activity it is the strategy of ISIS to involve appropriate organisations from the EU Member States in both the planning and evaluation of the work it performs. Direct collaboration with such organisations is also sought within the framework of shared-cost actions or otherwise. For the probabilistic safety assessment task, the forum is the set of participants in a concerted action on expert judgement. For FARO/KROTOS there is an Expert Group, as well as two shared-cost actions. STORM has a Scientific Committee, while Phebus is endowed with a hierarchy of committees, from the Steering Committee down through the Scientific Analysis Working Group and the Technical Group to Interpretation Circles focused on specific aspects of each test. ISIS' Phebus work is also supported by three shared-cost actions and two concerted actions. ISIS also seeks wider international collaboration: FARO is partially funded by the United States Nuclear Regulatory Commission (US-NRC), Phebus partners include the same body as well as the CANDU Owners Group (COG, Canada), Nuclear Power Engineering Corporation (NUPEC) and Japan Atomic Energy Research Institute (JAERI, Japan), and the Korea Atomic Energy Research Institute (KAERI, South Korea). Another route to dissemination of ISIS results is through International Standard Problems (ISPs) of the OECD-NEA. Two ISPs are in progress, one based on FARO and the other on STORM.

Probabilistic Safety Assessment

author: G. Cojazzi

Although Probabilistic Safety Assessment (PSA) methodology offers a rather comprehensive and stable integrated framework of techniques for the quantitative assessment of the reliability and safety level of nuclear Installations, specific areas of research remain open [8.1]. The research activity performed at ISIS concerns the Expert Judgement (EJ) problem, i.e. how specialist assessments can be integrated in the PSA study in a formal and disciplined way to guarantee the reproducibility and accountability of their judgements and hence of the whole PSA process. This question is of primary importance in Level 2 PSA which seeks to evaluate the so-called plant source term.

ISIS research in PSA has dealt with two main subjects:

- The development and application of a study case, based on ISIS experimental activities in severe accidents of a new approach to expert judgement in PSA, based on knowledge engineering techniques
- The organisation, running and documentation of a European Benchmark Exercise on expert judgement techniques applied with reference to level 2 PSA.

The perspective of the EJ methodology KEEJAM (Knowledge Engineering Expert Judgement Acquisition and Modelling) being developed at ISIS, is that uncertainty in general [8.2] and expert judgement in particular basically constitutes a knowledge problem. First, the experts' knowledge and problem-solving strategies applied to solve the problem at hand are acquired. Next, it is necessary to formalise the different problem-solving approaches proposed by the experts and build up self-consistent models. The resulting knowledge models constitute an explicit representation of the state of the art in the field of interest, which is made available to the user in a scientifically communicable and updatable form. In 1996, the requirements of the KEEJAM methodology have been laid down [8.3] and the methodology has been developed and applied within phase 1. This is devoted to forecasting the results of the L24 FARO experiment of the international benchmark exercise organised and launched by ISIS as a Concerted action within the EC Nuclear Fission Safety Programme [8.4-8.6].

Some activity on dynamic reliability for systems analysis and human performance assessment has been also performed based on the ISIS DYLAN-III software package and on the HERMES methodology [8.7, 8.8].

Corium Quenching and Spreading - the FARO Programme

authors: D. Magallon, I. Huhtiniemi

The experimental installations FARO and KROTOS are concerned with the important safety questions of core melt quenching in the reactor vessel lower head, and in-vessel steam explosions, respectively. The FARO plant is a large multi-purpose test facility in which up to 200 kg of UO₂-based melts at 3000°C are generated and used for melt/water and melt/structure interaction studies. It is the only experimental facility of its type. Associated with FARO are the small scale KROTOS tests, as well as COMETA code development and test analysis. The KROTOS FCI tests aim at providing benchmark data to examine the effect of fuel/coolant initial conditions and mixing on explosion energetics. Modelling and test analysis are focused on the development and validation of the JRC-Ispra COMETA computer code. Complementary analysis of the FARO and KROTOS tests is also performed with TEXAS-IV, IFCI and CORFLOW codes.

FARO Tests

Two quenching tests at 2.0 MPa (L-20) and 0.5 MPa (L-24) have been performed, which involved 96 kg and 176 kg of 80 w% UO₂ - 20 w% ZrO₂, respectively, and water at saturation and 2-m-depth. The tests simulated the penetration of molten corium into the water of the lower plenum and its subsequent settling on the bottom head of the reactor pressure vessel (RPV). The objective was to study the influence of lowering the system pressure on the melt/water quenching behaviour with respect

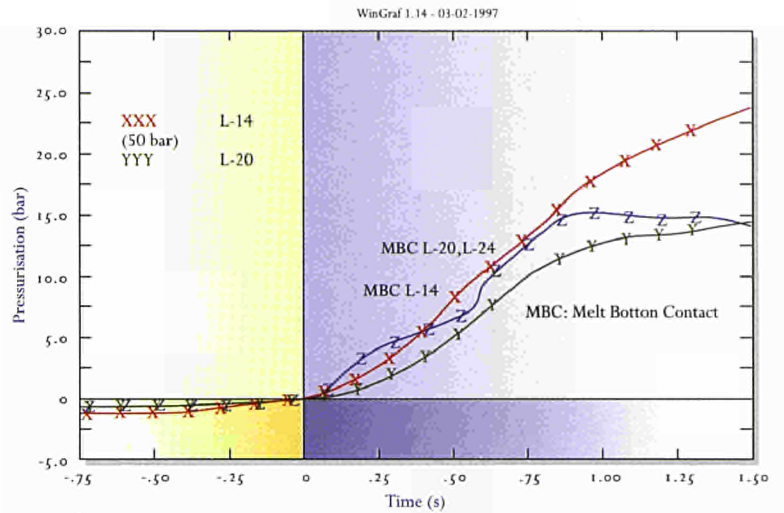


Figure 8.2: The FARO facility is used to study 150-kg-scale UO₂-ZrO₂ corium melt quenching in water during a severe accident. The figure shows the pressurisation of the interaction vessel in selected FARO tests ($t = 0 =$ melt/water contact). These curves are used to evaluate the potential of water to quench the corium during its slumping into a water-filled reactor pressure vessel lower head.

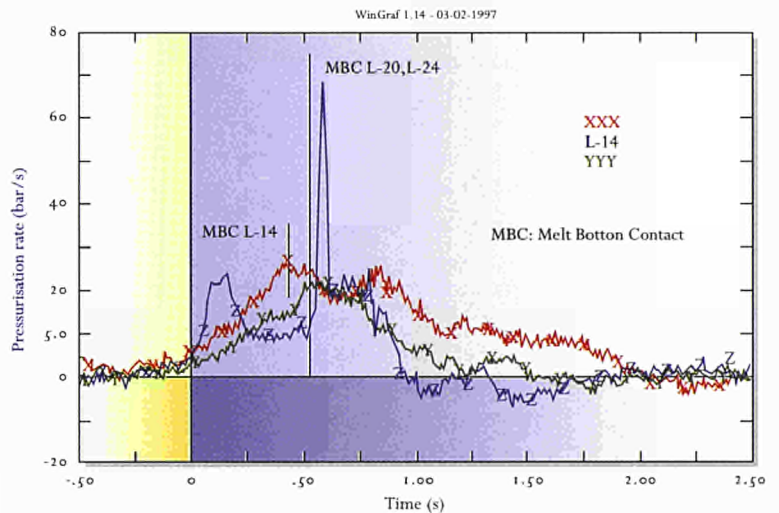


Figure 8.3: The figure shows the interaction vessel pressurisation rate in selected FARO corium melt quenching tests ($t = 0 =$ melt/water contact). It indicates a significant difference in quenching behaviour between tests at high pressure (5.0 and 2.0 MPa) and at low (0.5 MPa). No steam explosion occurred in any of the tests but part of the debris was entrained by the steam-water flow in the piping of the venting unit in the low pressure test.

R E F E R E N C E S

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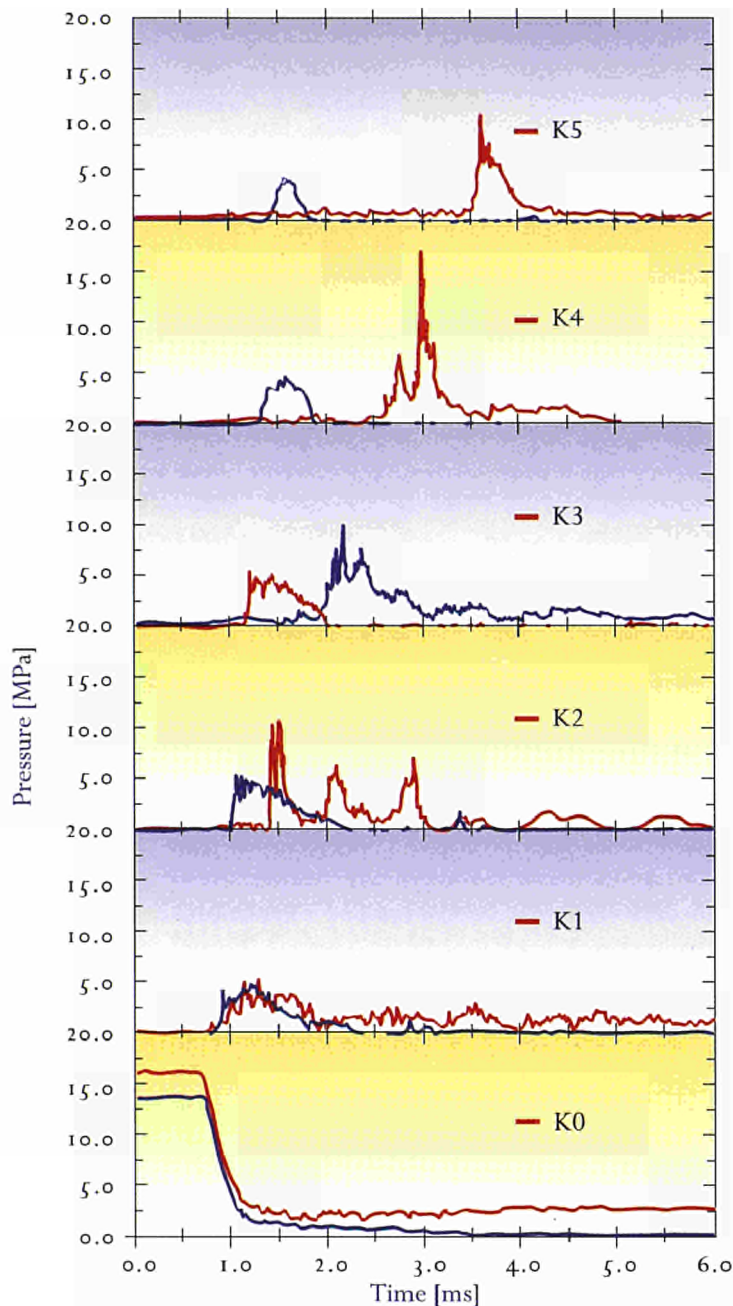


Figure 8.4: KROTOS is a small scale steam explosion facility at ISIS. It is used to study steam explosion triggering and energetics. The figure shows the propagating event with UO_2-ZrO_2 corium melt at temperature $2867^\circ C$ in test KROTOS 52 (K 0-5 refer to pressure transducers at different elevations in the interaction vessel; the blue line depicts trigger pulse propagation in water without melt). The interaction pressures can be used to evaluate the dynamic loading of the reactor pressure vessel during a severe accident.

to former tests performed in FARO at 5.0 MPa [8.9]. The test at 2.0 MPa showed a quenching behaviour similar to that in tests at 5.0 MPa. The test at 0.5 MPa has revealed a somewhat different quenching behaviour. The pressurisation rate, water temperature and water level swell exhibited jumps just after melt water contact and melt bottom contact, which was not the case in the tests performed at higher pressures. An example of these differences is given in Figures 8.2 and 8.3 where, respectively, the pressurisation and pressurisation rates of L-14 (5.0 MPa, 125 kg of melt), L-20 and L-24 are compared. No trace of a propagating event (steam explosion) was observed linked with the vessel pressure jumps. Also in the 0.5 MPa test a quantity of 5 kg of debris was entrained by the steam-water flow in the piping of the venting unit, which again was not the case at higher pressure where all the debris collected at the bottom of the interaction vessel. The production of a significant amount of hydrogen (of the order of 0.3 kg for 150 kg of melt) was observed in all tests, independent of the pressure. As most accident management strategies now include reactor vessel depressurisation before core melt down and relocation in the lower head occur, testing at low pressure will be pursued down to 0.1 MPa to understand better the role of this strategy in the overall system performance. In parallel to the quenching test series, tests for simulating the molten corium spreading behaviour in ex-vessel core retention devices (European Pressurised Reactor core catcher concept) have been prepared and will start in 1997.

KROTOS Tests

Six tests have been performed in 1996, 3 with UO_2-ZrO_2 and 3 with Al_2O_3 melts. The main objective was to understand the role of the melt composition in steam explosion triggering and energetics. So far, no energetic interactions have occurred with UO_2-ZrO_2 melt. This is in sharp contrast with the supercritical explosions observed in KROTOS with Al_2O_3 , which is often used as simulant for UO_2-ZrO_2 . However, a propagating event was observed in a very recent test with UO_2-ZrO_2 (K52). Figure 8.4 shows the pressure wave propagating upwards through the melt/steam/water mixture in the K52 test after an external trigger has been applied (blue

- 8.5 Cojazzi G. - *Benchmark Exercise on Expert Judgment Techniques in PSA Level 2* - Minutes of the Kick-off Meeting, February 8-9, 1996, JRC Ispra, EC-JRC, ISIS, Technical Note No.I.96.130, 1996
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- 8.9 Magallon D., Hohmann H. - *Experimental Investigation of 150-kg-scale Corium Melt Jet Quenching in Water* - in Proceedings of NURETH-7, Saratoga Springs, New York, September 10-15, 1995, Vol. 3, p. 1688

line depicts the trigger pulse in water without melt). The test was performed at 0.2 MPa system pressure to reduce void fraction in the mixture with respect of the former tests performed at 0.1 MPa [8.10, 8.11]. The energy conversion was low in the K52 test (0.05 % as against up to 2.5 % with Al₂O₃ melt), but this mild interaction indicates that within a certain envelope of initial conditions an energetic steam explosion might be possible.

COMETA Code Development and Test Analysis

authors: C. Addabbo, A. Annunziato

COMETA (Core MELT Thermal-hydraulic Analysis) is dedicated to the prediction of the thermal-hydraulic behaviour of the FARO facility [8.12] for design verification, definition of operational procedures and the interpretation of test results. In 1996 the code was extensively used for the FARO facility. An example of application of the code to test L-20 is shown in Figure 8.5. Pre-test calculation for this test was successful in predicting the correct energy released to the water but the resulting pressurisation was underestimated (Figure 8.5). A detailed analysis showed that the reason for this discrepancy was the absence of a model for hydrogen generation from oxidic melts. In the post test calculation, a model for H₂ generation based on the available data of FARO tests was introduced in the code resulting in considerable improvement in both pressure (Figure 8.5) and energy predictions. COMETA was also applied to the KROTOS tests in order to show the influence of the H₂ production on steam explosion triggering. It was shown [8.13] that, on including the H₂ production rate as for FARO in KROTOS tests with UO₂/ZrO₂, the void fraction produced in the mixture becomes so high that any escalation of a trigger event into a steam explosion is inhibited. The calculations also highlighted the importance of the H₂ production rate for the void fraction (Figure 8.6).

In a parallel line of development, the TEXAS code

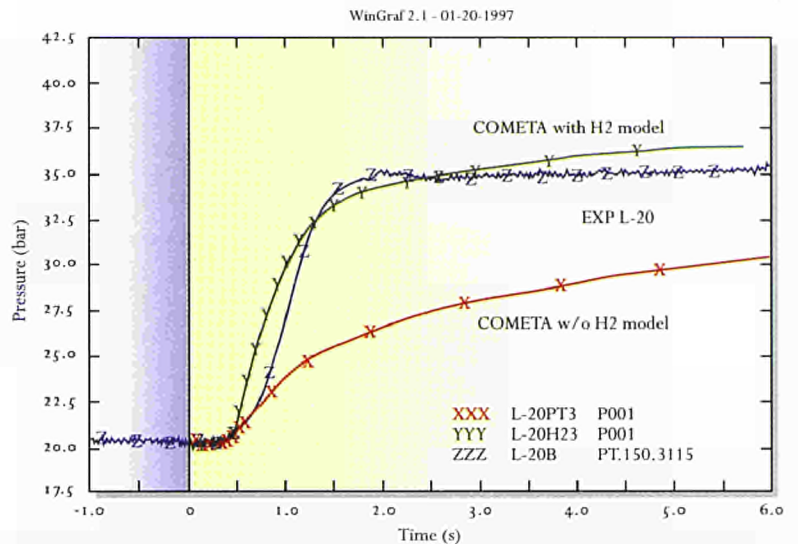


Figure 8.5: Pre- and Post-test calculation by COMETA (Core MELT Thermal-hydraulic Analysis) code of the FARO Test L-20. The figure shows the influence of the H₂ production model on the calculation.

was applied both to FARO and KROTOS test cases. The code displayed reasonable prediction capabilities following the optimisation of certain input parameters such as heat transfer coefficient for forced convection film boiling for quenching tests, and limiting void fraction and fragmentation time for explosion tests. Additional activities performed in 1996 were: the organisation of a benchmark calculation on the FARO test at 5 bar (L-20), and the continuation of the OECD-CSNI International Standard Problem 39 on FARO.

In preparation for corium spreading experiments and under a technical exchange agreement with Siemens, the CORFLOW code has been implemented at JRC and scoping calculations have been performed.

