Annual Report

Institute for Systems, Informatics and Safety

1999

Institute for Systems, Informatics and Safety Annual Report 1999

ISIS supports EU policies with systems oriented research in areas where safety and security are of concern. Its prime objectives are to develop techniques for the assessment of risk in complex systems and to apply information, communication and engineering technologies for improving their reliability, safety and security.

iSiS
Institute for Systems,
Informatics and Safety

ANNUAL REPORT 1999

Institute for Systems, Informatics and Safety
Applying technology for the safety and security of the citizen and society

**Institute for Systems,
Informatics and Safety**

ISIS management team: *Fernand L. Sorell, Alfredo C. Lucia, Marc Cuypers, David R. Wilkinson (Director), Horst Weisshäupl, Michel Géradin, Martyn Dowell (from left to right).*

Rapid change characterises more and more the activities of ISIS. For 1999 this has been driven by new objectives in the Fifth Framework programme, by the ever stronger focus on our policy customer requirements, and by the speed with which the European Commission must react to the impact of new technologies. The clear trend goes towards the information content. Dependability of information systems, web technologies, official statistics and technologies for combating fraud are our major growth areas. But also the more consolidated areas of research are following. Examples are remote surveillance in nuclear safeguards, exchange of information to combat industrial and natural hazards, communication technologies for environmental management, and computational methods applied to structural safety. The competitive approach has opened projects for the emergency response centre for industrial risk management in Italy, a study of seals for nuclear fuel assemblies in Japan, regional development in North Sweden, and the surveillance of fishing vessels in the North Atlantic. In addition, the Institute is negotiating 32 new shared-cost action projects during the first year of FP5.

Two elements which enable the rapid change are (1) the Institute's systems thinking approach and (2) the flexibility of our staff. ISIS researchers not only do research; they manage their projects, care about their customers, write project reports, adapt their skills to new challenges, arrange scientific collaborations, and scout out the short term staff needed to fill immediate skill requirements.

This year's report gives some emphasis to the Institute's "exploratory research". A number of projects are presented which started as exploratory projects a few years ago and which are now part of the Institute's remit. The exploratory research is one of the successful management tools used to prepare the Institute for tomorrow's problems. ISIS invests 6% of its Institutional budget. The ISIS Scientific Committee selects the projects on the basis of their scientific value, strategic impact, feasibility and cost.

ISIS has contributed, during 1999, to make the European Commission technically competent for meeting its changing policy challenges. We are ready for the new issues to come.

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

The Institute for Systems, Informatics and Safety is one of the eight institutes that constitute the European Union (EU) Joint Research Centre (JRC). The Institute's 350 staff, visiting scientists and students are based at Ispra, in the north of Italy.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

ISIS supports EU policies with systems oriented research in areas where safety and security are of concern. Its prime objectives are to develop techniques for the assessment of risk in complex systems and to apply information, communication and engineering technologies for improving their reliability, safety and security.

European Policy
Commission, Parliament, Council

Impartial advice and technical support

Technology base

Underpinning base of collaborative research activities

Science base

| Collaboration with industry, national laboratories and universities | Dissemination of information | Catalysing the integration of European research | Technology transfer to industry | Training of young scientists and engineers |

The Role of ISIS

ISIS's technology base makes it ideally suited for supporting Commission policies related to the general theme of enhancing safety and security of the individual citizen and of society as a whole.

The expertise base from which this support is drawn is maintained by the participation in underpinning research, which is increasingly based on networks and joint projects together with European industry, universities and national research organisations. This research can be classified into a number of main themes:

- *security and reliability in the information society*
- *safety of building structures and means of transport and the protection of cultural heritage*
- *safeguarding against the proliferation of nuclear materials*
- *safety aspects of nuclear energy*
- *fight against fraud*
- *risk management and decision support.*

The Application of Technology for the Protection of the Citizen and Society

Describing how ISIS's work programme is supporting EU policy and how the emphasis of the work is changing to reflect an evolving Europe

Security and reliability in the information society

ISIS supports the Commission's information society and electronic commerce initiatives focusing on aspects of security and reliability. By qualifying, testing and benchmarking embedded systems and trust technologies, ISIS is helping to provide the solid foundation of consumer confidence that is essential if the market in services such as cross-border electronic commerce is to flourish. Applications include improving access to official statistics, helping the exchange of educational information, validating medical imaging and data systems, and supporting the Commission's campaign against anti-personnel landmines.

Safety of building structures and means of transport and the protection of cultural heritage

European efforts to harmonise safety standards aim not only at lowering the risk of accidental death and injury but also at removing artificial barriers to trade.

Despite the best efforts of geologists, earthquakes remain unpredictable. Therefore the most effective way to protect the public from earthquakes is to ensure that buildings, roads, bridges and other infrastructure are built to withstand seismic shocks. The set of standards necessary to achieve this protection are specified in Eurocode 8.

ELSA, a unique reaction wall facility in Europe, is the hub of a concerted European network of laboratories and facilities that provide the necessary background research for the formulation and assessment of Eurocode 8. Joint projects with industrial partners assess the seismic resistance of new construction techniques and the ability of retrofitting techniques to protect existing buildings. Special emphasis is given to the protection of buildings of architectural or historical importance where ISIS also uses optical analysis techniques for assessing damage.

For car safety there are a number of evolving European standards for crash behaviour whose formulation provokes scientific debate among consumer groups and manufacturers. The large dynamic test facility (LDTF) helps the automotive industry understand how to meet present and future crash impact legislation with particular emphasis in developing techniques for reducing the weight of vehicles.

Safeguarding against the proliferaton of nuclear materials

The EURATOM Treaty of 1957 gives responsibility to the European Commission to satisfy itself that fissile materials, within the EU, are not diverted from their intended use. These responsibilities were extended when collaboration agreements with IAEA were signed in 1977 and further challenges are expected in the future from the entry into Safeguards of material released from excess weapons and from the enlargement of the Union.

ISIS provides direct support to both the Energy and Transport DG and to IAEA and also researches into techniques for meeting future requirements. The main areas of activity are in non-destructive assay, sealing techniques and remote surveillance. Based on experience of training inspectors at Ispra, a training centre at Obninsk in Russia has been set-up. New research has started to determine whether satellites can be used for remote detection of illicit activities, and to develop teleoperation techniques to allow surveillance operations to be controlled from a distant safeguards office.

Safety aspects of nuclear energy

Each Member State is responsible for licensing its own nuclear reactors and attempts to harmonise this procedure have, so far, been unsuccessful. Nevertheless nuclear energy provides 33% of Europe's electricity, the effects of severe accidents are not confined to one Member State and the Commission's nuclear safety research programme makes a major contribution to concentrating efforts in the Member States. The Commission has also promised that reactor safety will be an important consideration during the enlargement process.

ISIS's overall effort on reactor safety has been reduced sharply. The large experimental programmes STORM and FARO are closing. The study of severe accidents is continuing at a reduced level through the analysis of experiments elsewhere and the development of computational tools.

The emphasis is now to provide a more direct assistance to Commission policy. Support to the Environment DG's efforts to harmonise safety standards is continuing at the same level but more effort is being devoted to integrating the applicant countries into the European nuclear safety culture and helping to manage the PHARE and TACIS assistance programmes.

The fight against fraud

Fraud, if left unchecked, can attack the roots of society by destroying confidence in institutions and encouraging lawless behaviour. The Member States are legally responsible for ensuring that the financial mechanisms of the Union are not defrauded but it can be politically difficult for them to do so. An overview at European level is sometimes necessary, especially in cases of cross-border fraud.

Responding to a strong demand from those EU bodies, especially OLAF and DG Agriculture, ISIS has expanded its work in this area. The activities mainly involve information and communication technology, statistical analysis and electronic tagging schemes for animal identification.

Risk assessment and decision support

ISIS institutional work on risk assessment and decision support is based on two linked themes: firstly the development of harmonised European reporting systems for incidents so that risks can be compared, duplication avoided, lessons learnt, the public informed and mitigation measures found; and secondly the development of methods and tools for the integrated assessment of policy options.

European incident reporting systems developed and managed by ISIS include the Major Accidents Hazards Bureau for the chemical industry, the European Coordination Centre for Aircraft mandatory Incident Reporting Systems and the Natural and Environmental Disaster Information Exchange System.

The integrated assessment work concentrates on evaluating scenarios for the impact of policy options in sectors such as transport and agriculture, and developing communication tools that improve participation by the public in decision-making.

These institutional projects are backed by practical expertise in risk assessment, decision support and emergency management gained through participation in a number of case studies both in support of regional authorities and as contributions to collaborative projects.

CONTENTS

Security and Reliability in the Information Society

editor: F. Sorel

F ollowing the European Commission Programme Activity "Creating a User Friendly Information Society", ISIS has focused its research in the area of "Benefiting from the Information Society", where emphasis is given to the customers' needs and benefits in the emerging Information Society.
The ever-growing networking capabilities provided by Internet, and the convergence of communication and information technologies have led to enormous possibilities for the user but also to an increasing demand of confidence and security.
ISIS has therefore defined and investigated such information and communication attributes as: dependability, trustworthiness, easy access and processing for important societal applications related to health, elderly and disabled persons, education and training and electronic commerce. Considering the commitment of the European Commission in electronic commerce, a cluster at JRC level grouping the projects of three institutes (ISIS, IPTS, IHCP) has been set up with success.

Information Dependability

author: M. Wilikens

The Information Society, including electronic commerce, provides unprecedented economic and social opportunities for advancing the EU single market. To enable European citizens and businesses to fully exploit the manifold benefits of the Information Society and consistent with recent EU policy developments, ISIS focused on enhancing consumer **trust and confidence** in cross-border electronic commerce, on safeguarding **private** information assets and on securing access to **dependable** information. DG Information Society remains our main customer but working relationships were also established with other interested EC services including DG Enterprise, DG Consumer Protection and DG Internal Market.

Trust requirements in electronic commerce

author: M. Wilikens

The TRUST-EC project characterised important trust requirements in electronic commerce by means of case studies in the area of information brokering from a number of domains including virtual hospitals [1.1]. As a follow-on, the TRUST-CSP project was launched at the end of 1999. The TRUST-CSP project develops guidelines on how to evaluate the quality of electronic sig-

nature services. This is important for consumers in order to trust these services and for the legislator in order to legally accepts these signatures. TRUST-CSP is related to the EU Directive on a common framework for electronic signatures that has been approved by the Council of Ministers in December 1999 and will feed into the European standardisation process by means of ETSI.

Out-of-Court Settlement systems
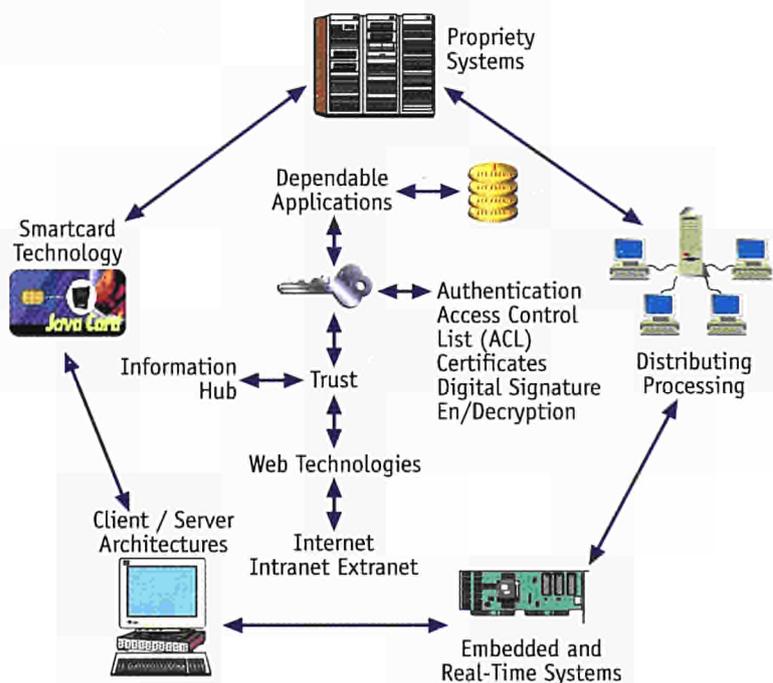
author: M. Wilikens

Whilst electronic commerce has many qualities that consumers find attractive, it also has properties that facilitate fraud and make prosecution difficult. For international business to consumer electronic commerce, characterised by a large volume of relatively low value transactions carried out across borders, the relevance and effectiveness of courts for resolving problems may be limited. Therefore, alternative dispute settlement mechanisms may in practice prove to be the most popular and appropriate solution. The issue is also addressed by recent EU policy initiatives such as the draft directive on: "certain legal aspects of e-commerce" and the Prodi initiative on e-Europe. ISIS explores concepts for on-line dispute settlement systems that are workable at a Pan-European level and that focus on cross-border consumer disputes. Eventually, pilot demonstrators will be set up to test the concepts.