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- 8.10 Huhtiniemi H., Hohmann H., Magallon D. - *FCI Experiments in the Corium / Water System* - in *Proceedings of NURETH-7*, Saratoga Springs, New York, September 10-15, 1995, Vol. 3, p. 1712-1727
- 8.11 Magallon D., Huhtiniemi I., Hohmann H. - *An Overview of the FARO and KROTOS Test Results* - in *Proceedings of Probabilistic Safety Assessment Meeting*, Park City, Utah, Oct. 1996, Vol. 3, pp. 1351-1358
- 8.12 Annunziato A., Addabbo C. - *COMETA, a Computer Code for Melt Quenching and Analysis* - International Conference on New Trends in Nuclear Systems Thermalhydraulics, Pisa, Italy, June 1994
- 8.13 Annunziato A. - *The Effect of Hydrogen Production on the Propagation of Energetic Fuel Coolant Interaction in UO₂ / ZrO₂ Mixtures* - JRC Technical Note L.96.108, June 1996

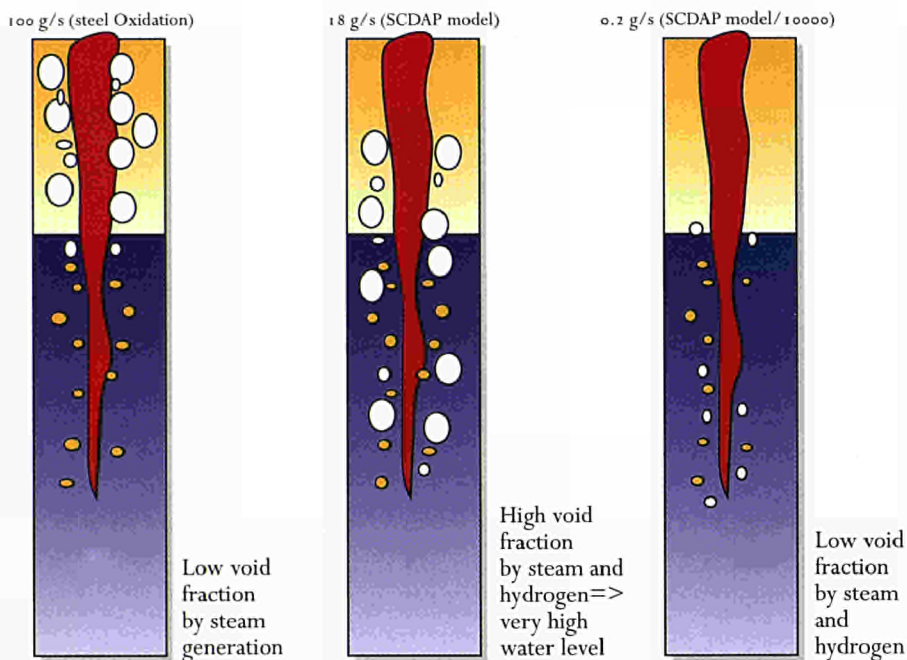


Figure 8.6: Influence of the H₂ production model in the KROTOS case: with a high production rate (100 g/s); the void fraction in the facility is not influenced. With a smaller production rate (1.8 g/s, Severe Core Damage Analysis Package (SCDAP) model), the void fraction in the water greatly increases. With a smaller rate (0.2 g/s), the void fraction is again very small.

material that can be released to the atmosphere in case of a severe accident. Decisive processes are both aerosol deposition and mechanical resuspension. The validation status of resuspension models has been poor to date, but with the initiation of the STORM (Simplified Tests On Resuspension Mechanism) full-scale experimental programme in mid-1995 a substantial database on resuspension is being assembled.

The STORM facility (Figure 8.1), with its aerosol generation system and a full range of classical and innovative aerosol instrumentation has been used for a number of deposition tests with tin dioxide particles, using nitrogen as a carrier gas. The aerosol particles are generated with a plasma torch that can vaporise up to 0.5 g/s of tin powder. The available range of nitrogen flow rates leads to velocities in the test pipe that go from less than 15 m/s to more than 200 m/s. Alternatively, steam can be used as a carrier gas. A description of the STORM facility and of its measurement systems is contained in references [8.14-8.23].

Aerosol Deposition and Resuspension in Reactor Piping: the STORM Project

authors: R. Hummel, G. De Santi

The behaviour of aerosols in the primary coolant circuit and containment of a nuclear power plant is important in determining the amount of radioactive

material that can be released to the atmosphere in case of a severe accident.

After a series of deposition tests (3 in the first half of 1996) the first resuspension test was performed in April 1996. This consisted in an initial deposition phase, in which tin dioxide aerosols were allowed to deposit in the test section, and a following resuspension phase in which clean nitrogen was blown into the pipes, at increasing velocities, until a good part of the deposit was resuspended.

In mid-1996 the STORM experimental configuration was changed according to the requirements of the second phase of the experimental program. The tests continued with one deposition and one resuspension test in the last quarter of 1996.

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8.14 Hummel R., Hautajarvi A., Krasenbrink A., Valisi M., De Santi G. - *Aerosol Deposit Characterisation by Radiation Technology* - TU Delft, 9-12 September 1996, Delft (NL), J. of Aerosol Science

8.15 Hummel R., Krasenbrink A., Valisi M., Schwab S., Schaetgen F., De Santi G. - *Application of a Three Wavelength Extinction Metre within the STORM Experimental Programme* - TU Delft, 9-12 September 1996, Delft (NL), J. of Aerosol Science

8.16 Krasenbrink A., Hummel R., Hautajarvi A., Areia C.J., De Santi G. - *Simplified Tests on Resuspension Mechanisms: the STORM Project* - in: Proceedings of the ENS Class 1. Topical Meeting on "Research Facilities for the Future of Nuclear Energy", BNS, SFEN, ENS, 4-6 June 1996, Brussels (B)

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8.20 Krasenbrink A., Hummel R., Areia Capitaio J., Hautajarvi A., De Santi G. - *STORM Test SD03. Deposition of SnO₂ in Complete Insulated Pipes* - Tech. Note/I.96.112

8.21 Krasenbrink A., Hummel R., Areia Capitaio J. - *STORM Test DO4. Deposition of SnO₂ in Partially Insulated Pipes with N₂ as Carrier Gas* - Tech. Note/I.96.183

8.22 Krasenbrink A., Hummel R., Areia Capitaio J. - *STORM Test DO5. Deposition of SnO₂ in Completely Insulated Pipes with Steam as Carrier Gas* - Tech. Note/I.96.184

8.23 Krasenbrink A., Hummel R., Areia Capitaio J. - *STORM Test DO7. Deposition of SnO₂ in Partially Insulated Pipes with Steam as Carrier Gas* - Tech. Note/I.96.185

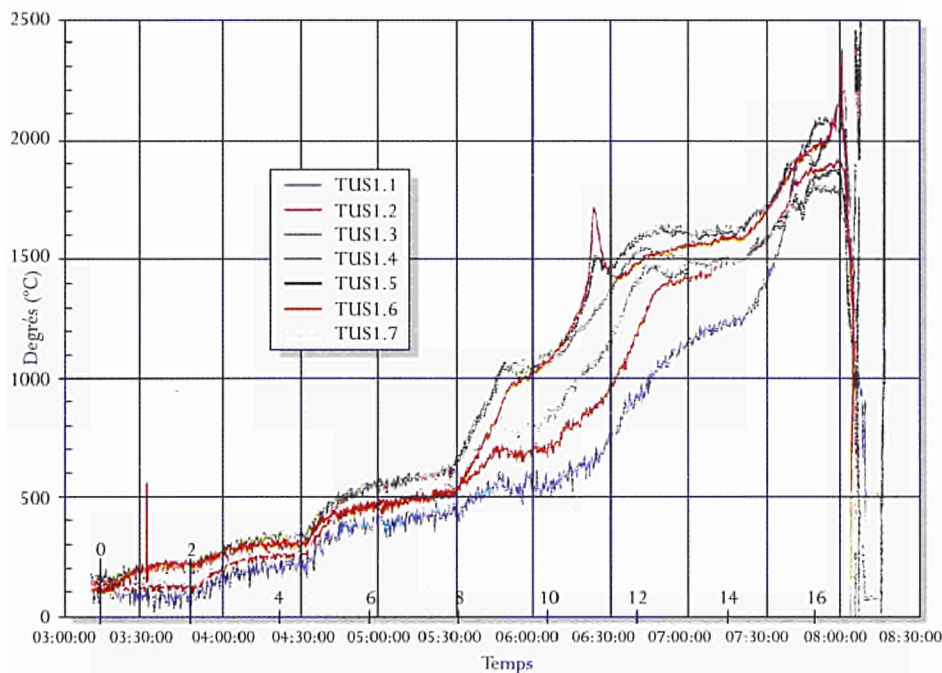


Figure 8.7: Readings of the ultra-sonic thermometres. These instruments confirmed the thermocouple readings. Moreover, they supplied data through the entire transient with a fine axial resolution. The ultra-sonic in-pile thermometres are a development of JRC Karlsruhe (DE) and Ispra (IT)

Since 1996, two sampling stations has been used, the first during the deposition phase and the second during the resuspension phase. To understand better what happens in the mixing vessel an extraction and dilution system has been mounted during 1996 on top of the mixing vessel. It allows aerosol to be extracted from different positions within the vessel and analysis of its characteristics after dilution using a single particle counter and filters for short time samples for post-test analysis. The radiation absorption system to measure deposit thickness on-line has been successfully used in the last four STORM tests of 1996.

Pre- and post-test calculations were performed during 1996, showing that the present generation of aerosol transport codes is capable of predicting deposition of solid aerosols in a straight pipe accurately when the temperature difference between the carrier gas and the pipe walls is large. In almost isothermal conditions, however, the codes tend to over-predict retention. A preliminary analysis of the resuspension tests shows that while the models used in the STORM benchmarks predict fast resuspension of the whole deposit or a slow resuspension of only part of the deposit, the experiments show fast resuspension of only part of the deposit.

In parallel with the test analysis, a new model for aerosol resuspension is being developed. During 1996 the development of the first version of the CAESAR model was concluded and the preliminary results obtained reproduce accurately the trends observed experimentally.

Phebus: In-pile Experiments on Core Degradation and Fission Product Release, Transport and Deposition

authors: P.Von Der Hardt, A. V. Jones, I. Shepherd, Y. Drossinos

The ongoing PHEBUS FP programme is the centre piece of an international co-operation investigating, through a series of integral in-pile experiments, key-phenomena involved in the progression of a severe accident. The PHEBUS facility at Cadarache (F), offers the capability to study the degradation of real core material, from the early phase of cladding oxidation and hydrogen production up to the late phase of melt progression and molten pool formation. The subsequent release of fission products and structural materials is also experimentally studied, including their physicochemical interactions, their transport in the cooling system, and their deposition in the containment. The revolatilisation of iodine due to radiochemical effects in the water of the sump and the amount of low-volatility fission products and transuranium elements reaching the containment are receiving a special interest, as large uncertainties related to their modelling persist.

FPT-0 and FPT-1, the first experiments of the programme, performed in December 1993 and July 1996, respectively, have generated a wealth of results on the later stages of core degradation and on fission product behaviour. The resulting database is being applied to develop and validate the computer codes used to assess the safety of the currently operating plants. They will also support the design of future plants having the capacity to confine core melt-down accidents within their containments. ISIS contributes substantially both to the preparation and analysis of the tests and to the management of the programme.

The main event in 1996 was the successful performance of the second experiment of the Programme, FPT-1, on July 26. Its operating protocol was nearly identical to the one of the first test, with slightly reduced steam flow and driver-core power (Figure 8.7), and revised sampling schemes. ISIS staff was actively involved into all stages of test preparation and operation. The two in-pile ultra-sonic thermometers supplied by the JRC's Transuranium Institute (Karlsruhe, DE) performed reliably throughout the high temperature transient (Figures 8.8)

As planned there was less fuel bundle degradation than in the first test. Significant liquefaction, however, was reached (about 20% of the fuel), and large quantities of fission products were released.

The first two Phebus experiments have drawn attention to a number of phenomena which were hitherto poorly understood and inadequately simulated in several severe accident codes, such as

- fuel degradation far below UO₂ melting point, probably due to the formation of eutectics with control rod materials,
- modest aerosol retention in the experimental circuit and unexpected aerosol morphology / composition,
- small amounts of gaseous iodine in the containment, early in each transient,
- unexpected, and as yet unexplained iodine and caesium speciation.

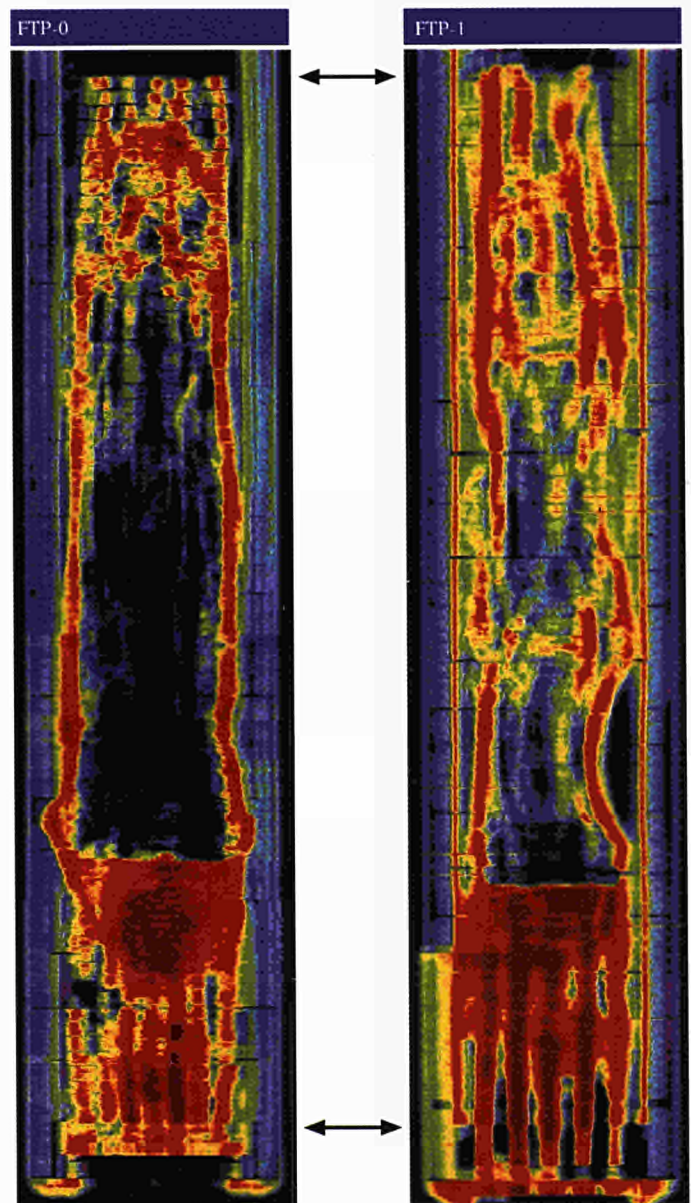


Figure 8.8: Post-test tomographic radiographs of the fuel bundles. Both Phebus tests achieved a degree of fuel degradation never reached before in in-pile experiments. As planned, the total amount of liquified fuel was less in FPT-1 (about 30%) than in FPT-0 (about 50%).

Separate effects experiments are planned to improve the understanding of these phenomena. Post-test evaluation of the FPT-1 experimental results was ongoing at the end of the year. Simultaneously, the main options of the third Phebus test, FPT-4, were defined, and hardware design started. The experiment aims at detailed studies of the debris bed/molten pool transition and of the release of less volatile fission products and transuranium elements. ISIS staff has been involved into all phases of scientific and technical definition of this first-of-its-kind experiment, planned for summer 1998.

The analytical work is largely performed in three Interpretation Circles, two of which are co-ordinated

by ISIS staff. ISIS both performs its own analyses and stimulates EU and non-EU partners to contribute calculations and expertise, which are then distilled into synthesis reports. The Phebus Bundle Interpretation Circle (BIC) co-ordinates efforts to come to a consensus about core degradation and fission product release behaviour in Phebus tests. As part of this work ISIS organised and took part in a benchmark calculation exercise where 12 different organisations used 4 different computer codes (ICARE-2, SCDAP/RELAP5, ATHLET-CD and MELCOR) in an attempt to understand the test. Even though the participants to the exercise had full access to the experimental measurements they were unable to reproduce the very early loss of geometry observed in the test. It is becoming clear from the post irradiation analysis of the bundle that the fuel was liquid at a temperature at least 350K cooler than the melting temperature of UO₂ (350K) and that this liquefaction was due to interactions between the fuel, the cladding and the control rods. Although the codes include models for liquefaction they underestimated its importance in tests where the coolant was oxidising (low concentrations of hydrogen) most of the time.

Another source of difficulty was the hydrogen generated during the exothermic reaction between Zircaloy and hot steam. All the codes except ICARE-2 assume that the oxidation stops once the cladding loses its initial geometry - i.e. when it melts or becomes particulate. This assumption contributed to the codes' understimation of the hydrogen production. Those involved with mitigating the consequences of severe accidents need to know the amount and rate of hydrogen generation so it is a priority for code developers to improve the models.

A draft report summarising the calculations has been issued by ISIS for comments and a final version will be prepared in 1997 [8.29].

Further work on core behaviour at JRC focuses on understanding why the fuel porosity increases under accident conditions. None of the core degradation codes model this phenomenon although swelling of 20% was observed in FPT-1 and up to 400% in other experiments. Initial work has concentrated

on seeing whether the mechanistic fuel codes LAKU and VICTORIA are capable of simulating these transients. First impressions are that they are but that a simpler approach with fewer parameters is required for severe accident analysis.

The release of iodine in FPT-0 was higher than might have been expected in a test with fresh fuel but lower than if irradiated fuel had been used. JRC, in collaboration with IPSN and AEA Technology, is currently comparing different models of fission product release in order to determine the minimum level of sophistication required. Large differences in approach as well as a number of errors in implementation in IPSN's ELSA and AEA's VICTORIA have been found.

The Circuit and Containment Aerosol Interpretation Circle (CACIC) was set up in 1996. It is co-ordinated by ISIS, which has contributed to understanding of both circuit and containment behaviour. Aerosol deposition in the circuit has been analysed by treating convective diffusion of aerosol particles in steady Poiseuille flow as an extended Graetz problem. It was found that particle concentration, in the flow and particle deposition on the walls, is significantly influenced by the form of the inlet profile. In contrast, the length of the entrance region remains practically unaffected [8.30, 8.31]. Definitive circuit data were not forthcoming in 1996, but the general status was that the codes failed to predict the quantity and distribution of aerosol retention in the various circuit components. Also unexpected was the similar deposition patterns of most elements. Various explanations have been advanced including chemistry effects and resuspension, but corrective model development awaits more complete circuit data from the first two tests, including speciation information.