Testing trust solutions

author: M. Wilikens

TRINIDAD, the laboratory for testing and assessing technological trust solutions was initiated. The concept was defined and the installation of the TRINIDAD basic hardware/software platform was completed. A number of demonstrators for secure electronic commerce (Figure 1.1) were developed on TRINIDAD using Java-based API's (J/CRYPTO from Baltimore) for security functions including hashing, symmetric/asymmetric key encryption, digital signature. One demonstrator concerned a kiosk for the secure retrieval by patients of medical documents.

Figure 1.1: Trial infrastructure TRINIDAD for dependable (trustworthy) applications of different technologies.

Citizen Privacy
author: M. Wilikens

Concerns about privacy arise from the undesired collection and (mis)use of personal data during Internet transactions. Mechanisms are required to empower a consumer in controlling the integrity and fair use of his personal data. The aim of our Privacy Enhancing Technologies (PET) project is evaluate, from the business perspective as well as from the consumer perspective, emerging privacy technologies (e.g. P3P standard from the W3C) and assess their conformity against the EU data protection Directive.

Dependability of large-scale information infrastructures
author: M. Wilikens

Global collaboration on dependability of large-scale information infrastructures was promoted in a workshop between EU and USA representatives. The workshop identified ways for closer R&D relationships [1.2]. An exploratory study was started with a number of critical infrastructure providers to look at vulnerabilities emanating from increased complexity and interdependencies of information infrastructures.

Decision making through access to dependable information
authors: J.-P. Nordvik, M. Atkinson

The Noemie project developed a methodology and tools to reuse corporate knowledge of large industrial companies, for improving the efficiency of the decision-making process across different departments. Whilst the access of information for a particular department was traditionally available, Noemie addressed the wider scope of providing access to information across all departments. Together with conventional data base interrogation mechanisms, the project has exploited and integrated two knowledge engineering technologies: Data Mining and Case Based Reasoning.
ISIS developed a JAVA based Internet Client/ Server Application. It allowed users to model their application domain. Then, they could logon to a Noemie Application and after characterising their problem, use previous interaction cases to propose possible solution methods, and then activate and display results.
The application of the methodology and customisation of the NOEMIE Software has been made for two pilot applications in the oil industry. One of the pilot applications concerned the analysis of the reliability of bore hole sensors, where information from operational as well as financial departments was used. The other pilot application consisted of detecting loss of mud pressure during drilling operations, again access across departmental information bases was necessary. The result of the project is an application configurable system where the user is supported in solving problems by using others' experiences. Either by using general knowledge (in a users domain model or solution task hierarchy) to find solutions, or by using concrete experiences that already contain a solution method.

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[1.2] Wilikens M., Morris P., EU-USA transatlantic workshop: A Joint Initiative on dependability in the information society, *Report of the Workshop held in Venice*, April 20-21, 1999.

Web Technologies

Generic Information Server Toolkit (GIST)
author: P. Henshaw

The Internet is growing at a ferocious rate, and finding high-quality specific information is increasingly difficult. Specialist web sites exist that have already categorised the Internet content and can therefore act as a quick source of high quality in-depth information, on specific subjects. Such sites are traditionally maintained by a "webmaster" who decides what information they contain; the users are permitted only to view the information. Unfortunately, such information is not always the most pertinent for the user. These sites also require high levels of maintenance and they become increasingly difficult to manage as they grow in size and content. GIST grew from the pressing need to provide specialist sites, without the need for full-time webmasters. Primarily, GIST recognises that web site users that are interested in specific areas can, in many instances, supply and maintain the most relevant information themselves. GIST aims to remove the technical issues associated with setting up an interactive web site. Information can be supplied, changed or removed over the Internet. By removing the technical barriers associated with interactive sites, GIST allows many more people to make highly significant information available to a wider audience. ISIS has used GIST to build sixteen on line information servers for DG Environment, Research, Enterprise, Health and Consumer Protection, and the JRC. Some of these services are open to the public:

http://gem.jrc.it	Global Education Multimedia
http://improving.jrc.it/	Improving Human Potential servers
http://directory.prometeus.org/	Prometeus Signatory Directory
http://ettn.jrc.it	European Technology Transfer
http://gold.bdp.it/	Global On-Line Documentation
http://vlibrary.bdp.it/	Virtual Library

A complete list of public information services built with GIST is maintained on the "screenshots" page of the GIST web site: http://gist.jrc.it/sites.gx.
The GIST software, documentation and a tutorial web site are available for download from the GIST web site, the site has been accessed over 180000 times from over 4000 sites since it was opened in July 1999, and over 1000 people have downloaded the software. Suggestions and contributions from
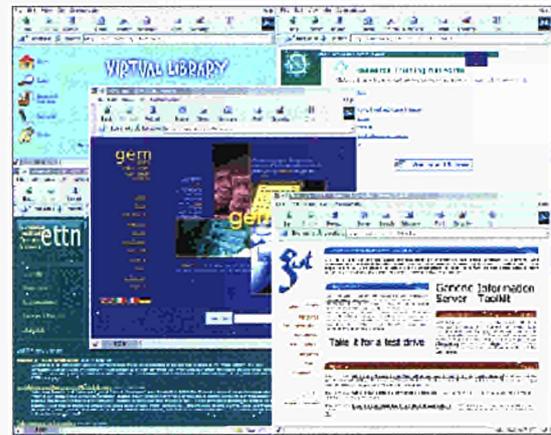

Figure 1.2: A selection of web sites built using GIST.

external users have already resulted in a number of improvements to the software. We intend to continue collaborating with external users and encouraging the use of GIST both inside and outside the JRC.
ISIS Contacts: Clive Best, Paul Henshaw
GIST team: gist@jrc.it
Web site: http://gist.jrc.it

Network Multimedia Education
author: C. Best

The potential expansion of Education and Training with new Information Society technologies is enormous. They provide new opportunities where traditional methods of learning are unavailable, either because of physical separation or time restrictions. They also enhance traditional methods by providing new access to media for use in normal lessons and lectures.
ISIS supports the Education and Training Programmes within DG Information Society and DG Education and Culture. A major contribution during 1999 has been the setting up and development of the PROMETEUS (PROmoting Education & Training in EUropean Society) electronic fora. PROMETEUS supports a memorandum of understanding involving over 800 signatories in some 500 organisations to work towards common electronic information tools and standards. PROMETEUS supports some 12 special interest groups who collaborate electronically through mailing lists and SIG Web pages. This is all hosted at PROMETEUS web site http://prometeus.org, which was developed from scratch by ISIS and is hosted at the JRC.

For new communication media on the Web for distance learning and collaboration, ISIS developed streaming video and audio conferencing synchronised to Web presentations. During the year a number of "hands-on" demonstrations have been made including a successful Open Distance Learning Workshop held in Ispra this October see http://prometeus.org/NME.

The JRC meteo Web station http://meteo.jrc.it gives an example for new web techniques for access and visualisation of scientific and geographic data for use in Education. Data is real-time. An example of virtual reality rendered from a satellite image and digital elevation model of the Lago Maggiore are is shown in Figure 1.3. This is taken from an animated fly over of the area.

ParlEuNet (European Parliament Network)
author: A. Reggiori

The ParlEuNet (European Parliament Network) has been the first European initiative to permit secondary school students to use state of the art networks and multimedia resources to learn about and do collaborative projects on the European Parliament. Internet connections, videoconferencing and a Web site containing a well-structured dynamic multimedia database of educationally relevant materials have been used by students to access information on the European Parliament, create their own projects, and exchange information and views with members of Parliament and students in other countries. The students' work has gradually supplemented the Web site with educational modules and resources which can be used by other students. The project started on the 1st of January 1998 and will end on the 30th of June 2000. During the project there have been two project intensive periods of each 8 weeks.

The ISIS contributed to ParlEuNet by developing a highly efficient dynamic multimedia database on the Internet to be accessed by 12 schools from seven European countries. The system has been implemented by leveraging on state of the art Internet technologies and standards such as the Extensible Markup Language (XML), fast database management systems, Web server extensions, session handling, HTTP statelessness, URNs, caching, user interfaces, encryption, multimedia content publishing and multilingual translation. On the server side, XML has been successfully used to layer down the system architecture, using a virtual space protocol over an object-oriented-like database. A fast networked transactional object store has been developed to allow users the manage-
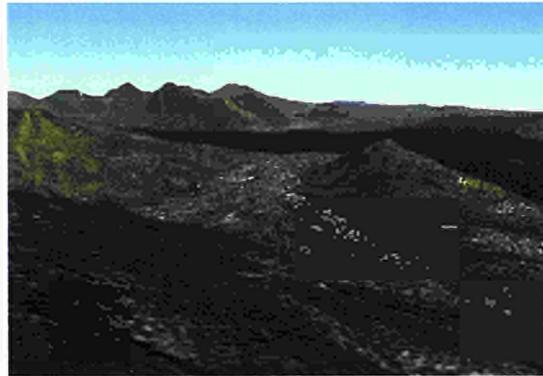

Figure 1.3: A virtual image generated from a digital elevation model and satellite image of the Lago Maggiore Region. The simulated view is calculated looking from Monte Zeda across the lake towards Laveno.

ment of hierarchical multimedia content. Capabilities such as user identification and authentication, HTTP content caching, HTTP session handling, code caching have been fundamental for the implementation of the production system. Most of these were implemented directly in the Web server using some extension modules or in the client Web browser and/or at the application level.

Information Highways and New Technologies
author: P.A. Loekkemyhr

Advances in informatics and networking together with the rapid development of the Internet has paved the way for many new technologies, protocols and applications. Eurostat had recognised the need to trace this development and commissioned the JRC to make an investigation of some areas that could be important for them.

ISIS has, in collaboration with the EI and SAI, investigated a range of these emerging technologies and evaluated their usability. The aim has been to asses how they can be employed efficiently to improve access to and interchange of information. The technologies that have been reviewed are:
- Multi-user Virtual Reality;
- Desktop Video-conferencing;
- Streaming video on the Internet;
- Tools for virtual meetings;

Figure 1.4: Feasibility and usability of current desktop video-conferencing systems: An infrastructure with directory - and conferencing - servers has been established and a set of recommendations for deployment of desktop videoconferencing are made as result of experiments.
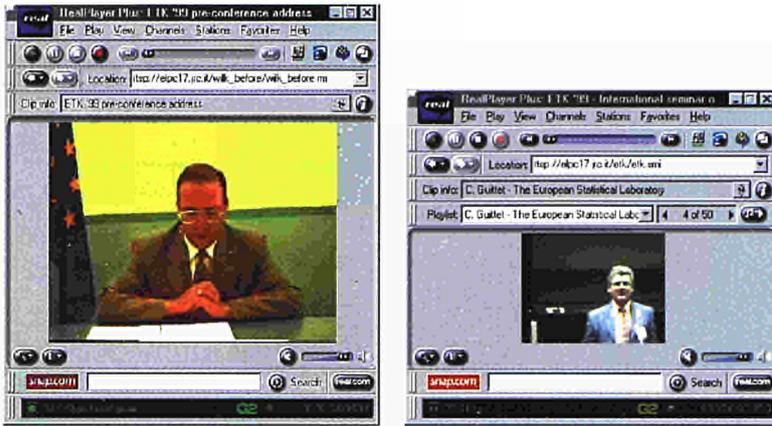
Figure 1.5: Broadcasting of live and archived video on the Internet using MS Windows Media Technologies and RealNetworks® technologies: Two permanent operational systems have been implemented. Modern Internet technologies such as multicasting, Real-Time Streaming Protocol (RTSP) and Synchronised Multimedia Integration Language (SMIL) are used. The system has been used to document two international conferences.