Concerning thermal-hydraulics and aerosol behaviour in the containment vessel an extensive numerical study of particle deposition in a turbulent boundary layer has been initiated, partly in an attempt to understand the unexpectedly large wall deposition in FPT-0 and FPT-1. A Lagrangian random-walk approach is used to track particle motion inside the boundary layer. It is found that even a small temperature gradient greatly enhances

- 8.24 Serre F. et al., - *Post-test Analysis of Phebus FPTO Degradation using ICARE2 Code* - CSARP Meeting, Bethesda, MD, May 6-10, 1996
- 8.25 Jones A.V., Jamond C., Shepherd I.M - *Investigation of Fuel Bundle Behaviour in Phebus FP* - CSARP Meeting, Bethesda, MD, May 6-10, 1996
- 8.26 Jacquemain D., et al., - *An Overview of the Iodine Behaviour in Phebus FPTO* - CSARP Meeting, Bethesda, MD, May 6-10, 1996
- 8.27 Haessler M., Von Der Hardt P., Schmitz F., Schwarz M. - *The Safety Research Programmes in the In-pile SURA and PHEBUS Facilities* - ENS Topical Meeting on Research Facilities for the Future of Nuclear Energy, Brussels, Belgium, 4-6 June 1996
- 8.28 Gonnier C., Repetto G., Clement B., Von Der HARDT P., Zeyen R. - *Lessons from Phebus FPTO Experimental Results* - Int. Top. Meetg. on Probabilistic Safety Assessment, Park City, Utah, Sept. 29-Oct. 3, 1996
- 8.29 Von Der Hardt P., Schwarz M. - *Status of the International Severe Accident Research Programme Phebus FP* - Workshop on Severe Accident Research in Japan (SARJ 96), Tokyo, 28-30 October 1996



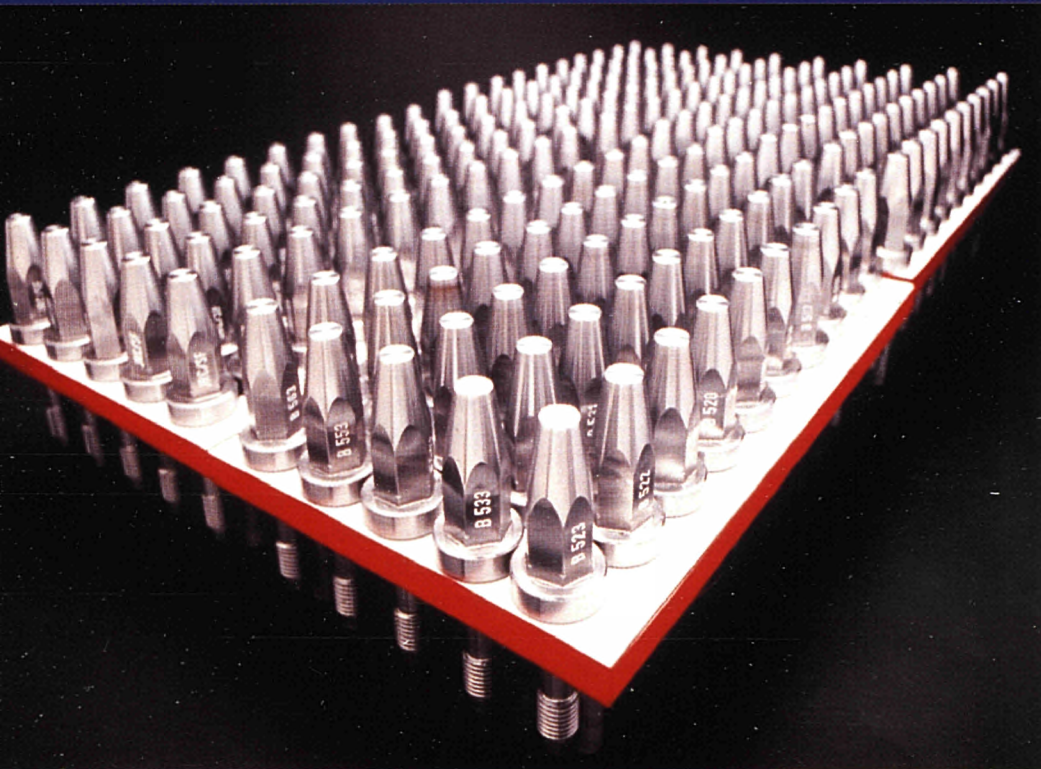
particle deposition [8.32]. Calculations with the simplified models of the CONTAIN code are in progress to understand the similarities and differences between the first two tests.

The third interpretation circle, CCIC, is concerned with containment chemistry. ISIS contributes to the task of understanding the mass of sometimes conflicting information resulting from the Phebus tests, and is making a special study of silver-iodine reactions. FPT-1 results confirmed the FPT-0 observation that silver has an important influence on the chemistry of iodine in the containment. Specifically, sump chemistry is marked by the formation of an involatile and insoluble species (silver iodide) that forms a Ag/AgI colloidal suspension. The formation of AgI prevents the production of volatile molecular iodine by radiolysis. The stability of the colloidal suspension in the presence of strong radiation fields and as a function of electrolyte strength is under investigation [8.33, 8.34]. ISIS is studying the effect of silver on iodine chemistry, partly supported by a Shared Cost Action. Separate-effects experiments have been analysed and a model for the reaction of solid silver, either in particular form or as a mesh, with iodide anions to form silver iodide has been developed. According to the model the reaction proceeds in two steps. The initial, fast step obeys a linear law and it describes the reaction on the surface of the silver sample. The second, slow step is modelled by a parabolic law, where diffusion through the silver iodide product layer is the rate-limiting step [8.35].

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- 8.30 Housiadas C., Hautojarvi A., Ezquerria Larrode F., Drossinos Y. - *Convective Diffusion of Aerosol Particles Flowing Non-Uniformly into a Circular Tube: an Extended Graetz Problem* - Int. J. Heat Mass Transfer (submitted), 1996
 - 8.31 Housiadas C., Hautojarvi A., Ezquerria Larrode F., Drossinos Y. - *Numerical Evaluation of the Graetz Series* - Num. Heat Transfer: A (manuscript), 1997
 - 8.32 Kroeger C., Drossinos Y. - *Particle Deposition in a Turbulent Boundary Layer over a Large Particle Spectrum* - 1997 European Aerosol Conference, Hamburg (1997)
 - 8.33 Jacquemain D., Drossinos Y., et al. - *An Overview of the Iodine Behaviour in Phebus FPT0* - 5th International Conference on Nuclear Engineering (ASME), Nice (F) (1997)
 - 8.34 Arnaud A., Clement B., Gonnier C., Jones A., Drossinos Y. - *Interpretation of the Phebus Fresh Fuel Test and Comparison with the Preliminary Results of the First Irradiated Fuel Test* - 5th International Conference on Nuclear Engineering (ASME), Nice (F) (1997)
 - 8.35 Krausmann E., Drossinos Y. - *Kinetics of the Reaction of Silver with Iodine under Severe-Accident Conditions* - Shared-Cost Action Document ST-IC/P (96) 07

9

Safeguards



Safeguards control of fissile materials is performed by the Euratom Safeguards Directorate (DG XVII-Energy - ESD) and IAEA in the framework of the Euratom and the Non Proliferation Treaties respectively. The JRC as a neutral and independent organisation gives scientific and technical support to ESD and IAEA, contributing substantially to the performance of their tasks. In order to respond to new challenges in safeguards, JRC has to carry out enabling research to develop safeguards methods and techniques. Once such methods have proven to be feasible, they may be used in direct support to Euratom and IAEA inspectorates and plant operators.

Figure 9.1: Special sealing bolts for unique and tamper-proof identification of nuclear containers

Measurement Techniques

Mass/Volume Determination

author: B. Hunt

High precision measurements for mass and volume determination of fissile material solutions contained in tanks of the fuel cycle facilities (e.g. fuel reprocessing and conversion facilities) and tanks often having a complex shape and a large capacity, is an important issue for NM (Nuclear Material) accountancy. At the TAME (Tank Measurements) laboratory of ISIS, experiments are carried out for the development, testing of instruments and of measurement methods.

As a support to the Euratom Safeguards Directorate (ESD), experiments were performed to determine the effects associated with off-centre loading of a harp-shape tank weighing system. The task involved close collaboration with the operators of the nuclear installation in determining the parameter settings of the tank weighing rig. High density solution was utilised as the calibration medium. The results are now being applied in the installation [9.1].

Experiments have also been conducted in the laboratory to study the phenomena of measurement-tube plugging in the tank or of "crystallisation" at the dip-tube lower end, in order to ascertain the effect and its error contribution towards the total volume interpretation [9.2].

Prototype measurement equipment has been developed such as the Portable Pressure Monitoring Device (PPMD), special measurement stations like the Unattended Volume Monitoring System (UVMS) and the Volume Long Term Monitoring Device (VLTM) for specific tasks in facilities where the monitoring of solutions in tanks is required. These units are ably supported by proven software for operating, control and data acquisition. Some of the mentioned measurement units have been supplied to ESD and IAEA, and installed in plant facilities.

In the framework of the activities performed for TACIS, support activity was provided by developing the design for a mass/volume laboratory, TAMSCA, to be installed at the Russian Methodology and

Training Centre at the Institute of Physics and Power Engineering (IPPE), in Obninsk, Russia. All items have been finalised and the call for tender will be made in 1997. The software for WECALSCA, for weighing balances and calibration set up and evaluation of error components was successfully installed in Obninsk.

A process level measurement unit and monitoring device (UVMS) was installed in the uranium conversion and pelletizing plant of Ust Kamenogorsk, Kazakhstan. As a follow-up, further system units will be supplied.

Training courses were carried out on mass/volume determination techniques for IAEA inspectors, ESD inspectors and for Russian personnel (inspectors or operators).

Non-Destructive Assay (NDA)

PERLA Activities in NDA

author: P.J. Schillebeeckx

The NDA-related activities deal in particular with methods to determine the amount and isotopic composition of Uranium and Plutonium in an item. These methods are based on active and passive neutron measurements, on gamma spectrometry, calorimetry, and are used either individually or in integrated way. Most of the NDA activities are performed in PERLA. The PERformance Laboratory (PERLA) facility is unique in the world due to the rich variety of Uranium and Plutonium samples [9.3, 9.4] available for calibration and the available expertise in the development of NDA instruments to be used by both Safeguards authorities and nuclear industry. The main objectives of the activities performed in PERLA are linked to quality control functions briefly described below (points 1-4).

In parallel to the experimental work being performed in PERLA for instrument testing, the performance of the various NDA instrumentation devices can be assessed by theoretical simulations, mainly based on the MCNP code.

- 9.1 Hunt B. et al. - *Commissioning Studies of an Output Tank Weighing System for Accountability Purposes Installed in the TAME Facility of the JRC Ispra - NMM Annual Meeting, Naples Florida USA, 1996.*
- 9.2 Hunt B. et al. - *Studies on Bubbler Probe Signatures and Pressure Patterns for Early Detection of Probe Blockages During Liquid Level Measurements - INMM Annual Meeting, Naples Florida USA, 1996.*
- 9.3 Guardini S., Mousty F., Nonneman S., Schillebeeckx P., Gerard J., Vanaken K., Aigner H., Bagliano G., Deron S., Vandeveld L. - *Procurement and Characterisation of LEU Special Nuclear Material Standards for PERLA - Proceedings of the 36th Annual Meeting, INMM, 9 - 12 July, Palm Desert, California, 1995, p. 1197-1204*
- 9.4 Guardini S., Guzzi G., Mousty F., Baumann S., Kuhn E., De Regge P. - *Quality Control Provisions Applied in the Preparation and Characterisation of Pu-bearing PERLA Standards - EUR 13038 EN, Brussels, 1990*

1. Gamma Measurements

author: R. Berndt

Growing amounts of spent nuclear fuel are stored under water in large spent fuel storage ponds. This material needs to be inspected by EURATOM and IAEA. An under-water measurement head for the inspection of spent fuel (Gamma-Taucher) has been developed in PERLA, as a support action to ESD. The core of the instrument is a small semiconductor detector (CdZnTe) for the detection of gamma radiation. The detector signals can be used for the measurement of a gamma spectrum. The quality of the spectra is better than that of NaI scintillation detectors. A collimation system allows the user to measure only radiation of one special object and to suppress the radiation of neighbour objects.

Three instruments, delivered to ESD in 1996, are now used in routine operation.

This instrument has been developed for the use in under-water inspection of irradiated nuclear material. On the other hand, such an easy-to-handle spectrometric under-water measurement head could also be useful to reactor operators for their inspections in shut-down conditions or for classifying activated material during the dismantling of a nuclear installation.

Moreover, as direct support activities to ESD and the IAEA, the study of new measurement techniques, as well as the adaptation of established measurement methods to new situations, is being carried out. Specialists of the JRC are sometimes invited to perform special inspections in-field. In 1996, the testing of a new light-weight multi-channel analyser for spectrometry purposes has been started

2. Neutron Measurements

authors: B.H. Pedersen, P.J. Schillebeekx

The evolution of the fuel cycle continues to stimulate the development of new NDA techniques. An example of an NDA instrument is the pin counter recently designed, constructed, and tested at ISIS (Figure 9.2). The instrument [9.5] has been designed for installation in a mixed oxide (MOX) fuel fabrication plant, and for routine safeguards control by ESD of fresh MOX fuel pins. This new instrument,

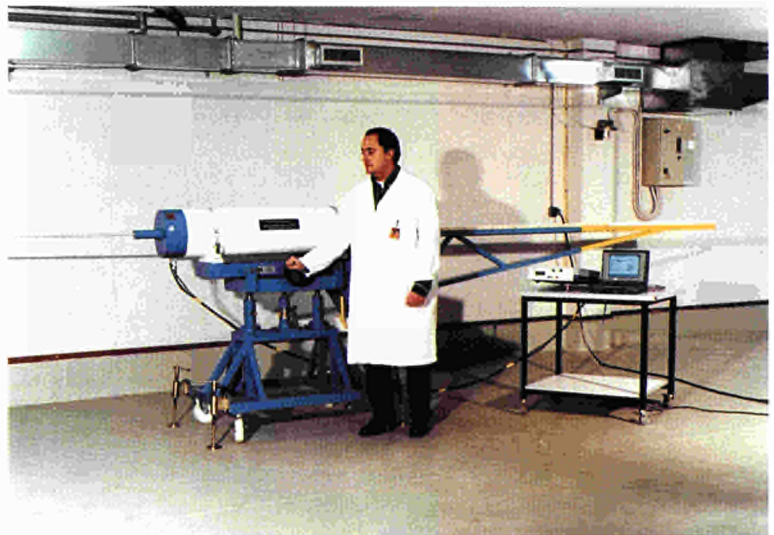


Figure 9.2: The new pin counter measures the plutonium content of fresh MOX fuel at high measurement accuracy through use of the passive neutron correlation technique developed at the JRC. The pin counter was built in the PERLA laboratory to be used by safeguards inspectors at the BNFL Sellafield MOX Demonstration Facility.

due to its improved design characteristics, can be used in conjunction with a neutron frequency analyser for the absolute determination of plutonium mass: this absolute measurement is based on an interpretation model developed by the Institute [9.6]. Besides the development of specific NDA instrumentation, basic research is performed in related nuclear physics fields. An example of this is the characterisation of a ^4He proportional detector as neutron spectrometer [9.6]. This work has been performed in collaboration with PTB Braunschweig (D) and BNFL Instruments Ltd. (UK).

3. Training in Non-Destructive Assay Techniques

author: R. Berndt

Training courses for nuclear material inspectors are held on a routine basis in PERLA, where a large variety of nuclear materials standards and extensive range of instrument types are available. The following courses are held from one to three times in the year:

- basic physics for non-destructive assay of fissionable material

- 9.5 Verrecchia G.P.D., Pedersen B., Di Cesare L., Looman M. - *A Passive Neutron Counter for Plutonium Assay of Fresh MOX Fuel Pins* - Proceedings of the 19th Annual Symposium on Safeguards and Nuclear Materials Management, Montpellier, France, 13-15 May, 1997
- 9.6 Hage W., Cifarelli D.M. - *Correlation Analysis with Neutron Count Distribution for a Paralyzing Dead-Time Counter for the Assay of Spontaneous Fissioning Material* - Nucl. Sci. and Eng. 112, (1992), p. 136-158



- gamma spectrometric measurement of the Uranium enrichment
- gamma spectrometric measurement of the isotopic composition of Pu
- active neutron interrogation (Active Well Coincidence Counter - AWCC)
- passive neutron interrogation (High Level Neutron Coincidence Counter - HLNCC)
- introductory statistics for safeguards
- advanced statistics for safeguards
- physical inventory verification

Although these courses are designed mainly for inspectors, they are open to other technicians. Special courses have been already given (and can be given in future) according to the demands from outside institutions.

4. Modelling of NDA Techniques

author: S.A. Nonneman

In continuation of the work launched in 1995, last year the modelling activity was mainly focused to the prediction of neutron coincidence measurements using Monte-Carlo simulations. The theoretical formalism based on the Kolmogorov-Dmitriev approach for the probabilistic description of system behaviour was studied and developed in the direction of pulse train analysis. The main conclusion of the performed work was that the space-energy-time-dependent model permits:

- the use of all possible detector combinations,
- the use of fission and non-fission interrogator

sources in a 3-dimensional geometry containing a sample (powder or fuel assembly) placed in a measurement cavity of an active or passive coincidence measurement instrument (neutron coincidence collar, high level neutron coincidence counter, active well coincidence counter, etc.).

To confront the proposed method with other types of prediction tools, all using Monte-Carlo simulation, an international benchmark exercise has been organised and co-ordinated. The technical specifications for the exercise were written, based on the fuel assembly and the neutron coincidence

collar present in PERLA.