Figure 1.6: A broadcasting centre for national statistical institutes: Each country in the EU and the EEA has a dedicated channel where they can broadcast important events and meetings via the Internet.
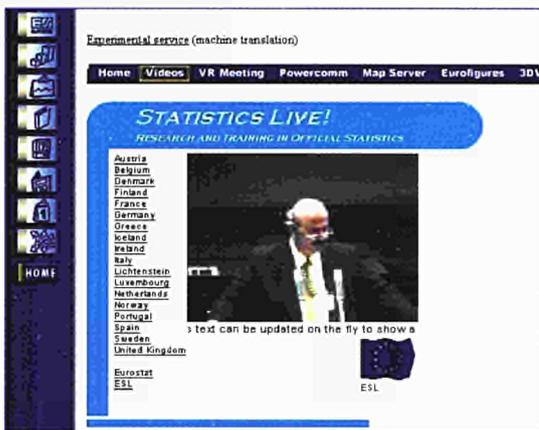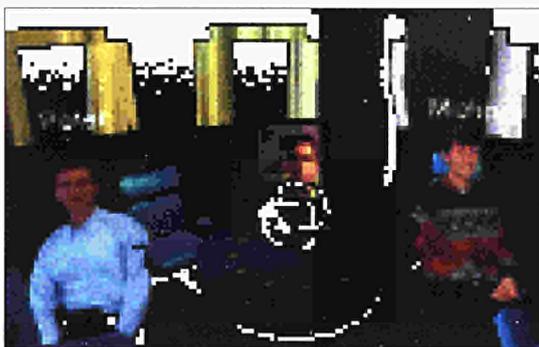

Figure 1.7: Multi-user Virtual Reality: Several virtual worlds have been implemented where people can interact with each other and work with tools and data.

- Interactive visualisation of Urban Landuse in Virtual Reality (SAI);
- Visualisation of geo-referenced data (EI);
- Web-based Geographical Information Systems (EI); Guidelines for the efficient implementation of new information systems were produced, as a result from surveys and experiments. Prototype systems have been developed to identify useful features and possible applications. All documentation and on-line demonstrators are available at http://vesl.jrc.it.

ETTN: European Technology Transfer Network

author: C. Best

The European Technology Transfer Network (ETTN) is an initiative to make technical research and expertise better available for European industry, and to stimulate their commercial exploitation. It aims to improve the technology transfer process through an effective network of services and information exchange. ETTN is funded and managed by DG Enterprise. ISIS has taken a coordinating role and has specified and managed the software and information services. These services focus around a Web site http://ettn.jrc.it. The Web site combines GIST and the CIRCA software to provide both public and secure private information exchange and collaboration tools.

The ETTN web site forms an information hub which allows technology brokers to exchange requests and offers for technology on behalf of Europe's SMEs. New research and technology opportunities can be advertised by authorised research organisations. By the end of 1999 some 375 SMEs were involved in the project spanning 15 technology platforms across Europe. Over 250 audited technology requests had been made with some 50 proposals targeted for business deals. The network runs until late summer 2000. A plan for self funded operations is being developed.

Virtual European Statistical Laboratory

author: P.A. Loekkemyhr

The Virtual European Statistical Laboratory (VESL) has the goal to become a focal point on the Internet for research and training in official statistics. The service will contain directories of people and organisations, libraries for software and documents, and interactive services that will enable users to announce events and share software, data and documents. Maintenance of the service is mainly done in a decentralised manner by the users themselves; VESL shall be an open self-populating web-site. Initial population will be done by qualified ISIS staff, particularly in the area of Time Series and Seasonal Adjustment. All information is structured and stored in a database and a fair isolation between data, business logic and user interface shall be ensured using current technologies for web-interfaces to databases. The technology chosen is GIST. The completed VESL site will be operated by ESL, the European Statistical Laboratory.

The European Statistical Laboratory

authors: A. Saltelli, F. Campolongo, K. Chan, C. Planas

Created in June 1998 by EUROSTAT and by the JRC, the European Statistical Laboratory (**ESL**) aims to ensure that European research and technological advances in fields relevant to official statistics are effectively taken up by the National Statistical Institutes (NSI). ESL is jointly operated by EUROSTAT and the JRC. Its main objective is to increase the efficiency and cohesion of the European Statistical System. http://esl.jrc.it/.

In 1999 the ESL focused its activity on *Time Series Analysis and Seasonal Adjustment* (Figure 1.8). ESL contributed to animate an interest group on the topic, performed methodological studies [1.3], and disseminated the results in papers and conferences. An ad hoc study was performed for the European Central Bank on the seasonal adjustment of monetary aggregates for the EURO area. ESL also supported EUROSTAT's development of DEMETRA, an interface system to seasonal adjustment software, contributing to its official release by EUROSTAT in February 2000.

ESL also coordinates a consortium, which includes three national statistical institutes, that has secured an ambitious project within the statistic cross-program line of FP5 (the EC 5th Framework Programme). The project, supervised by EUROSTAT, is named BUSY, and is aimed to make available to European economic and financial institutions an organised set of tools for the statistical analysis of business cycles.

Sensitivity Analysis

authors: A. Saltelli, S. Tarantola, F. Campolongo

A highlight of the year is the completion of the first handbook on sensitivity analysis. The book will be published Summer 2000. A draft version of the volume was used as didactic support for the Summer School on Sensitivity Analysis, held in Venice in July 1999 http://www.jrc.cec.eu.int/ uasa/.

The JRC has developed new global quantitative methods for sensitivity analysis, publishing several articles in peer reviewed journals [1.4-1.12] of good academic profile (impact index in the range 1-3 in 1999). As far as applications are concerned, ISIS has completed two studies for EUROSTAT (1) Evaluation of Sensitivity and Uncertainty Analysis Methods in the Quality Assessment Framework with Application to Environmental and Business Statistics. (2) Development of advanced corroboration - verification techniques for models embedded in Geographic Information Systems (Figure 1.9).

The main findings of the studies above can be summarised as follows:

- Sensitivity analysis can be effectively used to test the robustness of choices driven by the use of indicators. A test case studying landfill versus incineration options for urban solid waste showed that no defensible choice was possible based on the existing set of indicators.
- Sensitivity analysis can be used in time series analysis, (e.g. for forecast purposes), by optimising the selection of the time-series models with respect to the purpose of the analysis (e.g. trend extraction).
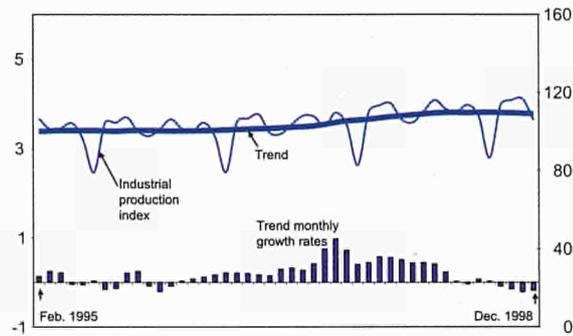

Figure 1.8: Economic time series embody irregularities (e.g. an outlier due to strike), yearly (e.g. Christmas spending frenzy, August or Easter recess) and longer-term movements (e.g. the trend of the economy). Central Banks need to understand the structure and the dynamic behaviour of these series. Extracting a trend from consumer price is crucial for the monitoring of inflation and is a constant concern of statistical offices and central banks alike. The figure shows the Industrial Production Index (1995-1998) for the monetary union together with the extracted trend and the trend monthly growth rates.

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Figure 1.9: How sensitive is a GIS-based impact assessment (bottom) to modelling assumptions? In this example, the population was alternatively assigned to the centre of gravity of the polygons (yellow dots) or assumed uniformly distributed in the polygon. Other uncertainties in the computation were outweighed by the model assumption on population. In this example the most efficient (economic) way to reduce uncertainty is to better attribute population values to areas.
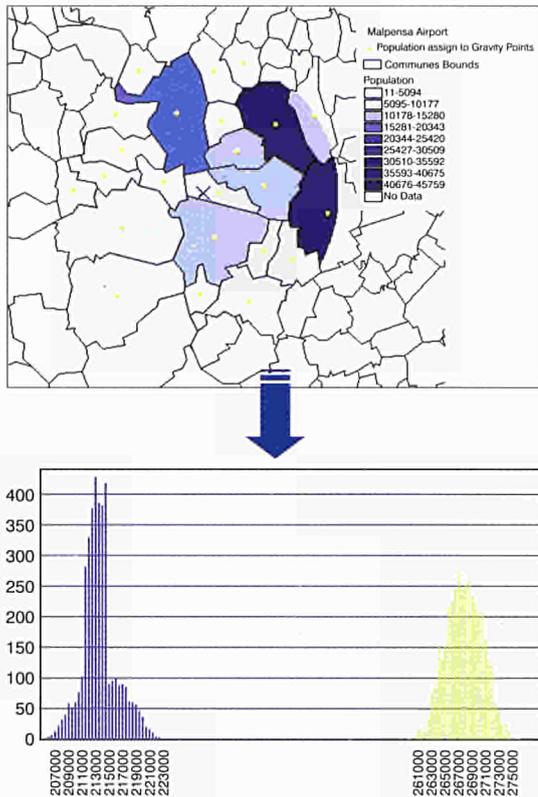
• For georeferenced data, sensitivity analysis can identify the optimal resolution levels in the input data given the task addressed by the model. This can lead to considerable saving in the building of a geographic information system, being data acquisition notoriously the most expensive step.

ISIS know-how in sensitivity analysis was instrumental in securing a number of new projects, among which:

• ARTEMIS - Assessment and Reliability of Transport Emission Models and Inventory Systems (GROWTH programme). The project involves 34 participant organisations and aims to develop a harmonised emission model for all transport modes, and to provide consistent estimates of emission from transport at the national, international and regional level.

• IMPACT - Estimation of Human Impact on the Environment in the Presence of Natural Fluctuations (IST programme). The specific objective of the project is to extract anthropogenic signals from time series of environmental monitoring data.

In 1999 ISIS also developed a software for sensitivity analysis (SIMLAB), in partnership with a software house. This project has attracted the interest of AGIP and a contract between JRC, the software house and AGIP is presently being negotiated.

Environmental Indicators

authors: J. Jesinghaus, S. Tarantola

The ambition of developing environmental and Sustainable Development indicators is to improve the existing environmental pressure indicators produced by EUROSTAT, and to move towards an aggregation of environmental, social and economic indicators to a "Sustainable Development Index" (or, more generally, "Policy Performance Index") that could challenge GDP in its current dominant role as lead policy indicator. The first volume of the Handbook of Environmental Pressure Indices is available at http://esl.jrc.it/envind/.

Neural Networks and Machine Learning

authors: A. Varfis, M. Alvarez

In 1999, the Neural Networks and Machine Learning (NNML) laboratory run several projects in support of EUROSTAT and anti-fraud service (OLAF). Three software prototypes involving machine learning techniques have been developed and delivered. One software tool implements a novel use of Dynamic Time Warping (a dynamic programming approach) to measure the lead-lag structure between connected series, as e.g. main economic indexes and leading indicator series. Another tool permits developing Multilayer Perceptron (a neural network method) forecast models for econometric time series. The third software product uses another neural network model (the Self-Organizing Map) to detect outliers in large databases. The latter project is being extended to include neural network approaches for data imputation. Finally, NNML also started a study on the achievements and perspectives of neural network methods for official statistics.

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Medical and Health Telematics

3D visualization of anatomical models of the human body

authors: A. Patak, L. Portoni, J.-C. Grossetie

The Visible Human Dataset is a collection of computer tomographic, magnetic resonance and photographic images of the human body, for a total size of 54 Gbytes. These are a set of two-dimensional images (slices). We used them to generate 3D models of human anatomical structures and organs. Creating 3D models requires to segment the images, that means to assign each image pixel to a particular anatomical structure. This is a complex and very time-consuming procedure.

Starting from the 2D slices of the Segmented and Classified Data Set distributed by Gold Standard Multimedia, we are now reconstructing more than 1600 anatomical structures of the human body. For image processing and 3D reconstruction we are using the freely available Visualization Toolkit (VTK) on a Silicon Graphics Octane. The graphic interface allows visualization and interactive manipulation of the generated models in many different ways.

3D visualization is obtained using a prototype of LCD autostereoscopic screen developed by Philips. This screen allows several observers to see simultaneously a real three-dimensional model without wearing any dedicated glasses or head-mounted displays. A specific software has been developed to visualize in real time the 3D models on the autostereoscopic screen connected to our SGI workstation. The reconstructed anatomical structures can then be 'printed' by a 3D printer (Stratasys Inc. GENISYS) as polyester models. These models can be used for educational purposes and rapid prototyping of prosthesis.