The PERLA version of the Unattended Measurement System (described in the following section) was installed and adjusted to facilitate good long period, time-invariant measurements. An extended set of preparative measurements were performed to verify the stability of the equipment. Finally, the reference measurements were performed for the benchmark exercise.

Unattended Verification Systems

author: M. Franklin

The development of modern automated facilities particularly in the MOX (Mixed Oxide Fuel) and reprocessing phases of the fuel cycle are creating a considerable challenge requiring development of new safeguards approaches which involve less inspector resources, less intrusiveness and yet meet safeguards goals. Recent theoretical developments on automated intelligence has opened up a new field of possibilities for intelligent technology which could substitute inspector presence in verification activities. These systems consist of intelligent subsystems (video, NDA, sensor) linked together on a network and capable of interpreting the continuous flow of raw data to provide information for inspectors. These type of problems have been under consideration for some time in the Euratom safeguards system [9.7, 9.8]. These studies have led to the discussion of approaches based on a more extended application of C/S (Containment/Surveillance) integrated with unattended automated NDA in systems which are both intelligent and tamper proof. The practical implementation of such systems has raised a host of new technical issues. Some of these are issues about intelligent interpretation of real time data, efficient management of raw data and the co-ordination of communication and modularity in complex systems.

In its support activities to ESD the JRC has collaborated in the experience of designing and creating such systems. One such collaboration was for the implementation of unattended monitoring and measurement in a reprocessing facility [9.9 -9.11]. A central feature of the application is the use of continuous unattended neutron and gamma

- 9.7 Chare P., Schenkel R., Smith B.G.R., Wagner H., Kaiser S., Saglini J.C. - *Safeguarding Large Plutonium Stores* - Proc. Of the 13 ESARDA Symposium, Avignon, France, May 14-16, 1991
- 9.8 Cuyppers M., Haas R. - *Can Containment and Surveillance Play a More Important Role* - Proc. 3 ANS International Conference on Facility Operations-Safeguards Interface, San Diego USA, Nov.29-Dec.4, 1987
- 9.9 Mercier M.T., Huckins R.J., Zalokar G.S., Smith B.G.R., Franklin M., Butez M., Edeline J.C. - *A Local Data Acquisition Subsystem for Plutonium Safeguards* - in: Proceedings of the IEEE Nuclear Science Symposium, Fall 1991, Santa Fe, New Mexico, USA
- 9.10 Zukoski P.A., Hodges J.K., Huckins R.J., Mercier M.T., Zalokar G.S., Koskelo M.J., Smith B.G.R., Swinhoe M., Franklin M., Butez M., Martin-Deidier L., Richard J.P., Tallec M., Petit S. - *A Host Computer System for Distributed, Unattended Plutonium Safeguards* - in: Proc. of the 33 Annual Meeting of the Institute of Nuclear Materials Management, Orlando, USA, July 19-22, 1992
- 9.11 Franklin M., Mercier M., Huckins R.J., Zalokar G.S., Zukosky P.A., Smith B.G.R., Swinhoe M., Butez M. - *Unattended Monitoring and Measurement for Safeguards* - in: Proc. Of the 15 ESARDA Symposium, Rome, Italy, 11-13 May, 1993

measurement at entries and exits of a PuO₂ product storage area. The PuO₂ container, a standard production item, passes through restricted entries and exits by means of an automated mechanical system under operator control. Each entry or exit incorporates neutron and gamma detection systems and the automated mechanical system stops the container in the measurement head so as to permit an independent NDA measurement for safeguards. Each neutron and gamma detection system has an associated intelligent data acquisition system (DAS) which must interpret its own stream of data and carry out basic data pre-processing and communication functions. The primary mission of the DAS is to recognise the passage of a PuO₂ container and to reliably select the gamma and neutron data segment that can be interpreted into a measurement by the host computer. All information describing an activity sequence passing through different locations will be linked into a coherent history from which auditing reports can be generated. This kind of system is designed to function without any intervention of the inspector and automatically implements a verification of facility operations which can be audited later.

A second experience of unattended verification has been the development of an integrated measurement station for assemblies in fuel fabrication facilities [9.12, 9.13]. The measurement station provides a neutron measurement, which is based on the shift register technique using an AmLi interrogation source (neutron collar). The system is meant to be installed in fabrication facilities where the assemblies will be verified for gross and/or partial defects by being placed in the measurement station by the facility operator in the absence of the inspector. The fuel assembly identification number is read by a video system that is integrated into the measurement station and uses optical character recognition. The system is designed to provide unattended service for months without inspector intervention. The only intervention of the facility operator that is required is to insert and remove fuel assemblies. All activities of the measurement and identification system including loading and unloading of the AmLi source are pre-programmed for automatic operation. The inspector can program the station to measure in

different positions of the assembly and to make a scan measurement of the whole assembly. The results are stored in a protected database to await the next visit of the inspector. This verification approach is being studied for application in both LEU (Low Enriched Uranium) and MOX fuel production.

Seals and Identification Techniques for Safeguards

In the field of nuclear safeguards, the safe and effective storage of nuclear material is considered one of the important issues. Verifying the presence and the content of each nuclear fuel container in a storage area is done regularly by inspectors. Each container - or item - has to be sealed, before being stored. During inspections the seals are verified.

Ultrasonic Sealing and Identification Techniques

author: B.C. d'Agraves

The development of reliable sealing techniques for nuclear containers and other nuclear items such as fuel assemblies as well as of special identification devices allowing to monitor such items in adverse environments like water and/or radiation is a major activity of the SILab laboratory (Seals and Identification Techniques Laboratory). Innovative systems, developed in SILab, have been or are being patented and have been implemented by ESD and IAEA. These systems usually comprise a passive, radiation proof, in situ ultrasonically verifiable seal (usually a sealing-bolt, or a sealing-nut, or a clamping seal) to be fastened to the container under Safeguards control and able to withstand several years stays, in underwater conditions, in a nuclear spent fuel storage pond. Associated to the seals themselves, special equipment is also studied and supplied by SILab. This equipment comprises tools for underwater operation for the application and removal of seals in-site and dedicated ultrasonic/electronic reading instruments, provided with user-friendly software, for the inspectors verifications.

- 9.12 Van Der Eecken D., et al. - *An Integrated System for Unattended Inspection of Fresh LEU Fuel Assemblies* – in: Proc. Of the 17th ESARDA Symposium, Aachen, Germany, 9-11 May, 1995
- 9.13 Van Der Eecken D., et al. - *Testing of Unattended Measurement Station for Fresh Fuel Assemblies* – in: Proc. of the 19 Annual Symposium on Safeguards and Nuclear Materials Management, Montpellier, France, 13-15 May 1997.



Figure 9.3: (a) Transport test for special safeguard seals. Preparing to install a special safeguards seal on a PuO₂ transport container at Cadarache (FR).

Based on the ultrasonic technique developed by SILab, two main applications have now been implemented. The first one relates to the THORP reprocessing facility of BNFL in Sellafield (UK). For this site, more than 1,000 MK-4 R sealing-bolts have been supplied by SILab. More than 700 of them have already been installed by inspectors on the same number of MultiElement Bottles (MEB), the spent fuel elements transport/storage containers used by BNFL, each container hosting about 4 metric tons of nuclear spent fuel. The production of these seals is expected to continue until 2003.

The second application has been the recent development and subsequent supply to ESD of a complete system (special MK-6 sealing-nuts and related equipment) for the Safeguarding of nuclear storage baskets located in the COGEMA reprocessing plant of La Hague (FR).

Other developments have been conducted in the framework of feasibility studies, such as the study

relating to sealing systems for the COGEMA PuO₂ transport containers used by PNC in Japan.

These techniques also apply either for identification only, or for the safeguarding, of LWR (Light Water Reactor) fuel. In particular, there is a recent and strong demand for the safeguarding of MOX fuel by using "permanent" ultrasonic seals able to withstand the fuel operating conditions related to the complete fuel cycle, from manufacturing to reprocessing, in particular the conditions related to the whole in-core stay period. For these special applications SILab has already developed the basic technology, applicable to various fuel bundle designs, in the framework of collaborations or contracts with fuel manufacturers and/or utilities.

These sealing and identification techniques apply also to the safeguarding of dry intermediate or permanent nuclear storage. In the non-nuclear field,

- 9.14 Sorel F. - Verification of E-metal Seals - Course at Obninsk, Russia, July 1996
 9.15 Bettendorffer E., Colzani S. - CIVES: Colour based Image Verifier for E-metal Seals - User manual, May 1997



Figure 9.3: (b) Verifying the mounted seal after arrival of the same container at Cogema, La Hague (FR)
Photos supplied by Cogema.

these techniques may be applied to the handling of waste, toxic waste and chemical substances, to the monitoring of weapons and weapon storage, etc.

Verification of E-Metal Seals

authors: E. Bettendorffer, F. Sorel

E-metal seals are low-cost seals applied to containers or cells of fresh nuclear material. The seal comprises two circular copper parts one inch in diameter in which there are randomly distributed solder taps and scratches. Before installation, seal images are taken from the bottom and the top part. The subsequent verification of this seal is performed by comparing the seal image recorded before the installation to the seal image recorded after removal. The scope of the verification is to detect possible tampering of the seal and its substitution by a similar one [9.14].

The developed system CIVES (Colour based Image

Verifier for E-metal Seals) includes the mechanical part for the seal positioning, a special illuminator, a PC with an image processing board and a magneto-optical archive unit of 20 GB capacity [9.15]. The selected illuminator causes minimal reflections on the metal surface of the seal. The image quality in the acquisition phase is determined by a high resolution colour camera with RGB output. The positioning of the seal is a delicate aspect of the verification procedure. The computer performs the automatic adjustment in x- and y-axes. The operator rotates the seal to the right angle by watching the superposition of the reference and verification images on the monitor. Changes in the seal pattern are indicated by flashing. The software performs this function by switching with a certain frequency both images in the image memory.

The developed software stores the reference images before installation and carries out the automatic verification of seals. This includes image acquisition, storage, semi-automatic positioning and detection of changes. The first prototype has been completed in 1996 and installed at ESD headquarters.

Application of Electronic Tags in Safeguards

author: C. Korn

New tagging systems and seals based on radiofrequency technology are under development in LaSCo (Laboratory for Surveillance and Containment). The most important application of this concept is represented by the electronic tags, based on the use of passive transponders, developed in the framework of the Electronic Identification of Animal project, described in Chapter 2.

In 1996, some prototypes of electronic seals have been developed for ESD, for evaluation of their applicability for containers of nuclear material and as a candidate for the replacement of the presently used E-metal seals (described in the previous paragraph).

- 9.16 Mol M - CARES-2 Computer Aided Review Station with Event Detector and Digital Storage to Event Scenes for Unattended Reviewing of CAVIS-2 Video Tapes - Technical note I.95.155
- 9.17 Bettendorffer E., Goncalves J., Nunes J. - Remote Video Surveillance Using ISDN - 19th ESARDA Symposium on Safeguards and Nuclear Material Management, Montpellier, France, May 1997



Surveillance/Monitoring Techniques, Remote Data Transmission, Mobile Robotics

Video Surveillance

authors: M. Mol, L. Kobus

The surveillance based on video technique is used in Nuclear Safeguards for assuring the continuity of knowledge between inspections. The activity in 1996 dealt with the upgrade of the video review station CARES-II (Computer Aided Review Station) and the development of a prototype for distributed surveillance on local area network.

Video surveillance systems, in particular multi-camera systems, generate a high amount of images since they operate over long periods in unattended mode. The review process of the stored images is manpower intensive; therefore a computer aided review station was developed and tested in field. The PC based station CARES-II performs the automatic reviewing of 16 multiplexed video channels recorded on tape [9.16]. The scene change detection is based on a cross-correlation of a set of polylines defined for each video camera. This method performs a high data reduction discarding about 97% of the raw data. The detected event images are stored on the computer disk and software tools allow these images to be easily reviewed. The upgrade of the station included a dual-recorder mode for different models of time-lapse recorders as well as the speed up of digital storage and erasure of event images from previous event sessions. The software development and the tests in field were successfully completed.

The second project concerns the development of a laboratory prototype of a distributed surveillance system over Ethernet. This system is based on digital cameras connected through industrial PC boards to a standard Ethernet and a central review station.

The advantage of this configuration is the use of a standard high speed network in nuclear plants which can also be used for connecting other devices than video cameras. The on-going software development includes the image acquisition, data reduction in the camera PC, storage and review of detected events on the central station. A local storage of images in the camera PC prevents the loss of data in case of failure or overload of the local network. Data authentication will be included in the transmission between cameras and central review station.

Remote Data Transmission

author: J. Gonçalves

Public communication networks provide a reliable and cost effective means for remote data transmission in Nuclear Safeguards. In recent years, many countries have created a wide infrastructure for digital communications based on the ISDN (Integrated Services Digital Network) standard. This infrastructure is widely accessible both for national and international communications throughout Europe.

Two projects have been launched for investigating the use and efficiency of ISDN for the remote transmission of Safeguards data [9.17]. The first project, in co-operation with the ESD, uses ISDN oriented commercial equipment and aims at the long term testing of image compression, encryption and transmission between the two sites. The equipment, in use for several months now, connects up to ten standard colour cameras to a programmable video digitiser which outputs a compressed data stream using the JPEG standard. Data are then passed to an encryptor and then to an ISDN terminal adapter establishing a 64 kbps data link. At the reception, data pass through a hardware chain with a decryptor, demultiplexer and JPEG decompression box, which outputs a standard PAL analogue signal.

The second project aimed at the evaluation of ISDN services standards, in particular video conferencing (e.g., H224, H261, H281), for Safeguards remote surveillance. A general purpose personal computer equipped with an ISDN interface and a video code-

- 9.18 Gonçalves J., Sequeira V., Sorel F. - *From Distance Measurements to Tele-Presence and Virtual Reality Applications in Safeguards* - in: Proceedings of Workshop on Science and Modern Technology for Safeguards, Arona, October 1996
- 9.19 Sequeira V. - *Active Range Sensing for 3-D Environment Reconstruction* - Tech note 1.97.26
- 9.20 Sequeira V., Millán J., Ribeiro I., Gonçalves J. - *Embedding Learning in Behaviour-based Architectures: A Conceptual Approach* - 2nd World Congress on Intelligent Manufacturing Processes, Budapest, June 1997
- 9.21 Millán J., Arleo A. - *Neural Network Learning of Variable Grid-Based Maps for the Autonomous Navigation of Robots* - IEEE Int. Symposium in Computational Intelligence in robotics and Automation, Monterey USA, July 1997

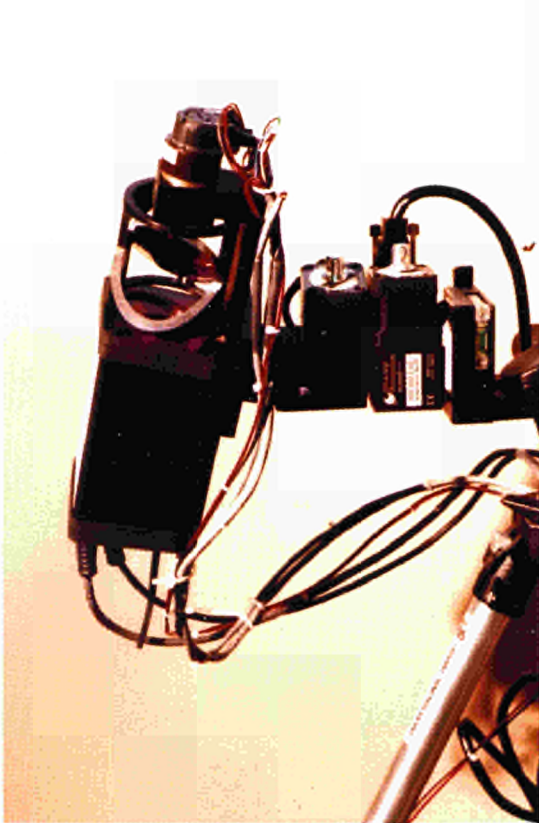


Figure 9.4: Laser Range Finder with fast line-scan unit installed

decoder is used. A dedicated software toolbox was developed, together with an appropriate user interface. Some implemented features are:

- the use of either 64 or 128 kbps channel;
- real-time interactive control of remote cameras equipped with programmable zoom and mounted on a computer controlled pan and tilt units;
- the simultaneous transfer of images and other data, e.g., files, documents or data from Safeguards sensors;
- the use of all services and hardware resources available on the personal computer for increased flexibility.

Further work will concentrate on the analysis, implementation and testing of security features for data transmission, in particular integrity, authentication and encryption.

Design Information Verification

authors: V. Sequeira, J. Gonçalves

The verification of plant design is a topic of increasing importance for Nuclear Safeguards. The aim is to detect the differences between the approved design plans and the plant “as built”. Differences can be of two types: i) unbuilt parts or ii) sections that were built either abusively or disregarding the original



Figure 9.5: Reflectance image of a laboratory scene.

plan. Most designs can be verified by comparing reference distances in the plant with those specified. Laser Range Finders (LRF) contribute to Design Information Verification, considering distances are directly measured with high accuracy (e.g., 1 to 4 mm), and unlike TV cameras, measurements do not depend on the illumination of the scene [9.18]. Scene reconstruction can be obtained by scanning the LRF in two directions (azimuth and elevation) [9.19]. The selection of the laser range scanner, i.e., the sensor itself and its associated scanning system, determines the quality of the range images obtained, and thus the quality of the extracted 3D models. Figure 9.4 shows a laser range finder with its corresponding scanning system (rotating mirror) mounted on a computer controlled tilt unit. Figure 9.5 shows the level of detail for a range image obtained with the equipment shown (up to 50,000 samples per second with an overall accuracy of about 3-5mm). The small diameter of the laser beam and its low divergence provide a very high spatial resolution, and are hence appropriate to industrial scenes with small details, e.g., pipes. Future work will concentrate on the registration of images with high levels of detail and on the automatic generation of plant models that can be compared with the plant’s design information.

Mobile Robotics

authors: J. Millán, J. Gonçalves

Mobile robotics technologies have been investigated aiming at the remote verification of fissile materials storage areas. Indoor environments can be complex and dynamic, making it principally impossible to pre-codify exact maps. Thus, a mobile robot requires sensory data to deal with local unexpected events in order a given mission can be accomplished with success.