3D Holographic Synthesis and Applications

authors: J.-C. Grossetie , H. Nguyen, A. Patak, J.-C. Francescatti

Improved and up to date mathematical packages have been developed to simulate synthesis of true real colour holograms for realistic 3D active optical components, 3D scenes reconstruction
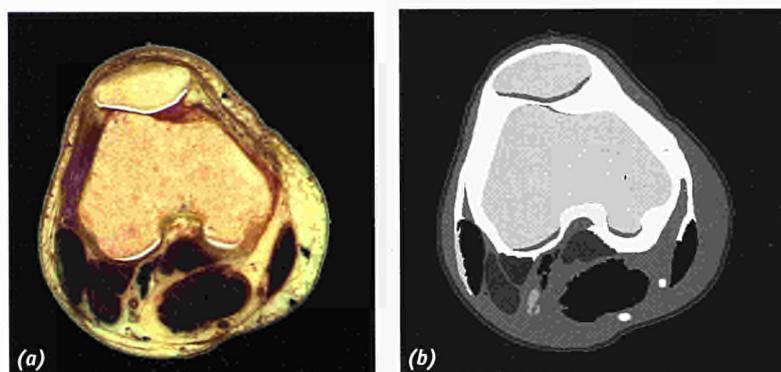
Figure 1.10: (a) Image of an original photographic slice of the Visible Human Male knee. (b) Example of manually segmented image. To each anatomical structure a grey level value has been assigned.

Figure 1.11: The reconstruction of several anatomical structures of the knee and simultaneous visualization of the model on the autostereoscopic screen. Also the 'printed' polyester model is shown.

and for studying natural vision. The associated software reconstructs multi-stage progressive and sequential 3D holograms, while maintaining a very good optical quality. A large number of applications (displays, storage, image synthesis and processing, etc.) can now be implemented. Since thin and volume holograms are mainly used for 2D and 3D static and dynamic recording, the first application and the most useful is 3D real time display, but other applications like interconnects, memory data storage, or optical correlators are important.
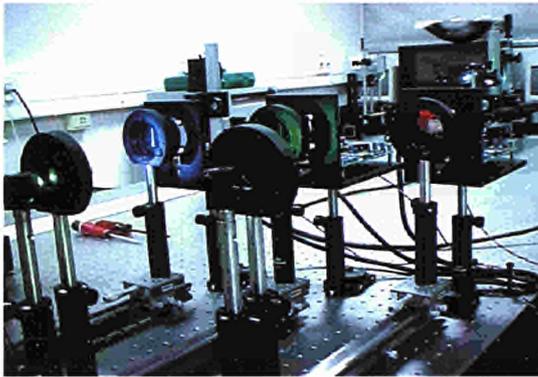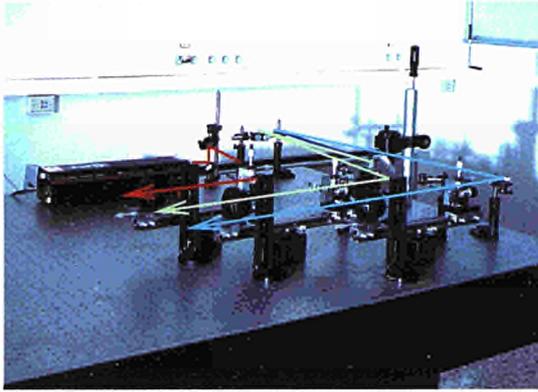
Figure 1.12: Real time colour holographic display set up.

Industrial applications of a Micro Holographic Flat LCD Display

authors: J.-C. Grossetie, H. Nguyen, A. Patak, J.-C. Francescatti

LCD technology was used to design an adaptive holographic display element. Unlike conventional LCD screens, this display has synthetic (computed) holograms as input and is driven in real time. The special light modulator is by itself a real time diffraction grating. An advantage is a very compact overall size compared with conventional optical set-up.

Potential applications are:

• Personal DVD Digital Video Disk;
• PC computer screens and wearable PC display;
• HDTV television and HDTV viewer;
• Desktop telephone for E-Mail and real-time handheld internet display;
• Video intelligent systems like head up avionic and aeronautic display;
• High definition holographic display screens for 3D CAD/CAM information systems;
• Visualization of real-time image and holography for 3D medical applications;
• Visualization of holographic interferometry for non destructive mechanical testing NDT;
• Holographic visualization for the high precision and metrology of manufactured mechanical;

Improving Access to the Information Society

authors: J. Gonçalves, J. Millán, G. Pirelli

New communication technologies have an enormous potential to enlarge the interactions which disabled and elderly citizens can have with their surroundings. ISIS focuses its studies on suitable human-computer interfaces.

Adaptive Brain Interfaces (ABI)

authors: J. Millán, J. Mouriño

From 1996 to 1998, ISIS carried out an Exploratory Research action on an alternative human-computer interface based on the analysis of electroencephalogram (EEG) signals. We have succeeded to demonstrate that people could communicate with computer-based systems through a conscious control of their thoughts. A portable, easy-to-use EEG system was used to demonstrate *brain-computer interfaces*. At the end of 1998, this Exploratory Research turned into the ESPRIT project "ABI" coordinated by ISIS. Other partners of the ABI consortium are an SME company, a neurological rehabilitation hospital, and a university; see: http://sta.jrc.it/sba/esprit/abi-esprit.htm.

The approach is based on a mutual learning process whereby the user and the ABI are coupled and adapt to each other. While a neural network learns user-specific EEG patterns characteristic to the mental tasks, users learn to think in such a way that they are better understood by the interface. The ABI approach has been evaluated with 8 healthy users [1.13,1.14]. It recognises three mental tasks from on-line spontaneous EEG signals. Correct recognition is around 70%. This modest rate is largely compensated by two properties of ABI: wrong responses are below 5% and it makes decisions every half a second. Moreover, since the user and his/her personal ABI learn simultaneously from each other, users master it rapidly; one of the users achieved excellent control in just 5 days of moderate training, around 1 hour daily (Figure 1.14). Ongoing research concerns, among other issues, testing ABI with disabled persons, recognition of more mental tasks and building an advanced wireless EEG helmet.

Future perspectives for ABI ranges from applied to basic projects. On the one hand, ABI can nat-
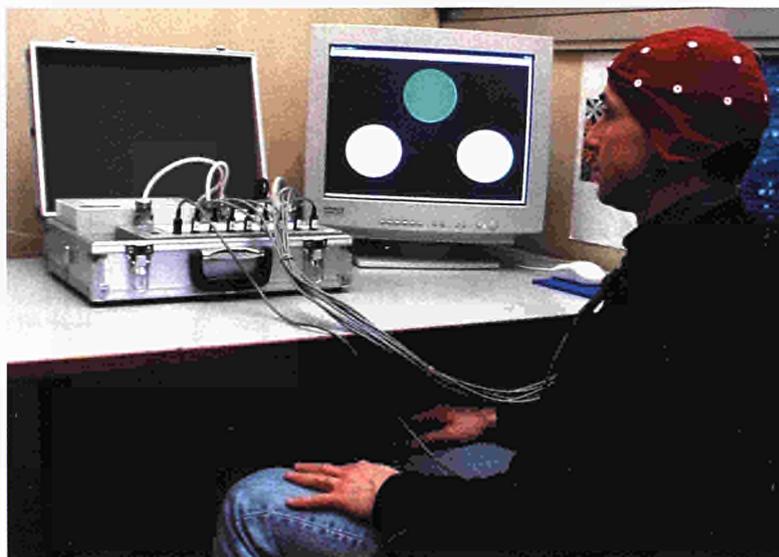
Figure 1.13: Portable EEG system. In this picture, the user holds a cap with integrated electrodes. The cap is connected to the dedicated hardware (left). The computer screen shows how the user receives biofeedback in real time. There are three buttons, one for each mental task to be recognised. A button lights up when the current EEG sample is classified as belonging to the corresponding mental task.
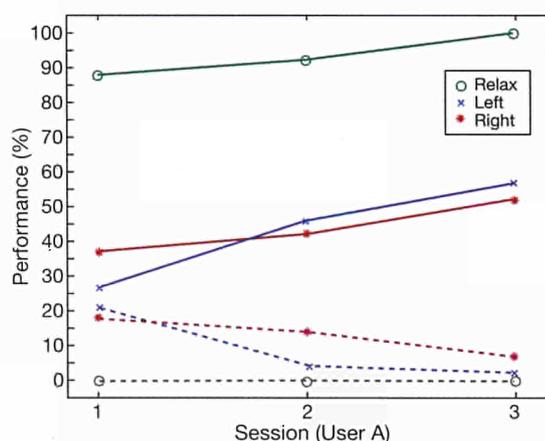
Figure 1.14: Evolution of the classification performance for two users over three and five consecutive days, respectively. Solid lines represent Correct Responses for the corresponding task, whereas dashed lines represent Wrong Responses. User B had no previous experience with brain interfaces before starting his training.
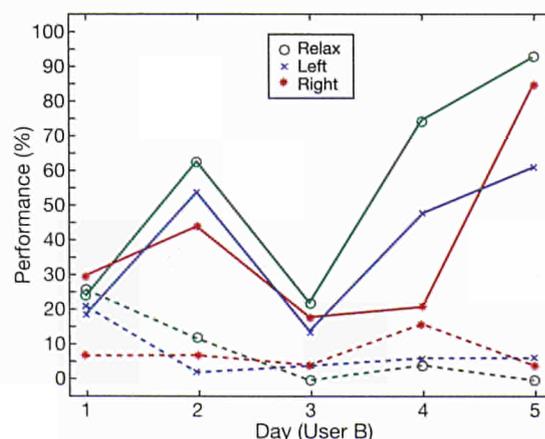
Figure 1.15:
Videoconference system with automatic live subtitling. A deaf user communicates with a colleague speaking to a microphone connected to a PC: the text generated by the speech recognition system is converted into subtitling lines and overlaid onto the correspondent's video image. The subtitling prototype is developed in several languages.

Figure 1.16: VOICE Project's Web Site. Partners exchange all information via a VOICE Forum on the Internet and spread the results and best practices via a VOICE Web Site.

VOICE: giving a voice to the deaf
author: G. Pirelli

The VOICE project demonstrates how speech recognition systems in conversation, conferences and school lessons, can be translated on-line into PC screen messages. ISIS develops prototype interfaces for an easier 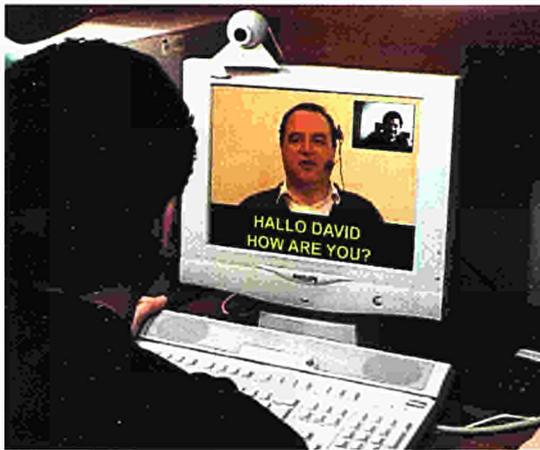use of commercial products, taking into account the requirements of citizens with hearing impairment, in view of reducing the gap between them and the hearing world. It is also investigating the use of this technology in television broadcasts and telephone calls.

The aim is to develop awareness in the field among users, systems producers and services providers, by organising and presenting VOICE at international workshops and congresses and creating a VOICE Forum on the Internet. The prototype demonstrator produced live subtitling of part of the VOICE Workshops and User Group Meetings in European conferences, as well as in a workshop with the European television broadcasters.

The VOICE project was initiated as an ISIS exploratory research project. It is now sponsored by DG Information Society's Telematics Applications Programme (TAP), as an "Accompanying Measure". The project involves the active participation of several associations of people with hearing impairment, from different European countries. The permanent outlet is the interactive website at http://voice.jrc.it.

urally augment capabilities of people, both impaired and healthy. Some examples are direct mental control (e.g. prostheses, writing devices) and monitoring (e.g. awareness of drivers and operators of safety critical systems). On the other hand, ABI can contribute to health research such as medical diagnosis of brain disorders and the study of neurocognition (during rehabilitation as well as in everyday life).

ACCESS: Access to Education for People with Disability
author: G. Pirelli

The ACCESS project investigates the development of multimedia applications for helping people with disability in accessing the Information

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Figure 1.17: The basic idea of ACCESS is to provide the written voice of a teacher and friends to those who cannot hear the spoken voice. This concept also applies to people with visual impairment who will be able to listen to the spoken Web pages by means of text-to-voice synthesis of the written page content.

Society in their education and training. The research aims are twofold:

- Provide design recommendations for contents in the Internet which can be accessed, irrespectively of the required human-computer interface; "design for all" approach.
- Recommend best practices, to enable the access of people with disability.