The incorporation of learning capabilities into mobile robots are important to bridge the gap between global map-based planning and local sensor-based control [9.20,9.21]. In particular, two complementary neural network learning techniques were developed. The first one allows a mobile robot to acquire incrementally a map by exploring

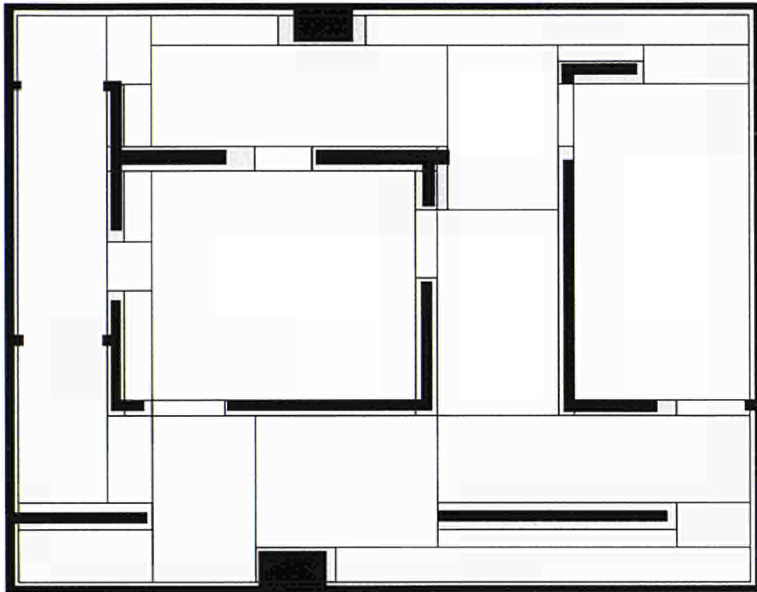


Figure 9.6: Learned map for a given environment. The grey partitions represent areas of the world considered as obstacles and the black rectangles represent the actual obstacles.

autonomously an initially unknown indoor environment. It creates a variable resolution partitioning of the environment. The robot's workspace is discretised in cells of different sizes, so as to use high resolution only on critical areas (i.e., around obstacles). Each cell represents a homogeneous area (free or occupied). The resulting topological map represents the spatial structure of the world, but does not model fine details—which are handled through sensor-based control—and allows fast planning of the robot's routes. Figure 9.6 shows the learned map for a given environment. The second learning technique is a refinement of a previous approach to rapid, incremental and safe learning of efficient sensor-based navigation strategies. The neural network is trained on-line by means of a combination of reinforcement learning and self-organising rules. In addition, the robot does not learn from scratch, but uses two types of bias: built-in reflexes (domain knowledge) and advice. Every time the robot fails to generalise its previous experience to the current sensory situation, it uses its own embedded reflexes and a new unit is added to the neural network. A new unit is also added whenever the robot receives advice from humans. This unit is integrated into a dynamic self-organising map and associates a region around the current situation to either the computed reflex or the advice. The resulting reaction rule is then tuned by means of reinforcement learning and self-organising rules. A second line of work deals with localisation, i.e., finding the position and orientation of a mobile robot inside a room. This can be achieved by receiving information from the outside world (e.g. GPS), or by referencing the robot to the environment after "looking" to a priori known landmarks. In the context of Nuclear Safeguards it is preferable to use natural

landmarks since it is not required to alter the environment. A localisation system using natural landmarks (i.e., corners, etc.) was developed. The system periodically scans (e.g., every minute) relevant areas of the environment with an on-board laser range finder in order to detect the natural landmarks, and then computes the robot's position and orientation with a typical accuracy of 1cm and 0.2 degrees respectively.

Surveillance Systems Based on Heat Flux Sensors

author: P. Guilmain

In LaSCo, the new surveillance system SYCLOP (SYstem of Control of Localisations and Object by Parabola) is being developed since 1994. This system is based on the use of a parabolic reflector, it concentrates the thermal radiation of the monitored environment on a radiant-heat-flux sensor. Every modification of the thermal equilibrium in the vigilated zone, due for instance to the intrusion of a person, is detected by the system. A room space, or even a specific object inside the room space, can be monitored by the system. This technology, due to its innovative and high reliability aspects, represents a new approach to remote pinpoint surveillance and monitoring. SYCLOP has been recently patented (Patent JRC Ispra No. Lu 2488 of 26.1.96). During 1996, nine SYCLOP surveillance systems have been installed on request of ESD in a nuclear material storage. A specific acquisition unit has been developed for alarms recording (Figure 9.7). New detectors, based on heat flow sensors (SYCLOP concept), with the relative acquisition units, are under development for application in other fields (in agriculture for animal surveillance, to improve livestock management and production; in museums for objects surveillance).

Environmental Testing of Equipment

author: C. Korn

Recently, the request for qualification-testing of equipment used for safeguards verification has strongly increased due to the unacceptable failure rate of some instrumentation acquired by the inspectorates and their special use in specific places. In fact, in the past most of the instrumentation used had been developed by research laboratories, whereas at present commercial equipment is used, mainly for surveillance and monitoring systems. Testing of

equipment under simulated environmental conditions is performed by ISIS in the TEMPEST (Thermal, Electromagnetic and Physical Equipment Stress Testing) Laboratory. This laboratory allows testing of equipment under various simulated environmental conditions according to the requests of the customers (other R/D laboratories, ESD, IAEA, industry) and/or in compliance of given standards, such as MIL, CEI, etc.

In 1996, the procedure for accreditation of the TEMPEST laboratory under EN 45001 (ISO 25) Quality Standard has been started. During the year, qualification testing of equipment for ESD and IAEA continued: among the tested equipment, we mention the electronic seals AFOS and MINAFOS, the surveillance systems GEMINI, EMOSS, VDIS. Standardised test procedures have been developed, such as "Qualification Testing of New Safeguards Equipment" - test procedure V 1.2, for the testing of IAEA's devices under thermal, mechanical and electromagnetic stresses to guarantee the required level of reliability and performances.

Integration of Safeguards Systems

Fuel Cycle Analysis

author: A. Besi

This activity is to be framed in the systems analysis studies in the safeguards area. These studies are performed to support the on-going research activities, to try to identify future lines of development of safeguards technology and thereby re-orient the current research work.

A study of the nuclear fuel cycle of the former Soviet Union countries (the so-called Newly Independent States, NIS) started in 1995. The aims of the study are:

- the investigation, from the nuclear safeguards point of view, of the organisation of the nuclear industry and research structures in the NIS;
- the analysis of some aspects of the nuclear fuel cycle, such as the identification of the flows of nuclear materials among the various fuel cycle facilities;
- supporting the strategic decision making in TACIS assistance programme.

A prototype of database containing data on the nuclear sites and the relative facilities and the



Figure 9.7: SYCLOP - 3.5 Surveillance systems based on heat-flow sensors

computerised representation of the fuel cycle schemes for the various categories of nuclear power plants are the main preliminary results of the study.

Statistical Tools for Nuclear Material Balance Analysis

author: C. Foggi

Accountancy of nuclear materials is based on measurements and therefore it is subjected to a certain degree of uncertainty from instruments errors. Good management of these materials requires that the uncertainty is kept as low as possible. Statistical models exist which can predict the range of uncertainty which can be expected from a given measurement system and given procedures. One of these models has been developed in the past by the JRC at Ispra.

Based on this model, a software for the Statistical Analysis of Nuclear Material Balances (SAMBA) has been developed in view of its use in the Russian Methodology and Training Centre (RMTC) of Obninsk for the purpose of training Operators of Nuclear Facilities and Inspectors in the use of statistical methods of data evaluation. This software runs on a PC computer in the WINDOWS environment. It can be operated either in the English language or in the Russian language (with Cyrillic characters); the computer environment shall however be English. The software has been demonstrated and installed in the RMTC.

SAMBA has also been adapted to application in a mixed oxide fuel fabrication plant. A contract has been obtained from the Belgonucléaire Company (B) for such a purpose.



Management of ESARDA

author: C. Foggi

ESARDA is the European Association for R&D in Safeguards. Its Secretariat and its day to day management are currently done by ISIS, together with the organisation of its Meetings, the publication of the Bulletin of the Association, the Secretariat of the Steering Committee, of the Scientific Council and Co-ordination Board, and of the Executive Committee.

The 1996 administrative tasks included the following: i) the duration of the Association was renewed for additional 5 years, ii) one of the partners (ENEA of Italy) left the Association, and iii) one new Partner (STUK of Finland) applied for Membership. Each of these events required changes in the contract of the Association. In addition, the new structure of the Association decided by its Steering Committee, was put into operation.

In May 1996, an Internal ESARDA Meeting and a joint Meeting with the Royal Society of Chemistry on "Analytical Measurement and their Interpretation for Regulatory purposes" were organised in Bath, UK, in collaboration with the UKAEA. The objectives of the joint Meeting with the RSC were to explore possible similarities in techniques and methods and to detect possible synergies. The Proceedings were published as a special number of the ESARDA Bulletin.

In October 1996 a joint Workshop ESARDA-INMM (Institute of Nuclear Materials Management, USA) was organised at Arona (I). The subject was "Science and Modern Technology for Safeguards". The objectives were to investigate the possible application to safeguards of techniques and methods that are already successfully applied to other fields of the human activity, but are not yet exploited in safeguards applications. It was attended by 118 participants, many of them from the academic field.

Ispira collaborated with other ESARDA Parties in defining and carrying out the preliminary organisation of several meetings to be held in 1997:

- the ESARDA Symposium on Safeguards and Nuclear material Management, to be held in Montpellier (F) in May;
- a Joint Meeting with the Russian Institute for Physics and Power Engineering on the co-operation with the CIS Countries in developing a Nuclear Material Accountancy and Control system (date yet to be set);
- the IAEA Symposium on the Fuel Cycle, to be held in Vienna in June;
- the IAEA Symposium on Safeguards, to be held in Vienna in November.

Activities for TACIS

author: S. Guardini

Various co-operation/assistance activities are being performed under the Commission TACIS programme. The main objective in the co-operation concerning the safeguards area is the establishment in the Russian Federation (RF) of an improved Nuclear Material Accountancy and Control (NMAC) system. One important project in this area being carried on by ISIS is the creation of the Russian Methodological and Training Centre (RMTC), at the Institute of Physics and Power Engineering (IPPE) at Obninsk, in the Kaluga Region: ISIS has been co-operating with MINATOM (the Russia Ministry for Atomic Energy) in the design and implementation of the Centre. The centre has already started to operate, even if some of the equipment for its facilities is still under procurement. The RMTC uses existing premises, already licensed for the use of bulk quantities of nuclear materials (U, Pu). These are now being equipped with instrumentation for hands-on training on nuclear materials measurements.

The principal task of the RMTC is the training of MINATOM plant operators as well as of Gosatomnadzor (the Russia safety authority) "domestic" inspectors, in domains relating to the development and implementation of upgraded approaches for accounting and safeguarding fissile materials. The RMTC is also intended to be a very important forum and meeting point for plant operators and inspectors

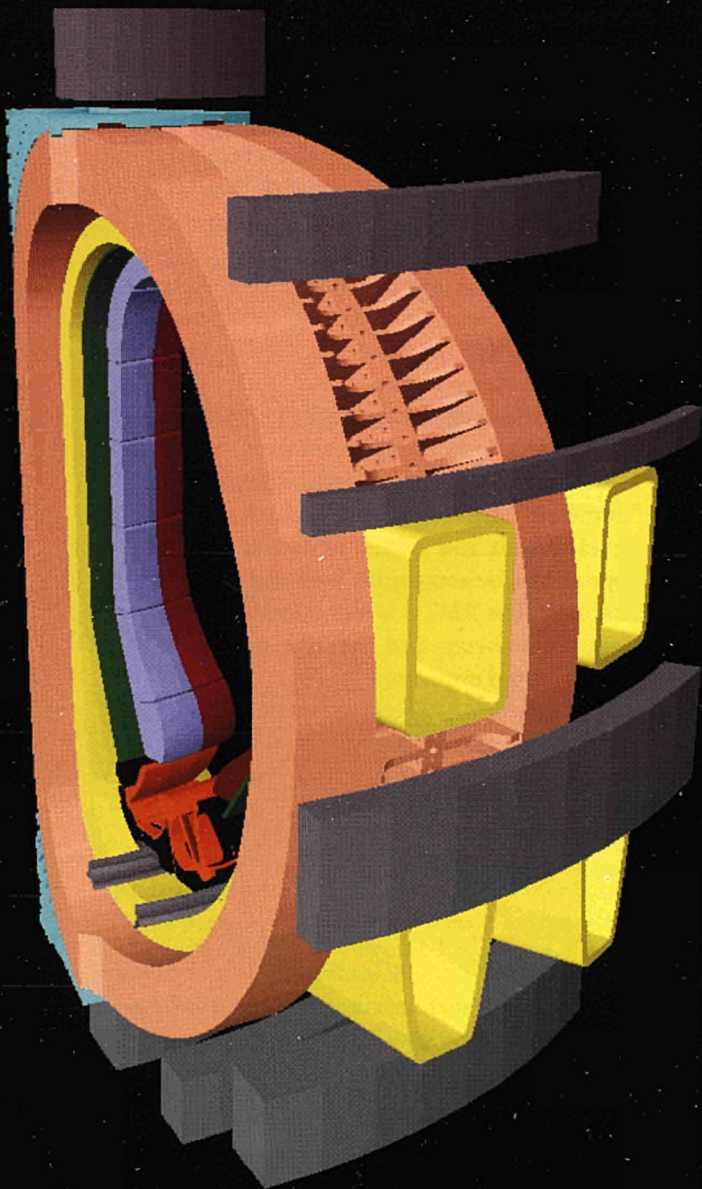
The first Russian-JRC course was held at the RMTC in July 1996, and two training courses were organised at Ispira for the training of future trainers and the two seminars (July 1996 and April 1997) have been held at the RMTC, jointly organised by JRC and IPPE.

During 1996 a new project has been prepared, with the strategic objective of leading the Russian industry to produce updated instrumentation for safeguards verification, to be installed in the Russian nuclear facilities for NMAC. This project includes also the development of tools on statistical methodology for NMAC. The Russian partner institute for this project is the Institute for Automatics of Moscow.

10

Remote handling

author: F. Farfaletti-Casali



Remote Handling has been developed as a Fusion activity within the frame of design tasks co-ordinated by the Fusion Directorate and NET (Next European Torus) Team, deal with critical safety aspects of future reactors, in particular the International Thermonuclear Experimental Reactor (ITER) design. The contributions of ISIS were in the following areas:

- Remote Handling Maintenance
- Structural integrity of vessel and in-vessel components, under plasma disruptions
- Safety and Environment

A reorientation of the ISIS programme, at the end of 1995, had concentrated activities in the first area. The other two areas of activity were concluded at the beginning of 1996.

The studies on Remote Handling and Maintenance have been pursued, in collaboration with ENEA, following the dual approach of computer simulation, inside the CAD/CAE laboratory TELEMAR (laboratory for Teleoperations and Robotics), and experimental simulation and validation at the ROBERTINO heavy robotics facility. This facility was upgraded with a flexible control system. A first model of the ITER design has been prepared on the simulator for robotics TELEGRIP™, in view of the simulation of the divertor cassettes removal. A test campaign on remote cutting and welding of pipes using bore tooling has been carried out on the ROBERTINO facility.

Figure 10.1: Simulation is the first step in the maintenance study of Fusion Reactors by remote handling. The figure shows one section of ITER (International Thermonuclear Experimental Reactor), a model suitable for kinematic simulation created using TELEGRIP™ of Deneb Robotics (USA). The model is then validated on the experimental facility ROBERTINO.



Figure 10.2: ROBERTINO heavy robotics facility: a big, 4 degrees of freedom, gantry robot for the experimental validation of the Remote Handling devices and procedures to be used for the "Next Step" Fusion Reactor maintenance as well as for industrial applications

In parallel to the fusion activities, intense marketing actions have been undertaken to identify applications for heavy robotics in industrial processes. Two competitive actions will be undertaken in 1997. The first concerns the demonstration of laser welding techniques applied to the construction of heavy components (in the frame of the DG XIII Programme Innovation). The second is on the commercialisation of the software used for the control of ROBERTINO (developed at ISIS) as a safety critical computer system for heavy robotics (technical support to DG XIII - Telecommunications, Information Market and Exploitation of Research).

Fusion Activities

For remote handling maintenance, an experimental validation of tools for pipe-cutting and welding (50 mm of inner diameter and 2 mm thickness) was jointly performed in '96 by JRC Ispra and ENEA-Fusion Division (I) on the ROBERTINO facility. The bore tools were provided by COMEX NUCLEAIRE in collaboration with CFFTP/SPAR (Canada). Tests have been carried out on straight pipes, both horizontal and vertical, representing the penetration lines through the access ports. The tests have demonstrated the feasibility of the cutting and welding processes. The test results [10.1] are

useful for the construction of the prototype tools for larger pipe diameters that will be used on the ITER Divertor Test Platform.

A first complete model of one sector of the ITER machine has been completed by using the simulation package TELEGRIP™, according to the ITER TAC-8 reference drawings, received from the ITER EU Home Team (Figure 10.1). The collaboration with ENEA on the 3D models of the Divertor Test Platform has been also pursued, in view of the simulation of the Divertor cassettes removal.

To simulate structural integrity of in-vessel components during plasma vertical instabilities, a numerical model has been developed. It evaluates the Halo current distributions and the resulting contact forces on the first wall.

In the area of safety and the environment, thermal transient analyses of various accident scenarios, including all possible in-vessel energy sources, have been completed.

An integrated set of software tools has been completed to support the various stages of the probabilistic safety assessment of ITER.

Industrial Spin-Off Applications

The laboratory was approached by several companies for the CAD/CAE Laboratory TELEMAR used for computer simulation of remote handling operations and for the ROBERTINO facility (Figure 10.2) used in experimental validation of heavy robotics industrial applications. One approach resulted in the participation of ISIS in a Consortium using the ROBERTINO facility for a demonstration of laser welding techniques applied to the construction of heavy components (LASERBOT).