ACCESS targets to students with special needs, but it also benefits the elderly. ISIS has a long standing, hands-on experience for supporting European policy makers, e.g., Netd@ys-Voice in 1998 and Netd@ys-Access in 1999, Socrates' MOISE and active participation at the Inter-Service Group on Disability. There ISIS helps identifying the user needs and translating them into recommendations and technical specifications. Workshops, videoconferences, tele-education sessions and Net-meetings offer opportunities for sharing common experiences and for the dissemination of new ideas.

The Internet ACCESS Forum discusses the adaptation of multimedia systems to the special needs of disabled people. Results and conclusions are published on the Web in several languages. This presentation follows the current recommendations for creating Internet contents accessible by people with visual impairment or reduced mobility as an example of a web-site designed following the rules of "Web-accessibility to all" http://voice.jrc.it/access. The technical and human facets of ACCESS overlap and help raising awareness for the problems faced by people with disability.

Training of Mentally Disabled People in Working Environments

author: C. Cacciabue

A scientific collaboration between ISIS and Istituto Scientifico E. Medea was set up in order to better integrate mentally disabled people in their working environments, namely in SMEs. The two-year project, financed by the Italian Ministry of Health, is focused on the development of a multimedia simulation system for improving error diagnostic skills in mentally disabled people.

The difficulty to recognise and react to our own errors is a common experience. In particular, this holds true for mentally disabled subjects because of their low projective capabilities, their attention deficit and the rigidity with which they apply resolutive schemes. Usually, during training they are taught how to operate machines by simple automatic sequences. In order to devise a new training methodology and an innovative way to deal with errors a quite innovative approach was taken.

In the first year, a conceptual framework of reference has been considered and observations of disabled people at work were carried out aiming at studying their diagnostic skills and how they react to abnormal situations. A classification of human-machine interaction mishaps was then developed in order to collect information on characteristics of the training received by these people and the relative approach to the working context. Moreover, the database also contains the neuropsychological cognitive profiles of these people as well as the type of machines they operate. It is expected that these studies will point out a methodology for evaluating and improving the way mentally disabled people interact with machines.
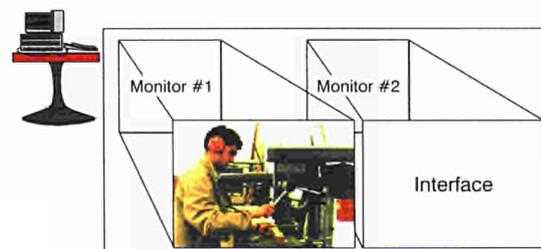

Figure 1.18: Multimedia Simulation System.

Three Dimensional Reconstruction of Real Environments
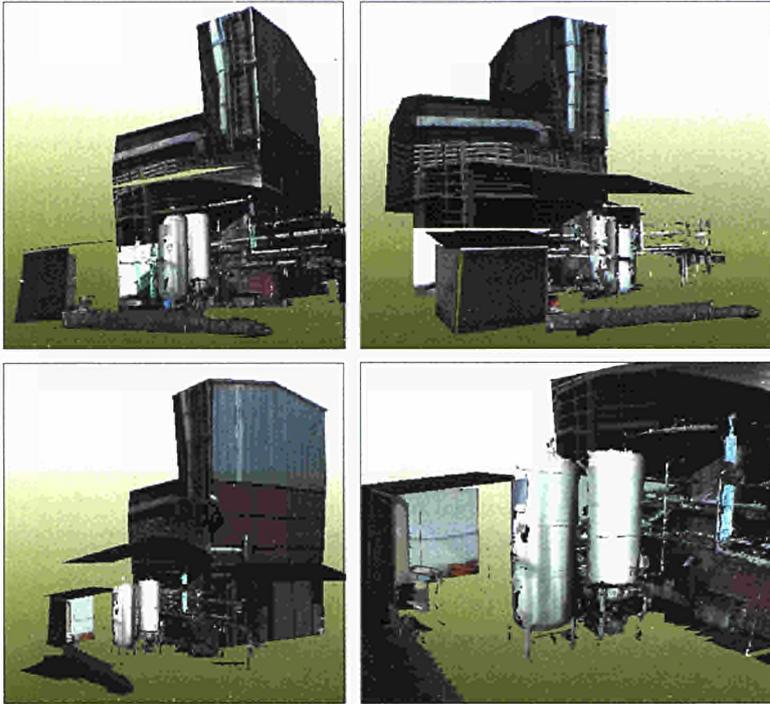
authors: J. Gonçalves, V. Sequeira

Figure 1.19: 3D Reconstruction of an outdoor industrial plant – the figure shows three snapshots of the final 3D reconstructed model as seen from three different positions and a close-up snapshot of the highly detailed 3D model of the pipe work.

Figure 1.20: 3D Reconstruction of the "Cour d'Honneur" of the French National Assembly – the figure shows two snapshots of the final 3D reconstructed model. The model is textured with the infrared laser reflectance data. The internal courtyard is about 80 m per 50 m.
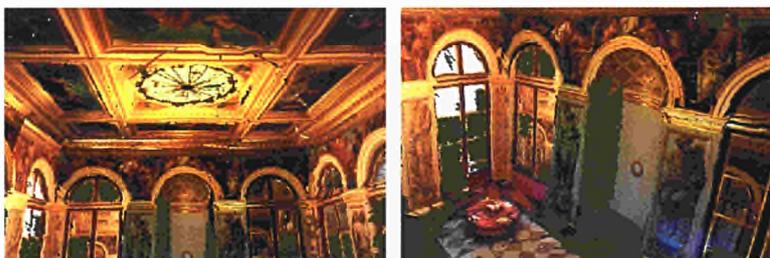
Figure 1.21: 3D Reconstruction of the Delacroix room at the French National Assembly – the figure shows two indoor images from the final 3D model illustrating the Delacroix paintings.

The objective of Three Dimensional Reconstruction is to create a model of a real environment as it actually is. It becomes thus possible to view the environment representation from any viewpoint selected by the user. Figure 1.19 shows the 3D model of an outdoor industrial plant as seen from different positions.

A complete 3D Reconstruction model requires data scanning and acquisition from multiple capture points. These multiple datasets resolve the occlusions, i.e., areas that are not seen from single views as what is behind a cupboard. Prior to having a single integrated model, there is thus the need to register and process the 3D data.

The long experience of ISIS in 3D Reconstruction has been recently extended by the participation in two competitive projects and a thematic research network.

RESOLV

authors: J. Gonçalves, V. Sequeira, E. Wolfart, E. Bovisio

The Resolv project aims at exploring new technologies for creating photo-realistic 3D models of indoor and outdoor environments. After four successful years, the project has come to an end. The participation of the JRC include the acquisition of 3D data, the development of algorithms for 3D reconstruction and the development of innovative applications and systems, e.g., 3D hand-held range scanner. Moreover, 3D models can be applied to 3D Omni-directional Virtual Studios, a novel TV/cinema production technique, combining the studio filming with virtual environments. Figures 1.20 and 1.21 show the 3D model of the French National Assembly's Cour d'Honneur and a detail of the Delacroix room.

INFOBOY

authors: J. Gonçalves, V. Sequeira, E. Wolfart, E. Biotti, E. Bovisio

The goal of this project is to evaluate the use of 3D Reconstruction techniques for the Web and tourist kiosk advertisement of farmhouses and small hotels in the Bavarian area. Figure 1.22 shows the 3D model and different views of a Bavarian farmhouse.

CAMERA

authors: J. Gonçalves, V. Sequeira, P. Dias, K. Klein

This research network on 3D Reconstruction aims at enhancing the scientific collaboration between the seven research laboratories involved and at providing training to high-talented young researchers. ISIS participation focused on two topics:

- Perception Planning, i.e., where to locate the 3D data acquisition equipment in order to build complete 3D representations of the environment;
- Registration of video and laser range data;

The network used the 13th century round churches of Bornholm, an island in the Baltic Sea, as a common dataset. Two views of a texture-mapped model of the inside of the church are shown in Figure 1.23. Figure 1.24 shows the best location for the second capture point inside one of the Bornholm churches.

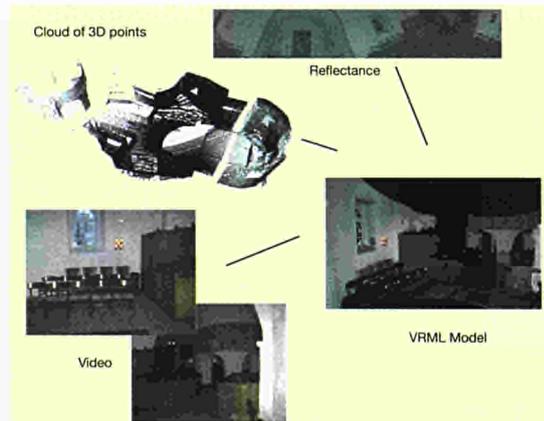Figure 1.22: 3D Reconstruction of a Bavarian farmhouse - several snapshots of the 3D reconstructed model.

Figure 1.23: 3D Reconstruction of a church at Bornholm, a Danish island in the Baltic Sea. The final model is based on the fusion of data originated from different sensors.
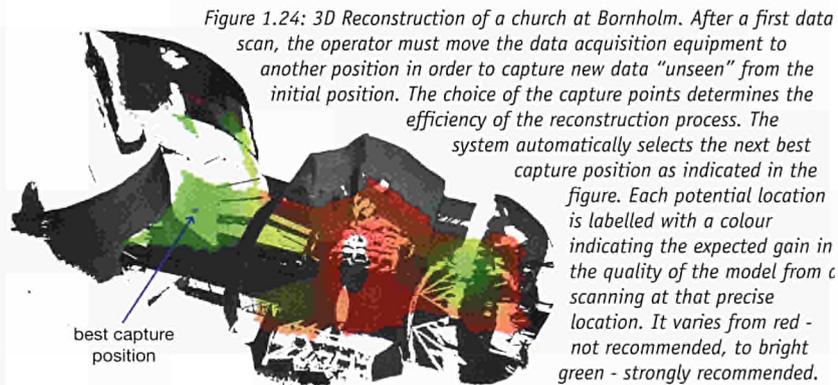

Figure 1.24: 3D Reconstruction of a church at Bornholm. After a first data scan, the operator must move the data acquisition equipment to another position in order to capture new data "unseen" from the initial position. The choice of the capture points determines the efficiency of the reconstruction process. The system automatically selects the next best capture position as indicated in the figure. Each potential location is labelled with a colour indicating the expected gain in the quality of the model from a scanning at that precise location. It varies from red - not recommended, to bright green - strongly recommended.

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(*) This paper won the Young Author's Award for Ng (Univ. Leeds) and Sequeira (JRC)]

Information Systems in Civilian Demining

Introduction
author: F. Sorel

At the Ottawa convention, the European Commission committed to pursue and reinforce its efforts in helping afflicted nations clear their lands of anti-personnel landmines. Even with the increased worldwide commitments to the financing of humanitarian de-mining operations, the de-mining effort will take many years. It is hence important to also pursue R&D efforts aiming at increasing the speed, cost efficiency and safety of these operations, and to co-ordinate these research efforts for maximum efficiency.

The main objective of the JRC activity is to provide a coherent technical and scientific support to the conception and implementation of the European policies in the field of humanitarian de-mining. This activity is carried out in close collaboration between SAI (Space Applications Institute) and ISIS. The aim of the ISIS project is to ensure that effective and safe information systems and technologies are made available to de-mining programmes.

The project started in 1999 along the following activity lines:

- Information hub of de-mining projects financed by the different services of the Commission;
- Support to de-mining operation planning based on geographic information systems and decision support;
- Support to close detection of landmines focusing on CAD databases and complementary sensors;
- Support to mine clearance through the evaluation of remotely controlled mechanical equipment and training methods for de-mining teams;

Information Hub, Geographic Information Systems and Decision Support
authors: I. Shepherd, R. Peckham, D. Sarigiannis, F. Ereno, H. Hardy, B. Eiselt, M. Saisana, V. Hoffmann

In the period 1992-98, the European Union committed over 180 M€ to support demining programmes, assistance to mine victims, and research and development of technology. EU Member States carried out bilateral programmes on a similar scale. Altogether, this has been a major contribution to the global efforts of the international community but much remains to be done.

In 1999 ISIS started a series of actions to improve the visibility, transparency and efficiency of the Union's mine action operations. As a first step it set up a web-site (http://eu-mine-actions.jrc.cec.eu.int) that explained the Union's policy, described where the responsibilities lie within the Commission and catalogued the past and ongoing mine actions according to the type of action (de-mining, victim awareness, rehabilitation etc) and the country concerned. This catalogue was rationalised and used as the basis for an on-line database, open to the public but with a limited number of areas reserved for the Commission services. A document repository, again with differential access, was also connected to the web-site. Work is ongoing to open a gateway to the Land Mine Information System, developed by JRC's Space Applications Institute, for archiving and distributing signatures from ground-penetrating radar experiments. In support of this signature database JRC developed an ob-

Figure 1.25: Unexploded ordnance in Laos (information courtesy of Handicap international).
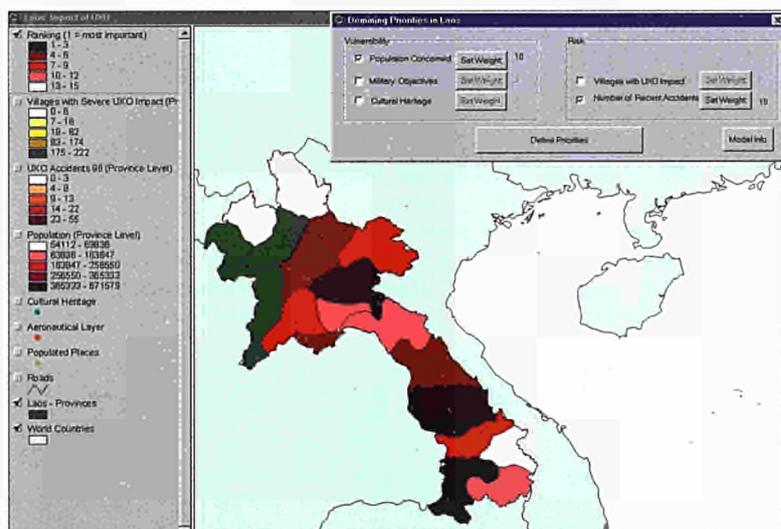
References

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ject-oriented software package for validating that standards are respected and converting between different formats (SEG-2 and MEG).

Work on Geographical Information Systems has started. Next year these will be linked to the web site but for the moment they are being tested off-line. Coarse-scale information on mine contamination has been obtained from the United Nations and this is being linked to commercially available spatial data on population density, sites of cultural interest, land cover, topography and administrative boundaries as well as information available from JRC such as the European soil map. Finer-scale information on contamination and casualties is also being collected from governmental and non-governmental sources. Data from Laos, where the main threat is from unexploded ordnances left over from the Vietnam conflict, was obtained from Handicap International. Data was obtained from Croatia following a visit to the Croatian Mine Action Centre. It is estimated that 10% of Croatian land is contaminated.

This information is being used firstly to determine priorities for mine clearances and secondly to identify the most appropriate clearance technology for a particular region. This will depend on soil-type, land cover, climate and the type of mine (anti-tank or anti-personnel) that is likely to be found.

A preliminary exercise in decision support used the Laos data as a basis. Land mines are an impediment to sustainable social and economic development so the prototype decision support system took into account social and economic factors as well as the distribution of mines. Two different methods were tried – the first evaluated vulnerability and risk separately and then combined them to determine impact. The second aimed to include some cost-benefit component. The results of both are still being analysed to see where the two approaches differ and what extra information is needed.

It is already apparent that there is a need to harmonise better the reporting of mine actions and the recording of information - both within the afflicted region and at the headquarters of organisations such as the United Nations and the European Union that coordinate mine actions. JRC is leading efforts to improve the harmonisation and has organised a workshop on the subject that will take place early in 2000.

Pilot CAD database for the close-in detection of landmines

authors: F. Andritsos, F. Littmann, I. Vakalis

One of the major issues in landmine detection is the very high false alarm rate associated with the high sensitivity metal detectors needed for the detection of the modern minimum metal mines, coupled to the usually high debris soil contamination. Actually, each metal detector alarm cannot be confirmed but by manual probing and digging, in order to identify visually the suspect object.

A survey on the existing landmine databases was carried out before implementing any new database. The work performed aims in using 3D Computer Aided Design (CAD) models of mines for a pilot multi-sensor data-fusion application (Figure 1.26). CAD feature extraction coupled to multi-sensor data fusion algorithms is expected to help in identifying the cause of many metal detector alarms, thus saving a lot of manual work and enhancing significantly the demining process.

A good understanding of the current humanitarian de-mining practices is vital in what has been undertaken. A demining training course, especially for R&D performers, has been organised in the frame of the ARIS network in Sweden and in Bosnia Herzegovina. ISIS personnel participated in that course (Figure 1.27) as well as in other related workshops and activities.
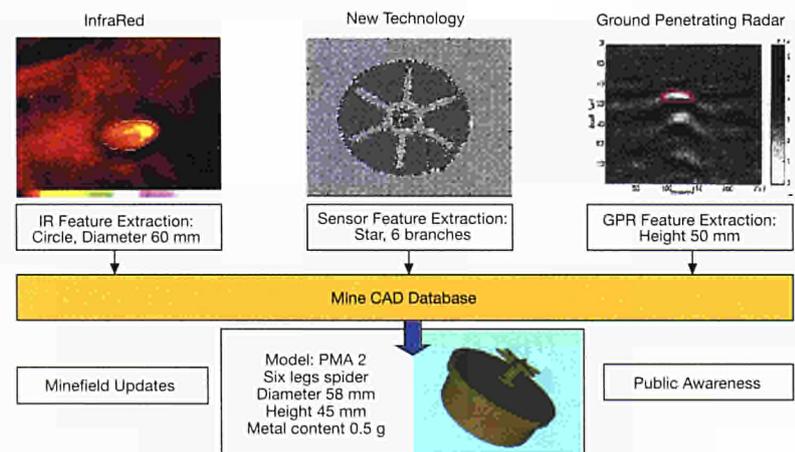

Figure 1.26: Example of target identification through the fusion of data from three different sensors with features extracted from a CAD database.

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Figure 1.27: Landmine Awareness.

Figure 1.28: Mechanically assisted demining.

Remotely controlled mechanical equipment

authors: F. Andritsos, F. Littmann

As became apparent also from our experience in Bosnia, vegetation and tripwire clearance may represent up to 70% of the time spent by a deminer. The use of remotely controlled mechanical equipment (such as Figure 1.28) could enhance significantly the demining process. ISIS initiated a survey of the existing remotely controlled equipment and of the operational needs (see http://demining.jrc.it/aris/events/eksjo/eksjo.html, http://demining.jrc.it/aris/events/sarajevo.htm).

Evaluation of Complementary Sensors

Chemosensors and Biosensors
author: J.M. Zaldívar

Chemosensors and biosensors incorporate respectively, a chemical (chemically selective membrane, film or layer) or a biological (enzyme, nucleic acid, antibody, bacteria, and tissue) entity as a fundamental part of the sensing process. These active sensors are coupled with an electronic device which act as an electronic transducer that interprets their activity.

Even though considerable research has been devoted to these sensors, the efforts have concentrated on the food and health industry and only recently their application for the localization and identification of anti-personnel mines has started. The development of a reliable sensing device for buried personnel landmines is still a mid-term scientific goal.

For chemical and biochemical sensors, ISIS has concentrated on an independent assessment to determine whether presently available technology could be adapted for explosive sniffing, a study of international on-going projects [1.27], and an assessment of possible JRC research activities that could help in order to speed up the development of these sensors [1.28].

Complementary activities that could help developers and sensor manufacturers in their work for the test/characterization of their sensors to the problem of landmine detection as well as an outline of possible future activities can be summarized as follows:

• Understanding the decomposition reactions in TNT, RDX and other landmine explosives and creating a Web-database with quantitative chemical data.

References

[1.27] Zaldívar J.M., Survey of the USA-DARPA research initiative for the localization and identification of anti-personnel mines: the Electronic Dog's Nose program, JRC Technical Note I.99.140, 1999.
[1.28] Zaldívar J.M., Biosensors, chemosensors and electronic noses for the localisation and identification of anti-personnel mines: Overview, prospectives and possible JRC contribution, JRC Technical Note I.99.160, 1999.

- Testing and modelling explosive vapour transport through porous media and into the air.
- Development of a testing facility for the calibration of electronic noses, biosensors or chemosensors prototypes as it is already done for other type of landmine detection systems.

Evaluation of electro-static sensors
authors: C. Coutsomitros, A. Kokonozi

An electrostatic sensor has the potential to detect plastic mines. It detects electric charges as low as 10^{-17} Cb. The tests have been performed using active methods to electrically charge plastic mines for close-in detection.
Positive results have been obtained with real mines positioned under ground. There is a very clear signal in positions where the mines were localised. In this configuration the mines were under ground in 1 cm below the sand. Tests were performed to investigate the effect of different climatic conditions. An electrostatic generator was used to charge by induction the plastic mines that are underground. First results give a positive response to this problem.
The realisation of a prototype version started. The first miniaturised device was tested successfully.
It is planned to develop an electrostatic scanner with 100 electrodes to be able to reproduce the geometric shape of the buried plastic anti-personal mines. This electronic board in A4 format will be designed for connection to a portable PC.

Infrared measurement method
author: C. Coutsomitros

Infrared spectral measurements have been performed, under different laboratory conditions to detect buried plastic anti-personal mines (APM). *Weak temperature gradients* were applied at the region where the landmine was suspected to be either by heating or cooling. Different static tests were performed with landmines partially or totally covered by sand and/or vegetation at a depth of about 1 cm. The IR camera is used as a
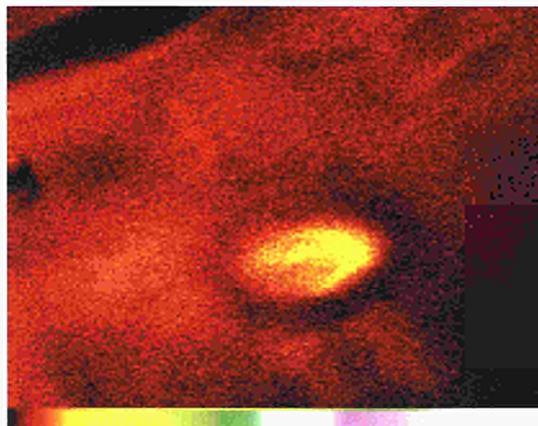
Figure 1.29: Infrared image of a mine totally covered by the sand: The measurement was performed after heating up the sand.

confirmation sensor, seeking to identify the cause of an alarm of a scanning sensor (i.e. a metal detector).
The IR measurement uses a local weak activation thermal field. It has been demonstrated that, at least under the given laboratory conditions, it can provide images clear enough to reduce manual probing and digging. Established, off-the-shelf image treatment techniques can further enhance this process.

Training for Mine Clearance Teams

author: M. Bacchi

Despite the amount of research conducted in order to identify new technologies to support Clearance Operations in Humanitarian Demining, detection and clearance are still performed manually using metal detectors and probes. The human being is the main actor in field operations.
In order to identify performance indicators and training needs, a literature review was carried out. The main conclusion reached is that Humanitarian Demining has been ignored by the scientific human factors community.
The main factors which have an impact on deminers performance are related to attention, risk perception, safety culture, mental and physical fatigue (normal duration of a single prodding task should not exceed 20 minutes). In particu-

References

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[1.30] Coutsomitros C., Kokonozi A., Andritsos F., Vakalis I., and van Wijk L., IR Mine Identification with Weak Activation Methods, *JRC Technical Note I.99.165*, September 1999.

lar, the following subjects have been identified for further study:

- Routine and complacency causing 'poor' or unsafe results as they decrease the level of attention of deminers.
- Risk perception, which is decreased by routine as well as the high rate of false alarms (100-1000 false alarms for each real mine detected).
- National culture, which determines the way in which Standard Operational Procedures and safety equipment are applied and used. For example, in some cultures, wearing protective equipment is seen as a sign of weakness.

A Pilot Research will take place early 2000 to identify deminers professional competencies, i.e. knowledge and abilities for safe and efficient Clearance Operations. These data will have direct impact on deminers training, as they are synonymous of training objective and contents. Moreover other applications would benefit from these results; expert systems are based on the identification of the knowledge and abilities that characterise the performance of experts in specific fields.

Safety of Building Structures and Means of Transport and Protection of Cultural Heritage

editor: V. Renda

The European Commission is strongly engaged in research and development for the protection of the European population against the consequences of natural and man made hazards. A significant effort is done in the field of safety in Structural Mechanics with reference to buildings and bridges, means of transport and protection of cultural heritage. The activities performed at the Institute for Systems, Informatics and Safety take advantage of unique facilities in Europe: the European Laboratory for Structural Assessment (ELSA) and the Large Dynamic Test Facility (LDTF). Full/large scale tests are performed at ELSA to assess the behaviour of structures of civil and architectural interest stricken by strong earthquakes. Crash tests on energy absorption devices for transport and road equipment are performed at LDTF. All these activities are complemented by advanced measurement techniques, sophisticated numerical modelling and analyses. The work related to the protection of cultural heritage includes the development of technologies for structural diagnostics and techniques for strengthening/repair of the structures validated through full/large scale seismic tests performed at ELSA.