Development of Robotics Control System

The activities carried out on the ROBERTINO facility for the Fusion Technology Programme required the development of a new control system for heavy robotics. The Control System was developed as a Safety Critical Computer System following the PSS-05 ESA standard for software development, and resulted in elevated performance regarding reliability, safety, maintainability and configurability.

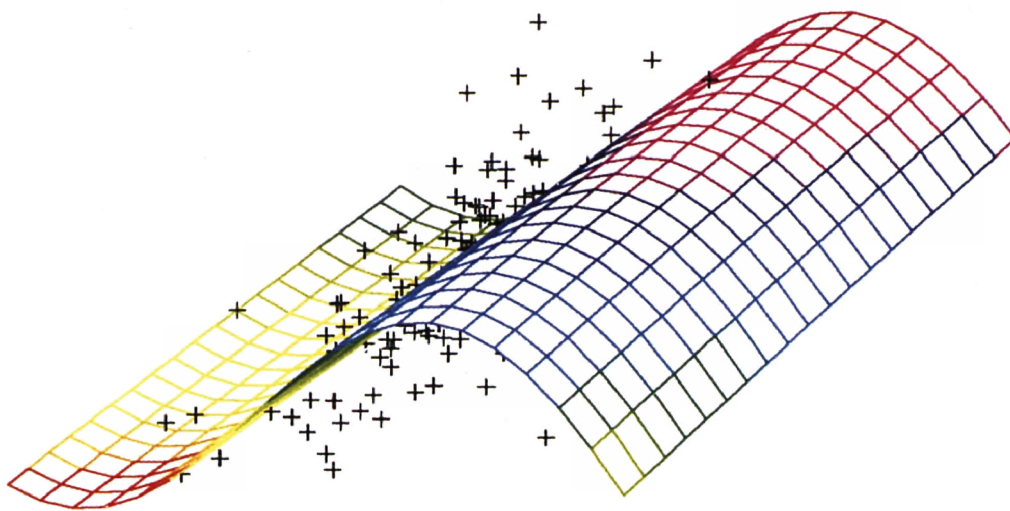
The ROBERTINO Control System has proved interesting for applications to complex robotics systems in the industrial field. It has been chosen by DG XIII for technology transfer to obtain a commercial generalised software control system for industrial robots (GENERIS).

10.1 Farfaletti-Casali F., Mercurio G. et al. -Pipe Handling Trials on the ROBERTINO Facility- JRC Report, Technical Note 1.96.238, JRC Ispra, 1996

11

Services to the Commission

authors: I. Shepherd, A. Varfis



In 1996 ISIS continued to support the Commission and its agencies' services with its unique blend of impartiality and scientific competence. Table 1 summarises how the ISIS research themes have been harnessed to support specific services of the Commission. The main achievements for each of the customer Services in 1996 are listed briefly below. More details of some of them have been included earlier in this report under the appropriate themes.

Figure 11.1: Forecasting of industrial variables using neural network techniques: Two short-term leading indicators of Industrial Production (X_1 , X_2) are used to forecast the actual annual production index (Y). The surface represents a neural network functional which interpolates smoothly the data (crosses).

ISIS was the main scientific adviser to the EURATOM safeguards directorate at Luxembourg (DG XVII, Energy) and provided the technical means whereby DG I (Foreign Affairs) supported the International Atomic Energy Agency (IAEA) at Vienna. The more significant achievements were the following:

- Remote transmission of safeguards data between headquarters and plant was tested through an ISDN connection Luxembourg-Ispira. Encrypted and compressed video images were transmitted at high speed in a remote surveillance application.
- A new surveillance system of a plutonium storage area based on heat flow meters has been installed and extensive field tests are now being conducted.
- An unattended measurement station for the determination of concentrations of U in LWR fuel assemblies was developed. The first field tests have been conducted in a fuel fabrication facility.
- Instruments and software for process monitoring for mass and volume determination in large tanks of bulk handling facilities have been installed. These instruments are now being tested by IAEA in selected facilities.
- A spent fuel monitor, based on a cadmium telluride gamma detector was developed and tested. The same detector is now being studied for the rapid verification of uranium or plutonium in containers.
- Safeguards equipment for both EURATOM and IAEA has undergone environmental testing under thermal, mechanical and electromagnetic induced stresses. Optical surveillance systems, sealing and non-destructive assay instruments have been tested according to a common agreed standard and protocol.
- The delivery of sealing bolts to be installed in the THORP (Thermal Offsite Reprocessing Plant at Sellafield, BNSL Plc., GB) spent fuel storage pond continued. A dedicated database management system for the management of the seal population was provided.
- Several demonstrations have taken place at IAEA on sealing equipment of plutonium dioxide transport containers sealing bolts for spent fuel multi-element bottles and special transport and storage casks.
- A large number of training courses for both EURATOM and IAEA inspectors were held. Subjects covered were the mass and volume measurement of liquids in large tanks and non-destructive assay techniques including the measurement of spent fuel using a JRC-developed underwater gamma measurement system.

DG I, through the TACIS (Technical Assistance for the New Independent States and Mongolia) Programme, is supporting efforts in the Russian

Federation to improve nuclear material accountability and control:

- As part of this work a Safeguards Methodological and Training Centre (RMTC) is being set up at the Institute of Physics and Power Engineering (IPPE), Obninsk, in the Kaluga region of Russia. JRC, together with IPPE, has been given the task of designing and implementing the Centre. The principal tasks of the RMTC are the training of MINATOM plant operators as well as of Gosatomnadzor domestic inspectors in fields such as development and implementation of upgraded approaches for accounting and safeguarding fissile materials. It will use existing premises, already licensed for the use of bulk quantities of nuclear materials. There will also be classrooms for theoretical lessons and laboratories where hands-on training will be given on nuclear materials measurements. The first joint JRC-Russian course was held in July, 1996 and two seminars were held at Ispira to provide further training for the teachers.
- A new TACIS project on instrument production for accountability and control has been prepared.

ISIS supported DG XI (Environment, Nuclear Safety and Civil Protection) by:

- Reviewing technical documents on probabilistic safety assessment, severe accidents, thermal-hydraulics, structural dynamics and seismic assessment submitted to the Nuclear Regulators' Working Group and the Reactor Safety Group. ISIS kept the members of these groups abreast of current international developments by following the reactor safety activities of the Organisation for Economic Co-operation and Development (OECD) on their behalf.
- Checking calculations for nuclear reactor accident sequences submitted by a number of organisations. A summary of the results was produced and recommendations made as to how the different approaches could be harmonised.
- Adding earthquake catalogues of areas from the former Soviet Union and Eastern Bloc countries to the European Seismic catalogue.
- Implementing the Seveso Directive on industrial hazards by operating the Major Accidents Reporting System (MARS) and the Community Documentation Centre on Industrial Risk. The Major Hazards Bureau also acted as scientific co-ordinator for technical working groups that provided advice on safety management systems and the production of safety reports. It held its largest technical seminar so far, on "Chemical Safety in Ports and Marshalling Yards"
- Analysing impact studies of installations for the treatment and disposal of toxic and dangerous

Theme	DG I	DG III	DG VI	DG XI	DG XIII	DG XVII	UCLAF	EUROSTAT	EEA
Decision support systems							●		●
Fraud control			●				●		
Information technology		●			●			●	●
Sustainable transport					●				
Cultural heritage					●				
Earthquake engineering		●							
Process industry and clean technology				●	●				
Nuclear safety	●			●					
Safeguards	●					●			
Remote handling					●				

Table 1: Summary of ISIS' support to Commission

waste in the European Union. A study was carried out to develop an overall strategy for research and development on environmental impact assessment and strategic environmental assessment.

- Implementing the Directives on the contained use, the deliberate release and the marketing of genetically modified organisms. During 1996 more than 200 dossiers have been examined and a software was developed to allow exchange of information on experimental releases of transgenic plants. Competent Authorities from all Member States (plus Norway and Iceland) were trained at Ispra.

ISIS helps DG III (Industry) make European industry more competitive. During 1996 ISIS:

- Organised on their behalf workshops on Requirements Engineering, industrial uptake of Requirements Engineering projects, Geographical Information Systems, High Performance Computer Networks in medical imaging applications and the annual meeting of the Euro-working group in decision support systems.
- Produced a state of the art report on safety analysis tools for software intensive systems
- Supported efforts to improve Eurocode 8, the new European design code for earthquake resistant structures. This required tests on a full-scale three-storey composite (steel and concrete) structure, as well as on a three-storey reinforced concrete frame with irregular masonry infills.
- Investigated applications of high performance computing and networking activities and have accepted a project on multi-site application of virtual reality.

ISIS is increasing its effort in making sure that programmes funded by the European Union are not defrauded. For DG VI (Agriculture):

- Work involving the identification of animals by electronic tagging has continued. A pilot study involved the identification of several thousand animals was carried out in collaboration with

eight other organisations. JRC's contribution was to develop technical verification systems, test equipment performance and evaluate in-field measurement results. Several commercial companies have developed hand-held and static electronic identifiers. These have been extensively tested in the TEMPEST laboratory according to a well defined protocol conforming to international standards. A larger scale project (IDEA), concerning the electronic identification of one million animals (sheep, goats, cattle) in different countries of the EU, has been formulated.

- Methods and instruments for the in-field verification of the volume and density of alimentary oil contained in a variety of tanks have been developed. Field tests have been conducted in Southern Italy in order to determine the performance of the dip tube technique and evaluate its sensitivity to fraud scenarios.

For the Commission's fraud control service UCLAF (Co-ordination unit for the fight against fraud):

- Information technology and statistical analysis have been employed to sift a database of fraudulent transactions. A first step has been the development of techniques to improve the quality of data and reduce the quantity to a manageable level without losing information. About 20000 transactions have been screened in the search for methods that identify errors and models of dependency.
- A report was written correlating particular incidences of fraud with country profiles and monetary impacts, a survey was made of data mining software and a feasibility study of an information system for UCLAF was completed.

For the European Environment Agency (EEA):

- ISIS has worked out a method of calculating pressure from measurable environmental indicators defined by EUROSTAT. The first stage of the project - the collection of reports on environmental indicators in the member states is almost complete.



- A study of good practice and user needs in integrated environmental assessment on behalf of EEA has also been completed.
- An interface to Geographical Information Systems through the World Wide Web was developed.

For the Statistical Office of the European Communities (EUROSTAT):

- Environmental pressure indicator models were collected and analysed.
- ISIS' neural network expertise was used to help EUROSTAT extrapolate time-series of data for industrial performance forecasting and to classify land cover (see below).

It is part of ISIS' mission to transfer technology developed at Ispra (I) to industry and to enable it to do so it bids for funding from DG XIII (Telecommunications, Technology Transfer). In 1996 ten of these spin-off projects were supported:

- Comparative testing of an opto-thermal device
- Differential thermal and pressure monitoring Thermal Detection Systems
- Exploitation of the batch chemical reactor relief line simulator package RELIEF
- Industrialisation of advanced adaptive wavelets and fractal compression techniques
- Electronic speckle photogrammetry interferometric based device for deformation measurement and mechanical characterisation of building materials
- Interferometric fibre optic sensor for structural real time strain monitoring and damage detection
- Exploitation of the STARS industrial reliability software
- Implementation of a commercial generalised software control system for industrial robots
- An interactive mobile surveillance system
- A graphical user interface for the gas dispersion and combustion code REACFLOW.

DG XIII also supported JRC's development of the European Co-ordination Centre for Aircraft Incident Reporting Systems (ECC-AIRS). A second beta release was issued and further work will be supported by DG VII (Transport).

Statistical Office of the European Communities

The objective of the Neural Networks Laboratory (NNL) is to study, develop and implement neural network modules for practical applications. The expertise is in the neural networks themselves rather than any particular domain. In 1996 the laboratory

bid for and won two contracts from the European Communities Statistical Office (EUROSTAT).

Forecasting of Industrial Variables Using Neural Network Techniques

The objective of the first contract was to see how neural networks could be applied to forecast annual values of structural variables such as employment or production for each Member State of the European Union and some 150 industries using a limited sample of monthly data. The problem differs from most applications of neural network (connectionist) methods for time series forecasting in two important aspects. Firstly, there are many thousands of time series and this precludes the use of models specially tailored for each series. Secondly, the minimum number of observations required for a neural network model is far greater than the ten to fifteen available for each variable.

To provide enough data for the model, observations from different countries were pooled to find a forecast model for each variable that is common to all the Member States. The method proved workable and the results obtained were benchmarked against EUROSTAT's own method for industrial variable forecasting. They used a form of double exponential smoothing that had outperformed the other mainstream methods. The connectionist method outperformed the conventional one in approximately 50% of cases and there are indications that *a-priori* analysis is able to predict which of the models will perform better (Figure 11.1)

Use of Neural Networks for Improving Satellite Image Processing Techniques for Land Cover/Land Use Classification

This second neural networks project is a joint venture between ISIS and JRC's Space Applications Institute at Ispra. Its objective is to describe, demonstrate and test the potential of neural networks to classify land cover/land use into classes defined by EUROSTAT's hierarchical statistical structure CLUSTERS (Classification for Land Uses Statistics of EUROSTAT's programme on Remote sensing and Statistics)

Two Landsat Thematic Mapper images and one Synthetic Aperture Radar image, which cover the area around the city of Lisbon (P) were analysed. There are tens of classes and the image pixels can be combined in thousands of possible ways to form image features. A complex system combining neural networks and conventional techniques has been developed. It extracts, encodes, selects and classifies features at a very large scale. This system enables the user to achieve a good automation level in image classification for land use and to analyse thoroughly the potential of neural network classifiers.

12 Regional projects

(author: A. Lucia)



The JRC in general, and ISIS in particular, are collaborating with regional governments for the preparation and realisation of projects aiming at technological, cultural and economic development of the regions. The presence of JRC is not only justified by reasons of excellence reached in some research fields, but by the added value coming from its neutrality, multi-disciplinarity and international dimension. The projects reported below are carried out in collaboration with Italian institutions; contacts and negotiations are going on for the extension of this kind of collaboration to other countries.

Figure 12.1: Two Regional projects carried out by ISIS



Region of Sicily (Italy)

A major development project was performed on behalf of the Regione Siciliana by the JRC, the Universities of Catania, Messina and Palermo. The duration of the project was 24 months and the JRC activities were completed at the end of 1996. ISIS provided the overall project management and co-ordination of the JRC activities. ISIS scientists participated in the following 5 (of a total of 6) individual projects whose main results are hereafter briefly described.

Project A: Management of water resources

Participating Institutes: EI (Environment Institute), SAI (Space Applications Institute) and ISIS.

Lead Institute: ISIS

The Project is divided in 4 sub-projects:

- 1 Research for the identification of criteria and methodologies for managing water resources
- 2 Research for assessing the possibility of monitoring water quality and quantity
- 3 Analysis of the consequences, on the coastal ecosystem, of the use of water resources
- 4 Development of a Decision Support System for management of water resources

ISIS developed an Internet-based distributed information system which contains the most relevant scientific outcomes of the project. This has had a remarkable technological spin-off on the information and communication tools of the Sicilian Universities. As far as the specific ISIS tasks were concerned, the activity was related to the development and implementation of a Multi-criteria Decision Support System (DSS) operating for two case studies of water management.

The first of these was on the water supply system of the city of Palermo. The set of possible alternatives has been generated starting from the "business as usual option", representing the management rule of the water supply system under normal conditions. The water system of the city of Palermo is composed of a set of natural elements (water bodies), a set of artificial elements (e.g. dams) and a set of decision structures which interact to reach one of more objectives. This system also includes water treatment plants that supply water for agriculture use (in particular "Conca d'Oro" and Partinico) and drinking water to the villages on the east of Palermo. The water of "Piana degli Albanesi" is used for energy production too. So, this system is quite complex since it is used for industrial, agriculture and drinking water supplies.

The second case study was related to the use of the waters of the river basin of Anapo. This is a typical example of conflict between the different users of a resource.

Seven criteria for evaluation of the alternatives have been chosen; the number of viable alternatives were eight, ranging from a base case scenario (actual situation) through various options for changing the current water use.

A Novel Approach to Imprecise Assessment and Decision Environments (NAIADE), originally developed at ISIS, was improved and made specific for the implementation to the two case studies. It is a discrete multi-criteria method, based on some aspects of the partial comparability axiom. NAIADe also performs conflict analyses. At the end of the process, the DSS supplies the decision maker with two pieces of information: a ranking of the alternative actions based on the selected decision criteria, and a second (normally different) ranking of the "acceptability" of these alternatives by the stakeholder groups.

Following various discussions with decision-makers and staff of various public and private corporations and social groups, we then summarised the judgements of the alternatives in a way that is consistent with the interests of the individual stakeholder.

Project B: Air pollution in industrial and urban centres

Participating Institutes: EI and ISIS.

Lead Institute: ISIS

The Project is divided in 4 sub-projects:

- 1 The city of Messina
- 2 The industrial area of Milazzo
- 3 The city of Catania
- 4 The city of Palermo

The emission of atmospheric pollutants from vehicular traffic and industry cause an environmental impact which ranges from the deterioration of urban quality (in terms of health risks for the inhabitants) to the loss of cultural heritage (via the state of conservation of the monuments) as well as causing possible damage to agricultural-alimentary areas due to the transport of atmospheric pollutants. The JRC analysed the problem of urban and industrial air pollution from two angles: (i) monitoring the atmospheric pollution and modelling the atmospheric diffusion of pollutants in the urban areas of Messina, Palermo and Catania and the industrial site of Milazzo; (ii) developing an information system to support the decision of environmental strategies for these cities. Winter and summer campaigns for the measurement on NO₂ level in Catania, Messina and Palermo have been carried out by EI. About 300 sensors (diffusion tubes) were installed in properly selected locations and the NO₂ concentration maps have been produced. In the city of Catania a measurement campaign has also been performed by EI for the

measurement of the concentration of volatile organic compounds, namely benzene, toluene and xylene (BTX). In the industrial area of Milazzo, the atmospheric pollution has been measured by a mobile laboratory, while atmospheric models have been developed and tested. These results are presented in the EI 1996 Annual Report.