Safety of Building Structures

introduction: G. Magonette, A. Pinto

Recent disastrous earthquakes in Japan (Kobe, 1995), Turkey (Izmit, 1999) and Greece (Athens, 1999) demonstrate the importance of seismic risk mitigation. Appropriate design of new constructions and retrofitting of existing ones are two basic requirements. Therefore, scientists and engineers work to improve the protection of buildings and bridges against extreme loads as from earthquakes and wind. New construction materials and technologies attract the interest and attention of scores of researchers requiring substantial efforts to set-up safety recommendations, and related norms and standards.

The European Laboratory for Structural Assessment (ELSA) offers scientific and technical competencies as well as large-scale experimental facilities to investigate technologies for safe and economical design of civil engineering constructions against hazardous loading. Five research areas were covered during the last year: 1) Development and assessment of seismic retrofitting solutions and techniques for ordinary buildings and for bridges; 2) Assessment and retrofitting of buildings with cultural value; 3) Vibration control methods and systems for bridges under wind loading; 4) Development of the Pseudo-dynamic (PSD) testing method - continuous PSD testing and nonlinear substructuring techniques; 5) Development and calibration of analytical models and tools for the seismic assessment of structures.

Activities supporting Eurocode 8

author: P. Negro

The ELSA Laboratory provides experimental data for the calibration and verification of Eurocode 8, the harmonised code for Earthquake Resistant Design of Structures. This work started immediately after the construction of the Laboratory, with the first seismic test on a complete building designed in accordance with the current version of Eurocode 8 [2.1,2.2]. In addition, a number of pre-normative research projects took advantage of the ELSA Laboratory [2.3].

The network on Innovative Concepts for new and existing structures (ICONS) performs pre-normative research for the new generation of design codes. This includes the assessment of the so-called *Displacement Based Design*, which may completely change the philosophy of seismic design procedures in the future. A complete four-storey reinforced concrete building has been designed and built (Figure 2.1). One of the frames has been designed according to the current version of Eurocode 8, and the other according to the new *Displacement Based Design method*. The results are expected to show the advantages of the new design concept, and will yield information about the seismic behaviour of dual struc-

Figure 2.1: The four-storey dual (frames and shear walls) building was designed according to the Displacement Based Design *method and will be used to test the new design concept.*

References

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[2.2]   Pinto A.V., Research in Structural Mechanics in Support of Standardisation. In *'The IPTS Report, Vol. 35 (June 1999)- Special issue: standardisation and RTD'*, edited by IPTS, JRC, Seville, 1999.

[2.3]   Severn R.T., Calvi G.M. (Eds.), European Activities for the Development of Eurocode 8, Summary Report, *ECOEST/PREC8 Report No. 9*, LNEC, Lisbon, 1997.

tures (structures which combine frames and shear walls). Tests are also being prepared to study the seismic behaviour of irregular (U-shaped) shear walls. These structures typically resist a large portion of the total seismic forces, and the non-linear behaviour of shear walls with complex cross-section configurations is largely unknown.

Other tests were performed to explore the possibility to release the current limitations imposed by Eurocode 8 in terms of strength of the materials. The upper limit imposed on the strength of reinforcing steel seems to be inappropriate for the case of confinement. With this aim, a series of columns equipped with stirrups made of high strength steel (yielding strength 1000 MPa) were performed, and the results seem to confirm similar studies recently conducted in Japan.

A more direct connection between research and CEN technical committees is needed. In this respect, the newly signed agreement between the JRC and the CEN will certainly have a positive impact.

Earthquake protection of buildings using high damping rubber isolators and viscoelastic dampers

author: G. Magonette

Isolation of buildings from the horizontal component of seismic ground motions is becoming more accepted as an effective method of providing protection from earthquake damage. By reducing the seismic forces transmitted into a building, this technique also protects the contents and secondary structural elements. High damping rubber (HDR) bearings are a simple and economical means of providing isolation. They possess the low horizontal stiffness needed and are capable of safely withstanding the large horizontal displacements imposed on them during an earthquake. Sufficient damping is present in the rubber to suppress excessive displacements and reduce the response at the isolation frequency. The ELSA laboratory has extended successfully the application of the pseudodynamic testing method to the assessment of structures equipped with strain rate sensitive material such as HDR.

Figure 2.2: Rubber based dampers installed in the superstructure of buildings can substantially reduce interstorey drift during earthquakes. In this test, the dampers were mounted below the ceiling of the ground floor and below the roof at the point where the diagonal bars meet.

The REEDS project, funded by the Commission's Brite-EuRam programme, examines a new technology in which the earthquake resistance of a building is enhanced by rubber-based dampers in the superstructure [2.4]. The effectiveness of the dampers has been assessed by tests performed on a mock-up of part of a reinforced concrete frame structure. The results [2.5] showed that it is feasible to incorporate the dampers into a non-seismically resistant structure and thus reduce the interstorey drift produced during a typical design earthquake (Eurocode 8: medium soils) to a level at which the structure responds only elastically. This technology has potential application to both new and existing structures (Figure 2.2).

Active control in civil engineering

author: G. Magonette

In recent years, improvements in materials and computational techniques have led to progressively longer, structurally more efficient and more slender structures. Consequently, they are increasingly flexible and more sensitive to wind as well as to live load induced vibrations.

Furthermore, structural damping is usually lower than one percent. For large bridges this justifies the development of active damping devices. The Active Structures Laboratory of the Université Libre de Bruxelles has recently developed a robust decentralised control strategy for cable struc-

References

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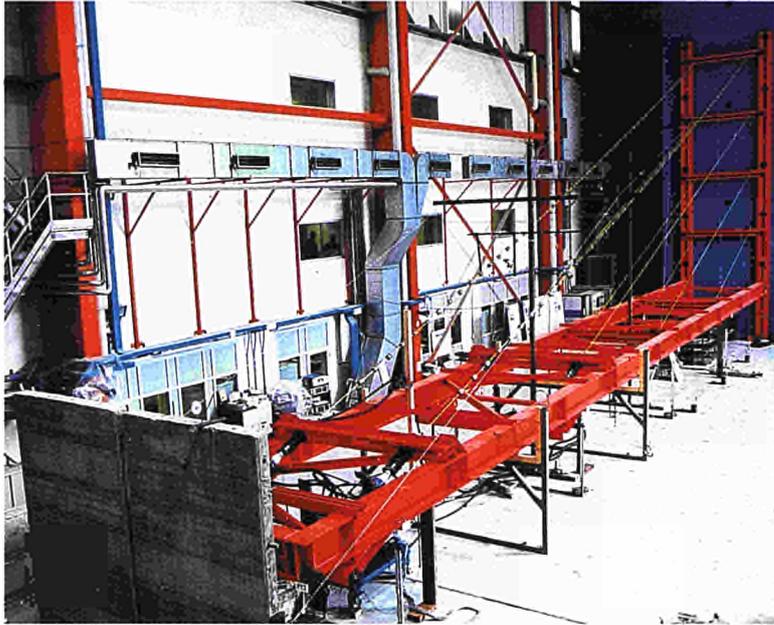
Figure 2.3: The Large-scale cable-stayed bridge mock-up at the ELSA Laboratory used to validate active vibration control devices.

Vulnerability assessment of bridges

author: A. Pinto

Recent seismic events show that long bridges as highway and railway viaducts are particularly sensitive to the effects of earthquakes. Insufficient consideration for seismic risk in bridge design has resulted in inadequate detailing of confining steel and insufficient shear reinforcement in the bridge piers, insufficient seat length of bearings, and inadequate design of the bridge abutments. There are many open questions concerning the ductile behaviour of large bridge piers, in particular those with rectangular hollow cross-section commonly used in Europe.

ISIS is participating in the VAB project ("Advanced Methods for Assessing the Seismic Vulnerability of Existing Motorway Bridges - contract ENV4-CT97-0574) as the major partner for the testing activity. Four large-scale models of typical bridge piers with different span ratios will be tested at the ELSA laboratory using non-linear substructuring techniques.

The work in 1999 concentrated on the development of the non-linear substructuring to be used in the on-line control of the experiments [2.8]. Final definition and design of the scaled models (1:2.5) of the bridge piers were performed. The four piers (two squat piers and two bending dominated piers) will be constructed at the beginning of the next year and the testing campaign will start by March 2000. An initial displacement controlled test will be performed on a short pier allowing to calibrate the required non-linear models for the pseudo-dynamic test with substructuring. It is also foreseen to assess experimentally the effectiveness of seismic retrofitting solutions and techniques for bridge piers with rectangular hollow cross-sections.

tures, using a collocated force sensor and a displacement actuator. This strategy has already been successfully applied for several laboratory-scale demonstrators. To show its applicability on real structures, large-scale experiments have been carried out at ELSA. The test-bed is a 30 m long model of a cable-stayed bridge during its construction phase (Figure 2.3), equipped with hydraulic actuators on the two longest stay-cables.

A complete series of over 100 experiments performed on the model bridge clearly demonstrated the efficiency of the active damping system [2.6,2.7]. The tests covered the analysis of numerous critical situations, emphasising also the performance of the entire system. This included the behaviour of sensors, controllers, actuators and power generators. Moreover, a number of implementation aspects were addressed as intermittent and fail safe operations, integrated safety, reliability, and maintenance.

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Assessment and retrofitting of reinforced concrete frames

author: A. Pinto

Within the ICONS project ("Innovative Seismic Design Concepts for New and Existing Structures" - Contract FMRX-CT96-0022) [2.9], performed jointly with eleven European research institutions, ELSA is performing a wide testing campaign on reinforced concrete frames representative of the construction of the 1950's. Main objectives are the identification of structural vulnerabilities (assessment) and development/qualification of retrofitting solutions/techniques. Selective retrofitting techniques were successfully applied and tested. Assessment of more conventional techniques (e.g.: shotcrete of infill panels) and of new solutions based on dissipative devices will be performed next. Figure 2.4 shows the reinforced concrete frames under testing and compares performances of the original structure with the retrofitted one.
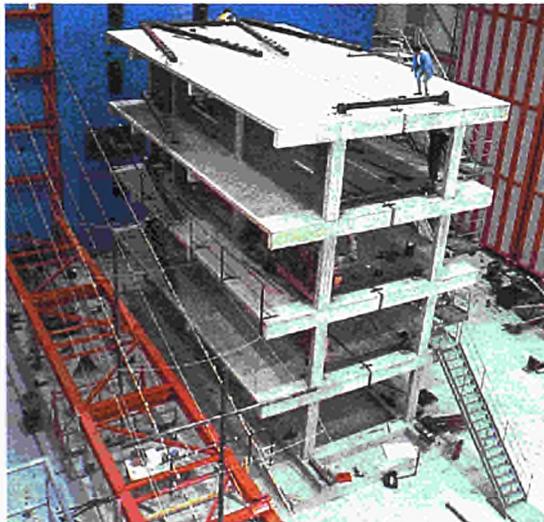
Strengthening of masonry infills

authors: A. Anthoine, P. Negro

Within the EUROQUAKE project ("Towards European Integration in Seismic Design and Upgrading of Building Structures" - Contract IC15-CT-97-0203), a particular strengthening technique for masonry infills (insertion of polymeric grids in the mortar bed joints and in the plaster of both external faces of the masonry infill) has been assessed experimentally. Two infill layouts, one without opening, the other with non-symmetrical openings (a door and a window) have been tested successively. For each configuration, two masonry panels, one plain and the other reinforced, have been contemporaneously submitted to cyclic horizontal displacements of increasing amplitude. The bene-fits brought by the use of polymeric geogrids are presented in Figure 2.5 for the infills with openings: the reinforced infill exhibits a higher strength and an enhanced ductility. Moreover, the reinforcement prevented the complete collapse observed for the plain infill.

Figure 2.5: Top: Increased strength and ductility of the reinforced infill with openings (red curve) when compared to the plain one (blue curve). Bottom: Final state of the reinforced infill (the complete collapse of the plain infill is visible in the background).