Moreover, from these data ISIS has:

- integrated demographic data with the results of the applied models to a database;
- created a decision support system (DSS) which respects the specific decision rules and reaches the integrated database;
- created a World Wide Web interface documenting the project and the DSS by presenting the geographic database and the environmental models of the cities.

Project C: Pollution and erosion of soil

Participating Institutes: EI, SAI and ISIS.

Lead Institute: EI

The Project is divided in 4 sub-projects:

- 1 Estimation and control of soil erosion
- 2 Management of sediments
- 3 Soil pollution due to the use of reflux water for irrigation
- 4 Soil pollution due to solid waste disposal

The work related to data collection and analysis for management of soil erosion, management of sediments and use of reflux water for irrigation was performed by EI and SAI Institutes. ISIS contributed by developing of a DSS for managing urban and industrial waste collection. The system developed is applied to a sub-region of Sicily in order to find the most reasonable solution to the urban solid waste management (USWM) in the refereed area. The provinces involved are both Palermo and Trapani, including 27 municipalities. The research mainly concerns the design and implementation of the DSS including the technological aspects.

Project D: Safety and reliability of chemical and petrochemical installations

Participating and lead Institute: ISIS.

The Project is divided in 4 sub-projects:

- 1 Identification of risk and accident sequences
- 2 Prevention and mitigation
- 3 Estimation of consequences
- 4 Risk analysis

The overall goals were (i) to adapt, according to requirements expressed by the three Sicilian Universities, various software packages and methods related to safety and reliability of industrial systems;

(ii) to transfer these packages and methods to the Universities; (iii) to train the technical staff of the Universities and provide support to the case-studies run by the Universities.

The main specific objectives, duly reached during the course of the 2-year project, are listed hereafter:

- Adaptation and transfer of tools and methods for hazard identification, probabilistic safety assessment and reliability data management, namely: the STARS suite, Ispra-FTA, Harp and MARS-related database.
- Development of innovative tools and methods for consequence assessment and support to the evaluation of the DOMINO effect, namely the STARS-DOMINO package.
- Transfer of tools and methods for integrated risk assessment, principally the ARIPAR method and related tools.
- Adaptation and transfer of 1-dim. and 2-dim. models for heavy gas dispersions in presence of obstacles and continuously variable sources, principally the DISPLAY 1 and 2 models.
- Set-up of a laboratory for calorimetric measures of polymerization reactions; experiences on the 100 litre reactor FIRES; adaptation and transfer of the FISIM software.
- Analysis and design of safety relief pieces of equipment using the RELIEF software package and validation experiences on the DRACULA facility.
- Adaptation of mathematical models for simulation of thermal hydraulic networks in accident conditions using the RELAP5-MF software package.
- Design, development and validation of systems for structural integrity monitoring based on acoustic emission techniques and laser holographic interferometry.
- Transfer of probabilistic codes, developed by JRC, for damage modelling and structural failure probability estimation (COVASTOL; RELARMAN)

Project E: Protection of Cultural heritage

Participating and lead Institute: ISIS.

The Project is divided in 3 sub-projects:

- 1 Characterisation of historical centre degradation and proposals of interventions: the case of Palermo
- 2 Cadastre of Sicilian architectural lithic materials and their mineralogical, petrographic and mechanical characterisation
- 3 Characterisation of the degradation of stone monuments and works of art in Eastern and South-Eastern Sicily and proposals of interventions.

The activity of ISIS has led to the achievements of



the four main results foreseen in the project:
 a) Development and Application of a Complete Procedure and Methodology for the Survey and the Structural Analysis of Historical Buildings and their Protection against Seismic Loads

Palazzo Geraci (see Chapter 5) was chosen as the test site by the Region of Sicily. It became the object of a complete survey by numerical photogrammetry, consequent digital modelling and 3D reconstruction, with the possibility of virtual navigation and vibration measurements by laser interferometric technique. The response of the building to static and dynamic loads was calculated and its 1:2 scale model designed and built, using properly chosen Sicilian material (limestone) in the ELSA laboratory in Ispra (see Chapter 6). This large-scale model has been tested at the Reaction Wall with simulated earthquakes. Consolidating elements has then been designed, produced, installed on the model and tested.
 b) Application of Optical, Non-invasive Methods for Monument Inspection

Besides the measurements performed on Palazzo Geraci, numerical photogrammetry surveys and vibration measurements by laser technique have also been performed on some sculptures of the Pretoria Fountain and on the building of the ancient jail situated in the Steri building complex, both in the historical part of Palermo (see Chapter 5). In the latter, some of the mural paintings probably drawn by the prisoners themselves, have been inspected by numerical photogrammetry.

c) Mechanical Characterisation of Stone Materials by Optical Methods

A non intrusive optical technique, based on the use of ESPI (Electronic Speckle Pattern Interferometry) and allowing higher precision, full field measurement, has been applied on the specimens, sent by University of Messina, of local marbles, for the characterisation of their mechanical behaviour under compression loads. The results contribute to the creation of Cadastre of Sicilian architectural lithic materials and their mineralogical, petrographic and mechanical characterisation.

d) Design and Realisation of a Multimedia Data and Image Archive with Hypertext Facilities
 The archive has been designed and realised, after having discussed agreed upon, with the relevant collaborators of the three Sicilian Universities, its main requirements and data format. All the data, pieces, images and films coming from the JRC activities in Project E have been stored in the archive which is now ready for receiving also data from the Universities. The archive is on Internet.

ENVIREG SICILY (Italy)

The JRC performs two projects on behalf of the Italian Environment Ministry with the aim of setting up an integrated system for monitoring and preventing pollution and managing emergency situations from industrial sites and risks associated with the transport of dangerous substances in Sicily. In particular, the two projects are:

- Realisation of new integrated technologies (NTI) in network, for controlling, monitoring and preventing pollution and risks associated with the transport of dangerous and toxic substances;
- Realisation of a Centre for preventing pollution (CPI) and risks associated with the transport of dangerous and toxic substances.

Three industrial sites will be considered: i) Augusta-Priolo-Melilli (Siracusa), ii) Gela (Caltanissetta) and iii) Milazzo (Messina). A limited number of industries will be selected for each site, and for which a monitoring network will be set up and installed. The data gathered on each site will automatically be transmitted to a processing station located in the corresponding Sicilian Prefecture (main unit). A system based on positioning beacons will also be set up in order to monitor transport of dangerous substances in relation to the industries in question. Each of the three main units will therefore be equipped with a computerised system comprising two operational centres.

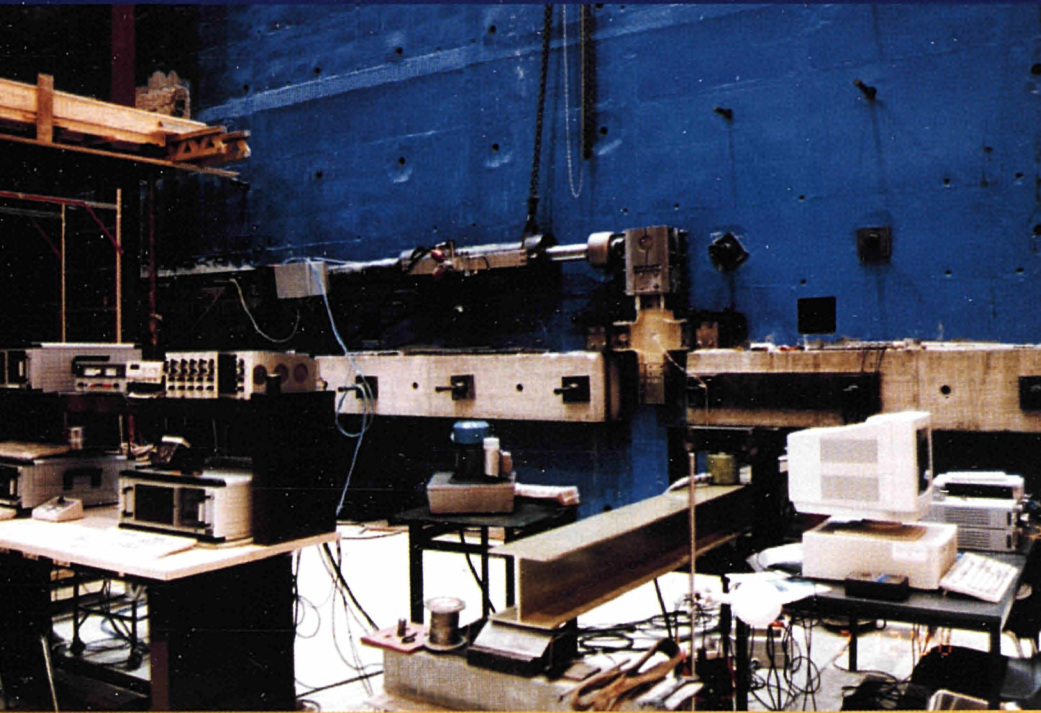
The first, called 'NTI centre', is devoted to distance-managing the monitoring network and the beacons, processing and analysing the data downloaded, and communicating the data or other results of analyses to other computer systems. NTI will also be capable of suggesting, by a dedicated Decision Support System, appropriate actions for facing pollution emergencies.

The second, called 'CPI centre', will constitute the basic element of a management and control centre for cases of emergency of an industrial nature, and for the implementation of appropriate intervention measures.

Each Prefecture will also be equipped with electronic information terminals, connected to its NTI and CPI centres, providing information to the general public concerning the current environmental situation. In addition, the Sicilian Region in Palermo, and the Ministry for the Environment in Rome, will be equipped with a control desk connected with the three Main Units. The existing monitoring networks will be integrated, as much as possible, in the new one. ISIS also provides the overall project management for ENVIREG. The projects will be concluded during 1997.

Exploratory research

author: I. Shepherd



A levy of 6% of the institutional budget is used to finance exploratory research. In 1996 the scientific staff of ISIS made a total of 65 proposals. The ISIS Scientific Committee then judged the proposals on originality, appropriateness, soundness and cost. Special priority was given to those projects that had a high potential to generate future work for the Institute and those that combined the skills of the two merged institutes - ISEI (Institute for Systems, Engineering and Informatics) and IST (Institute for Safety Technology).

Figure 13.1: ISIS is currently working in the field of Smart Composite Materials. This particular set-up involves the characterisation of pultruded composite structural elements using developed fibre optic strain sensors. Shown are the instrumented 3-metre composite beams in the three-point bend test rig, alongside related opto-electronic sensor demodulation equipment



On these grounds, the Scientific Committee produced a shortlist of 16 proposals, 12 of which were then funded. Work started in May 1996. It is expected that most of the projects will continue until the end of 1997 but there have already been a number of results obtained:

- 1) An instrument, based on Hopkinson's bar, was designed for in situ measurement of longitudinal and shear seismic waves during and before earthquakes. A model that correlates these wave records with rock fracture is being developed.
- 2) Algorithms for the identification of a chaotic system were tested on an unstable servo-controlled piston (see box).
- 3) A sensor for measuring very small displacements and low frequencies using optical interference techniques was developed. A network of such sensors might be able to detect the unusual patterns that are the precursors to an earthquake.
- 4) The use of fibre-optic sensors in composite materials was studied (see box). A computer model for the tracking of particles was devised that would be compatible with the REACFLOW code and be applicable to the study of dust explosions. More details of REACFLOW are included under the theme of Industrial Processes and Clean Technologies (Chapter 7)
- 5) A computer model of a car was developed in order to determine its overall ecology including manufacture, use and disposal. Dynamic structural analysis was employed to examine its interaction with safety barriers.
- 6) A project was launched to determine how hydrological modelling could be combined with vulnerability analysis in order to develop land zoning strategies that take flooding risk into account. Data from a catchment of the Loire has been obtained.
- 7) A method was developed for combining remote-sensing images with ground data in order to calibrate hydrological models. More details are given under the theme of Decision Support Systems for Environmental Management (Chapter 1)
- 8) An innovative method of using Web Hypermedia Authoring Systems was developed together with the Centro Nazionale di Ricerca (CNR) Istituto di Museologia in Florence to create educational tools in the area of cultural heritage.
- 9) Adaptive learning algorithms are being applied to see whether electroencephalogram signals can provide quadriplegics with a means of communication. The idea is to use only a limited number of commands (*move cursor up, ...down, ...left, ...right, ...click*). So far the system has been tested with pre-recorded signals only and the next step will be to test the algorithm with a real subject
- 10) The application of voice to text conversion systems to help deaf people communicate is being studied in collaboration with Commission services and associations that work on behalf of the deaf.
- 11) A safety analysis was made of accelerator driven nuclear reactor systems. This new concept, proposed by the Nobel laureate Professor Rubbia, can be used either for power generation or actinide burning. The aim of the study was to examine a number of possible accident scenarios including loss of coolant. Long term coolability was found to pose a risk if the accelerator beam remained in operation

Application of Non-linear Time Series Analysis for Control of Servomechanisms

authors: J.M. Zaldivar, E. Gutiérrez

The basic aim of time-series analysis is to determine the behaviour of a system using only an observation of its outputs. A number of new techniques in non-linear time series analysis, are now available that can offer significant improvements over the previous linear Fourier-based analysis. The aim of the project was to test a number of these techniques on a practical problem. The problem chosen was a servo-controlled piston used in the ELSA structural mechanics laboratory that, under certain unusual circumstances, becomes unstable. Specific objectives were to analyse the behaviour of the piston and, if possible, to develop a method for controlling its motion.

The piston was connected to a rigid cage and an oscillator set up within the cage to mimic the behaviour of a structure being tested in the Reaction Wall facility. A regular periodic motion was applied to the cage and the resulting displacement and velocity of the oscillator measured (Figure 13.2). The critical parameters of interest are the time between observations and the predictability of the system expressed as the number of timesteps (n) that can be predicted ahead. The system was characterised as a chaotic attractor. Analysis of our system determined that the fractal dimension was

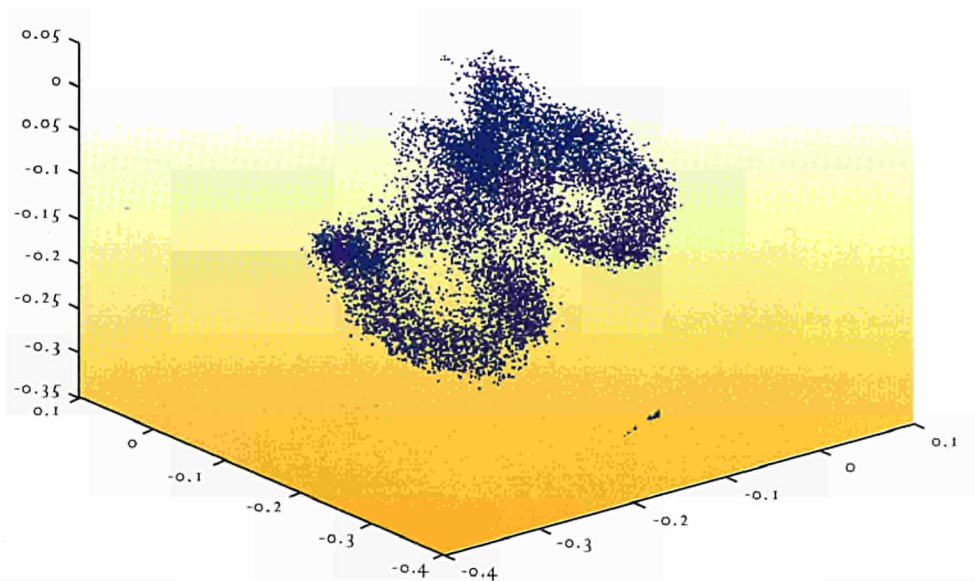


Figure 13.2: The displacement of an oscillator on the servo-controlled piston. This piston is a small-scale reproduction of the large one in the European Laboratory for Structural Assessment (ELSA) Reactor Wall facility. This experiment shows the unstable behaviour plotted in time delay space. The axes are $((s(t), s(t+), s(t+2)))$ where the time of 9 milliseconds was chosen from the first minimum of the average mutual information function. In this particular case, the system was characterised as a chaotic attractor.

4.3 and this indicated that only chaotic control systems can bring it under control [1]. The next step is to investigate the feasibility of such systems and to identify other areas where this type of analysis can be fruitfully employed.

Characterisation and Testing of Structural Pultruded Composite Beams

authors: E. Gutiérrez, R. Kenny

Smart Composite Materials offer the promise of strength, lightness and corrosion resistance as well as increased safety because their state can be continually monitored by networks of fibre optic sensors embedded within the material during fabrication.

The composite beams under study are manufactured using a widely used automatic technique known as pultrusion, in which the fibre reinforcement is impregnated with resin and drawn through a heated die, resulting in a continuous length of constant cross-section. Such beams offer great potential for use within civil engineering due to their excellent strength/weight ratio and corrosion resistance. But before they achieve widespread application their short and long-term behaviour must be characterised and jointing techniques need to be improved. The aims of the exploratory research are to:

- characterise the structural behaviour of pultruded structural beams;
- compare the behaviour of optical sensors with traditional electrical strain gauges;
- develop techniques for optimising the layout of the sensors so that the displacement of the composite material can be reconstituted from the measured strain.

- 1 Gutiérrez E., Zaldivar J.M. - *Non-linear Time-series Analysis: Application for Identification, Prediction and Modelling of an Unstable Servo-controlled Piston* - JRC Ispra Technical Note number I.96.126., 1996

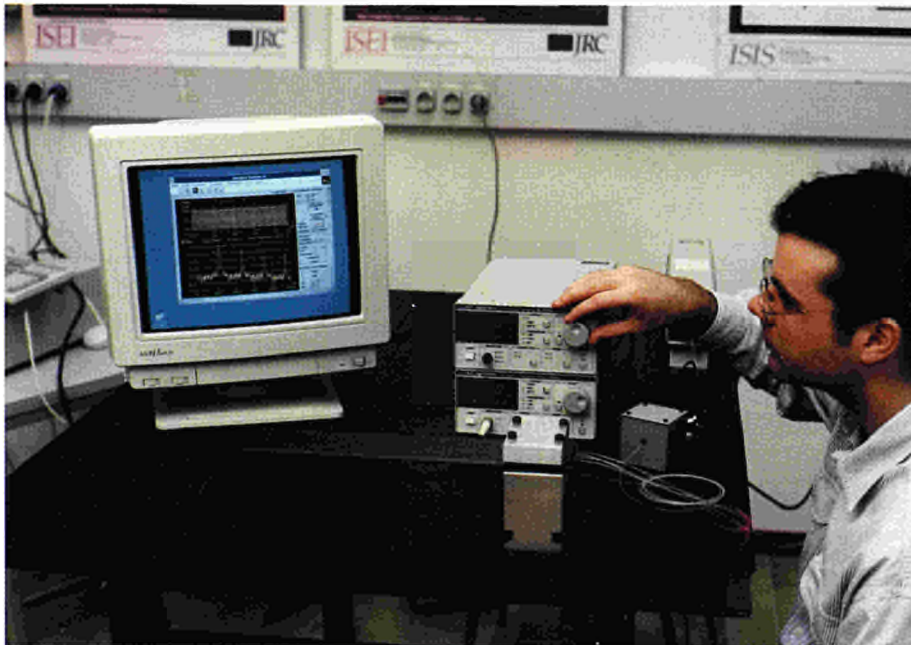


Figure 13.3: ISIS is currently working in the field of Smart Composite Materials. This particular set-up involves the characterisation of pultruded composite structural elements using developed fibre optic strain sensors. Shown are the instrumented 3-metre composite beams in the three-point bend test rig, alongside related opto-electronic sensor demodulation equipment

The specimens obtained for testing are 3 metre long H-section beams, nominally 203x203 mm, with a uniform 9.5 mm thickness. They have glass fibre reinforcement within a polyester matrix, and have been selected not only because they are commercially representative, but also because similar beams have been tested by other workers.

The optical fibre sensor systems have been developed within JRC for this and related work in smart materials. Given the complexity of the composite material and the relatively innovative nature of the sensors being used, a well understood three-point bend test configuration was chosen for initial testing: a knife edge and roller at either end of the lower flange span, and a roller connected to a single-acting hydraulic jack at mid-beam on the top flange. The beam was instrumented at mid-length with five electrical strain gauges and three optical fibre (2 Michelson and 1 Bragg grating) sensors positioned on the bottom (tension) flange of the beam. The

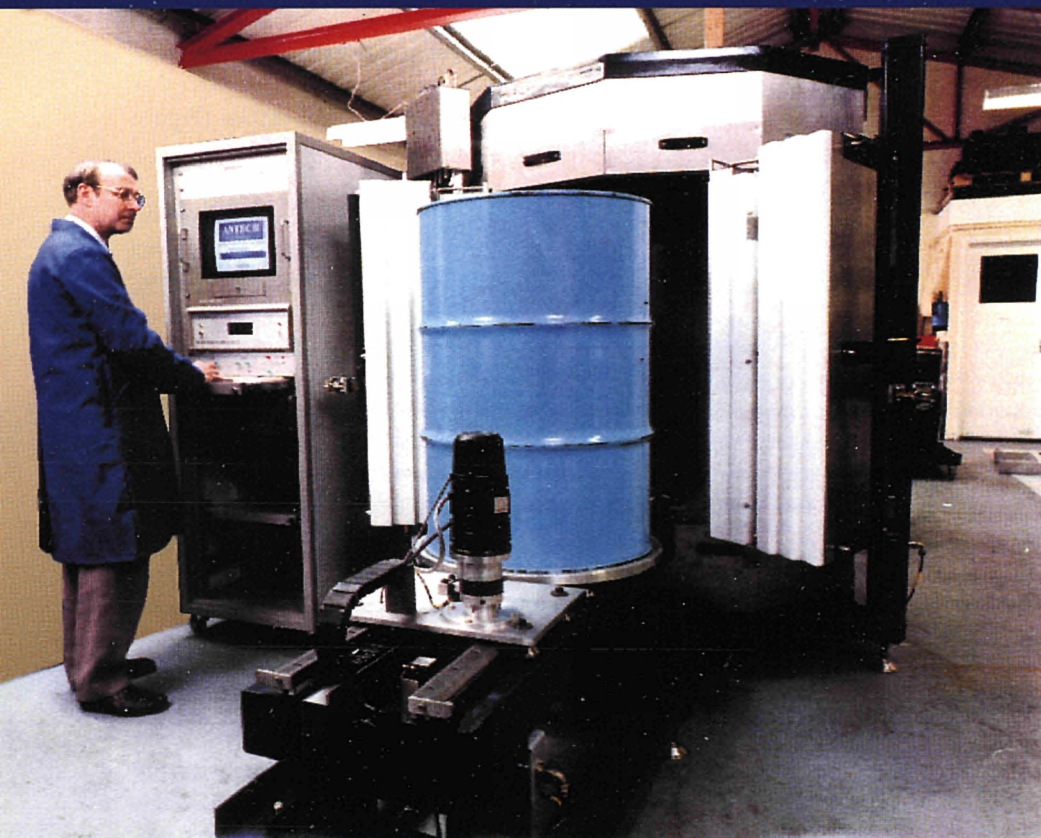
optical and electrical gauges to be directly compared were placed as close together as possible (Figure 13.1).

The strain measured by the electrical strain gauge measurement agrees with that predicted by using simple strength of materials equations to within 5 percent. The measured modulus in the main axial direction was found to be 20 GPa, in reasonable agreement with the value of 21 GPa provided by the manufacturer. These predicted

results are satisfactory if we consider the orthotropic nature of the material. Comparisons of strain measured by electrical and optical gauges compared reasonably well, but results displayed some non-linearities. Work is underway to optimise strain transfer from the beam to the optical fibre by varying the fixing technique. The beam manufacturer is closely involved with the project and is preparing to deliver beam-column joints with embedded, rather than surface-mounted, fibres for testing. ISIS will then examine the feasibility of continuous monitoring of a structural frame consisting of pultruded and moulded composite elements [2, 3].

- 2 Kenny R.P. - *All-fibre Grating Sensors Employing Many-cycle Directional Couplers* - Pacific Northwest Fibre Optic Sensors Workshop, Oregon, U.S.A, May 8-9, 1996, SPIE Vol. 2872
- 3 Kenny R.P., Gutiérrez E., Lucia A.C., Whelan M.P., Gaiazzi F., Sheridan J.T. - *Fibre Optics In-fibre Bragg Grating Sensors for Use in Composite Material Structural Element Characterisation and Structural Monitoring* - Optical techniques for smart structures and smart monitoring, London, IEE, Feb 17, 1997

Technology transfer



An important part of the role of the Institute is to ensure that its expertise and technology are applied to the wider European economy and, where appropriate, transferred to industry. Interfaces for such technology transfer have increased in recent years as a consequence of the competitive approach.

Figure 14.1: Dr. John Mason presents the first ANTECH drum monitor to measure the Plutonium content in closed 220 litre drums. The instrument is based on JRC development and has been adapted to meet customer specifications by ANTECH. It employs the ANTECH Time Correlation Analyser (TCA).

Mechanisms for transferring technology are:

- direct work for third parties
- collaboration projects for common customers
- shared-cost action collaborative projects with partners from Universities, national research centres and industries for research and development
- shared-cost action collaborative projects with partners from Universities, national research centres and industries for technology transfer and validation (INNOVATION programme)
- demonstration and validation of results and technology owned by JRC, on behalf of DG XIII-D
- direct actions by ISIS for selling products, mainly software
- licensing of technology
- direct research collaborations
- staff exchanges under various schemes

Specific projects to support the transfer of JRC's technologies to industry are performed as part of the support to DG XIII-D (Telecommunications, Information Market and Exploitation of Research, Dissemination and exploitation of R&TD results, technology transfer and innovation). The projects focus on the validation and demonstration of research results protected and owned by the Community. Each project has at least one external partner. During 1996, ISIS won the following validation and demonstration projects:

1. "Opto-thermal sensing device"

Objective : To develop an industrial prototype of a hypersensitive sensor to measure very small changes of light flux or temperature.

ISIS-Technical Responsible: C.Th. Coutsomitros
External partners: University of Limerick (IE), CRN (IT), University of Thessaloniki (GR), Nodal (FR)

2. "Differential Thermal and Pressure Monitoring"

Objective : To demonstrate an optical force sensor using interferometric signal enhancement to measure small deformations for temperature and pressure monitoring.

ISIS-Technical Coordinator : C. Th. Coutsomitros
External partners: Endoscan Ltd. (GB), CSL-Limerick (IE)

3. "Thermal Surveillance Sensor"

Objective : Demonstrate a prototype thermal surveillance sensor suitable to detect presence of persons or animals.

ISIS-Technical Coordinator : M. Cuypers/Guilmain
External partner: Captec (FR)

4. "Exploitation of the software package RELIEF"

Objective : Preparation of a commercial version of

the RELIEF software to simulate emergency pressure relief scenarios for safety calculations of chemical reactors.

ISIS-Technical Coordinator : J.S. Duffield
External partner: Inburex (DE)

5. "Demonstration of image compression techniques"

Objective : To provide an industrial demonstration of using wavelets, fractals and lossless image compression techniques.

ISIS-Technical Coordinator: J. C. Grossetie
External partner: Consorzio Milano Ricerche (IT)

6. "Deformation measurements of building materials"

Objective : Demonstrate an industrial prototype device for automatic in-plane deformation measurements using Electronic Speckle Pattern Interferometry.

ISIS-Technical Coordinator: A.C. Lucia / M. Tatti
External partner: Dublin Institute of Technology (IE)

7. "Structural strain monitoring and damage detection"

Objective : Optimise and demonstrate an optic interferometric sensor for monitoring composite materials.

ISIS-Technical Coordinator: A.C. Lucia / M. Tatti
External partner: University of Limerick (IE)

8. "Control of Industrial Robots"

Objective : Develop a generalised, modular software for control of industrial heavy robots.

ISIS-Technical Coordinator: F. Farfaletti-Casali
External partner: Erxa (IT)

9. "Environmental Chemical Data and Information Network"

Objective : Information updating and promotion of the Environmental Chemicals Data and Information Network Databank.

ISIS-Technical Coordinator: R. Roi
External partner: CRC-Cancer Risk Consultants, SAS (IT).

10. Innovation Project "LASERROBOT"

Objective : Demonstration of heavy robotics application for laser welding of generators.

ISIS-Technical Coordinator: F. Farfaletti-Casali
External partner: Framatome (FR), GAER Engineering (FR), RTM (IT).

A Technology Transfer Case

ANTECH - A.N. Technology Ltd.
Multiplicity Counting (Neutron Time Correlation Analysis) to measure Plutonium in sealed drums

The road from technology to a successful product can be long.

Dr. John Mason, owner and Managing Director of A. N. Technology Ltd. (ANTECH), signed his first technology transfer contract with the JRC in January 1992. He was attracted by scientific publications and successful demonstration measurements performed at the JRC by Dr. W. Hage and his graduate student Bent Pedersen.

The new instruments allow in most situations a calibration-free measurement of Plutonium in sealed drums. This is based on research results which have shown that the signal pulse train arising from neutrons emitted from spontaneous fission of Plutonium can be decomposed into single neutron events, correlated neutron doublets, and correlated neutron triplets; and these quantities can be measured by the JRC Time Correlation Analyser (TCA). In the point source interpretation model developed by Dr Hage, each of the correlated multiplets, which are determined from the measured quantities, is directly proportional to the spontaneous fission rate in the sample. A system of three equations can be solved to determine three of the four unknown parameters in the Hage point source model. In a majority of measurement situations, one of the four parameters is known and in these cases an absolute determination of the Plutonium mass may be made.

In contrast to the work at Ispra, traditional neutron coincidence counting measurements exploited only the counts of single neutrons and correlated neutron doublets. This could lead to significant errors when the Plutonium was not homogeneously distributed in the drum, or when an absorbing material was used as filling matrix (e.g. concrete).

A key aspect of the technology transfer and development project was to build an improved speciation neutron TCA (multiplicity counter). It required extremely high time resolution over a sufficient sampling time to detect correlated signals. User friendly application software could then interpret the signals to calculate the amount of Plutonium.

The development project has had its set-backs. Technical difficulties almost halted the development after the third year, although these problems were overcome by ANTECH. The production instrument



Figure 14.2: The ANTECH Series 1000 Neutron Time Correlation Analyser for Multiplicity Counting allows improved non-destructive measurement of Plutonium. It is a result of JRC's safeguards research and recent implementation efforts by ANTECH as part of the technology transfer process.

was presented in August 1995 for testing by JRC. The ANTECH TCA has been subjected to an intensive quality testing programme at the JRC-PERLA laboratory and it has completely met the specification of the technology transfer agreement..

During 1996, six institutions have purchased the ANTECH Time Correlation Analyser for multiplicity counting during 1996. One ANTECH designed drum monitor has been installed in a Ministry of Defense facility in the UK. Further instruments have been ordered and future market prospects are very promising. Applications lie in the areas of nuclear safeguards, especially in MOX fuel related applications, and for decommissioning applications related to nuclear weapons or nuclear installations by measurement of scrap and waste material.

The development is continuing. In 1997 ANTECH and JRC plan to upgrade the software to include a 'dead time correction' which will increase accuracy for larger amounts of Plutonium and materials with a high (alpha, n) reaction rate. ANTECH are building an enhanced TCA capable of operating at even higher count rates. Nuclear materials assay software packages for special applications of the TCA counting electronics are also being developed. Dr. Pedersen is now the staff member with technical responsibility at ISIS. Dr. Hage has retired but continues his contribution as a consultant with advice and theoretical analysis.

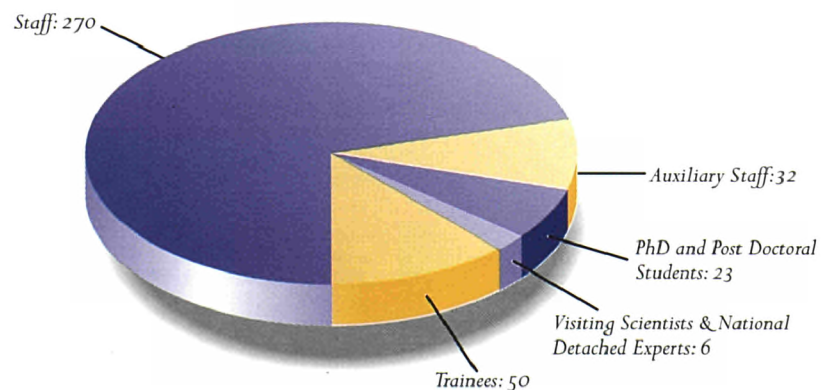
ISIS Personnel

ISIS personnel in December 1996 were:

Staff:	270
Auxiliary Staff:	32
PhD and Post Doctoral Students:	23
Visiting Scientists & National Detached Experts:	6
Trainees:	50

At the beginning of 1996 the staff numbers were somewhat higher. Permanent staff have reduced by 11 during the year. 16 persons have left and 5 new scientists have been appointed. Turnover of auxiliaries, students, scientists and trainees have occurred during the year, but the overall levels have remained constant. Some new research students have been appointed via the Commission's Training and Mobility of researchers scheme.

New procedures have been introduced which will allow a faster process for recruitment of staff on short-term contracts. This is particularly important for competitive contracts of short duration. Recruitment procedures for such staff are already in progress.



ISIS Finance

ISIS projects can be funded from many different sources. Customers include many sectors of European industry, regional governments, other European Commission Directorates General. Many projects have been awarded after open competition, others are executed as part of the European Union's Fourth Framework Research Programme.

The three tables below show details of income and work executed in 1996 (with 1995 figures for comparison).

Comparisons are made between achieved values and our previously defined targets.

Table I shows the new contracts which have been signed in 1995 and 1996 .

Table II shows the competitive work executed in 1996 in comparison with 1995.

Table III shows the institutional work executed on each line of the Framework Programme.

From the tables, it can be seen:

Previously set overall targets for contracts signed and work executed have been met.

The percentage of the total work executed in 1996 which was competitive was approximately 17%.

Competitive contracts are well spread across the range of possible actions

Table I - ISIS Competitive Contracts Signed 1995 & 1996

Type of Activity	Value (Mecu) of Contracts Signed			
	1/1/95-31/12/95		Cumulative 1995 and 1996	
	Target	Archieved	Target	Archieved
• Competitive Support to Commission				
• Other Competitive Activities				
• Training and Mobility of Researchers (grants, networks and large-scale facilities)				
• Shared Cost Actions (50%)	0.50	0.40	3.1	4.90
• Shared Cost Actions (50%) (for industry, regional governments)	3.75	6.70	7.5	8.10
Total	9.65	11.20	20.40	21.94

Table II - ISIS Competitive Work Executed - Comparison 1995-1996

Type of Activity	Value (Mecu) of Work Executed			
	1995		1996	
	Target	Archieved	Target	Archieved
• Competitive Support to Commission	0.0	0.10	4.00	4.00
• Other Competitive Activities				
• Training and Mobility of Researchers (grants, networks and large-scale facilities)				
• Shared Cost Actions (100%)	0.50	0.00	0.80	1.23
• Third-party Work (for industry, regional governments)	3.75	3.80	3.75	3.84
Total	3.75	3.90	8.55	9.07

Table III - ISIS Institutional Work Executed in 1996

Framework Programme Theme	Value (Mecu) of Work Executed	
	1995	1996
Information Technologies	1.95	2.95
Measurement and Testing	7.63	5.36
Environment and Climate	8.50	5.69
Life Science and Technologies	0.21	0.74
Nuclear Safety and Safeguards	28.41	29.18
Controlled Thermonuclear Fusion	1.83	1.45
Total	48.53	45.37

The 1996 Annual Report of the Joint Research Centre's (JRC) Institute for Systems, Informatics and Safety (ISIS) summarises the Institute's work carried out during the year. The research activities are presented under the following themes:

- Decision support systems for environmental management
- Detection of fraud and countermeasures
- Information and telematics technologies
- Safe and sustainable transport
- Cultural heritage protection
- Earthquake engineering and dynamics of structures
- Industrial processes and clean technologies
- Nuclear safety (severe accidents)
- Safeguards
- Remote handling
- Services to the Commission
- Regional projects

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