Figure 2.4: Assessment and retrofitting of reinforced concrete frame structures:
Top - Test model;
Bottom - Experimental vulnerability functions (maximum inter-storey drift) for the original and retrofitted frames.
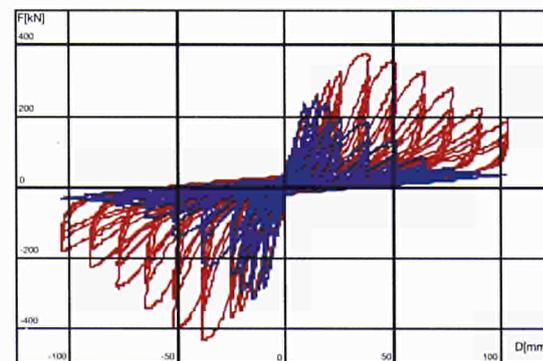
References

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Figure 2.6: Dynamic pull-out test at the LDTF of a 16mm-diameter undercut anchor; fast film photography (4000 frames/sec) is employed for monitoring the phenomenon.
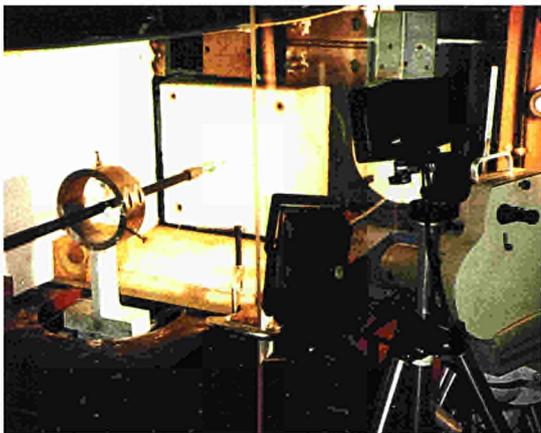
Anchorages in concrete under dynamic loading

author: G. Solomos

High strain rate pull-out tests of metallic anchorages in concrete were performed using the Hopkinson bar technique in the Large Dynamic Test Facility (LDTF). Samples included plain cubic specimens, 20 mm diameter rebars, anchorages (cast-in-place and post-installed), and anchors of up to 16 mm (Figure 2.6). Material modelling work is carried out for concrete along the lines of the lattice, microplane and strain gradient plasticity models.

Results lead to improve the base material mechanical characteristics and help understand the anchorage response to dynamic loads [2.11]. This should lead to new materials design of high performance concrete (with steel fibres), materials modelling (including the strain rate dependence of the stress-strain curve of concrete and its softening branch), and numerical simulation tools.

Anchorages consist of a metallic element, rebar or anchor, and the concrete base material, where the metallic element is embedded with or without a bonding agent. The special attention given to anchorage systems in the concrete construction industry is being driven in part by the following global trends: Increasing use of pre-fabricated structural elements; increased interest in earthquake retrofitting world-wide; increased interest in preservation of the historical built environment, and in the re-use and rehabilitation of existing structures, particularly in Europe; other special anchorage demands come from offshore construction, road safety barriers, nuclear power plants etc.

The activity is performed mostly within the framework of the EU Brite-EuRam project ANCHR (BRPR-CT97-0549) "Anchorages in normal and high performance concretes subjected to medium and high strain rates". Other partners include: DENSIT a/s (DK), HILTI (LI), ENEL-CRIS(IT), Politecnico di Milano (IT), University of Patras (GR), Bekaert (BE).

References

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Protection of Cultural Heritage

introduction: A. Pinto

Earthquakes can have devastating effects to both life and urban environments with important cultural value (e.g. the Italian Umbria/Marche earthquake crises, 1997). There is a need to increase the earthquake resistance of these structures, preserve cultural heritage, reduce rebuilding costs (which can significantly exceed upgrading cost), and minimise disruption to way of life and loss of business (such as tourism).

It is also urgent to implement an upgrading strategy since many historic structures in Europe are being redeveloped without strengthening that is compatible with the original structure. In fact, the current repair/strengthening technology is based mainly on very simple reinforcing systems, which are often intrusive. In the case of historic structures where the retention of the original façade without any modification is essential, most of the existing techniques are not suitable. Major rebuilding work is required as well as the development of non-invasive retrofitting techniques.

Seismic assessment of masonry structures

author: A. Anthoine

Redesign after earthquake damages and retrofitting against expected earthquakes are essential parts of the entire process for seismic protection. The seismic Eurocode (EC8) includes a section called "Repair and Strengthening" (Part 1.4). This section contains a general framework dealing with assessment, decision-making and redesign as well as concise descriptions of intervention techniques for different materials including masonry structures. Particular considerations for historical buildings and monuments are also given.

In load-bearing masonry constructions, masonry walls usually carry both gravity and lateral loads. Under seismic lateral loads, masonry buildings may collapse due to the in-plane and/or out-of-plane failure of these walls. The in-plane failure may occur according a flexural, sliding or shear mode. Failure due to the shear mode is by far the most likely and usually takes place in the form of one or two diagonal cracks. Many repair/strengthening techniques are presently available for masonry walls. Some of these have been applied for years on existing structures but have not always been tested in a systematic way, others have been proposed recently and have not been used in practice nor even tested yet. In particular, basic data about the respective performances of traditional/innovative techniques as well as advanced numerical tools able to reproduce the cyclic in-plane behaviour of plain/reinforced masonry are still lacking.

Our institutional project, launched this year, is intended to fill these lacks and thus to allow the development of precise design guidelines for the repair and strengthening of masonry buildings, monuments and other constructions typical of the European Cultural Heritage. To this end, an experimental campaign has been designed in order to assess the efficiency of traditional and innovative repair/strengthening techniques and also to allow the calibration/development of advanced numerical models for masonry with particular emphasis on the in-plane cyclic behaviour.

Two Solutions for the Retrofitting of Masonry Structures – A Comparison

authors: E. Gutiérrez, V. Renda

Two different techniques using novel materials have been applied to an identical masonry structure (see Figure 2.7a, Figure 2.7c): 1. *The application of Shape Memory Alloys* [2.12] and 2. *Preimpregnated composite jackets* [2.13]. Both investigations used specimens with identical geometry and construction details.

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[2.13] Triantafillou T. Strengthening of masonry structures using epoxy-bonded FRP laminates, *Journal of Composites for Construction, ASCE, Vol. 2, No2, pp 96-104*, 1998.

Shape Memory Alloys

Shape Memory Alloys (SMAs) allow the realisation of mechanical and seismic protection systems based on devices having intrinsic energy dissipation capabilities [2.14]. SMAs materials are characterised by super-elasticity allowing energy dissipation through a phase change from austenite to martensite and vice-versa. Stress-strain cycling does not produce material damage and is always performed in traction, allowing to use cables in the unprotected wall. Experiments were performed with increasing intensities of the assumed reference earthquake signal. The original (unprotected) model showed stability until 300% of the signal. The shearing forces caused big cracks in the wall. The protected wall with SMAs reached 500% of the signal with much greater energy dissipation. The crack pattern was similar. Figure 2.7a shows the wall incorporating the cross-bracing system including the SMA devices and Figure 2.7b shows the force-displacement loop for the protected wall for a seismic input equal to 500% of the nominal one. Shape memory alloy devices are indicated in appli-
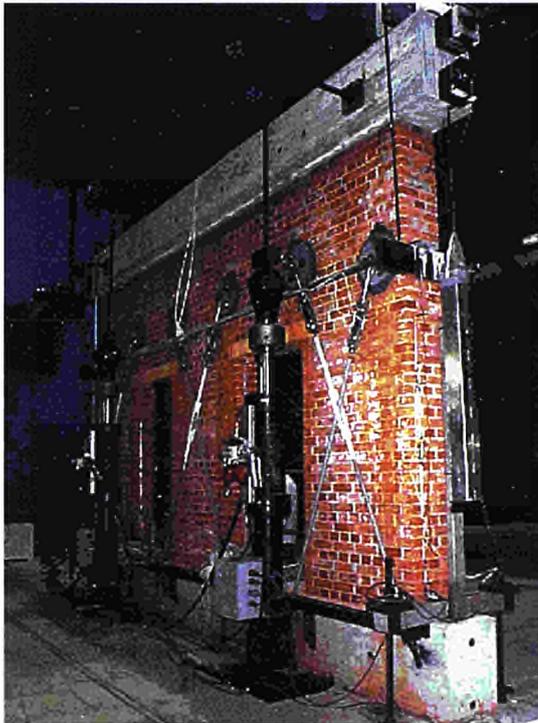
Figure 2.7a: Masonry wall protected with Shape Memory Alloy devices at the ELSA laboratory. In applications as in the bell tower of Trignano (RE, Italy) or the tympanum of St. Francis Basilica, Assisi, the Shape Memory Alloy devices are installed maintaining the architectural appearances of the buildings (V. Renda).
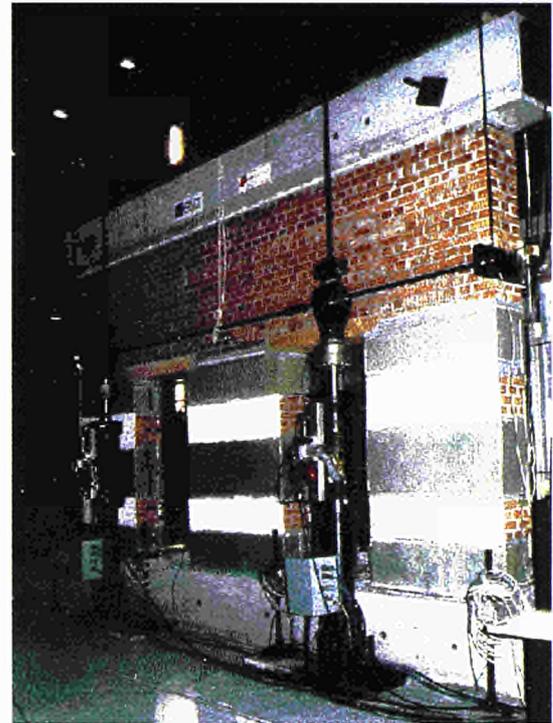
Figure 2.7c: Masonry wall reinforced with fibre composite material. The Fibres are shown in light green colour (E. Guitiérrez).
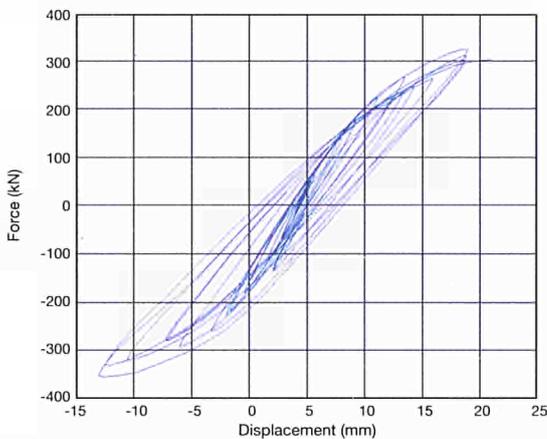
Figure 2.7b: Force-Displacement loops for cyclic test. Protection of the building is obtained through energy absorption in SMA device and structure. The hysteresis shows that the structure dissipates part of the energy.
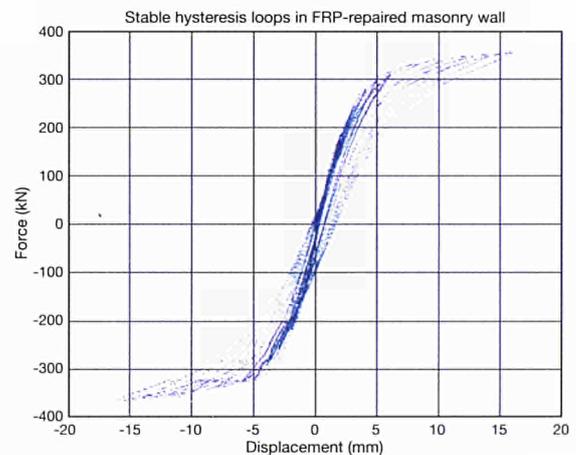
Figure 2.7d: Force-Displacement loops of the masonry wall protected with fibre composite material. The structure remains intact.

cations where large displacement occurs between architectural elements that need to be protected. SMAs can also be applied to rigid structures. In that case, the wall shows stable crack growth during the earthquake, and the protection system helps the structure to dissipate the energy.

Pre-impregnated composite jackets

Retrofitting of masonry walls using pre-impregnated composite jackets is another method for upgrading the seismic capacity of masonry walls that was examined in ELSA. The method consists in applying thin skins of *pre-preg* fibre reinforced composites, so-called because the reinforcing plies are made from fibres already impregnated with an epoxy matrix. The skins with fibres oriented at ±45°, allow the structure to escape the seismic action by a stable, recoverable, mechanism. The experiments showed that in the upgraded system the shear crack mechanism is inhibited. Instead, a stable rocking mechanism (see Figure 2.7d) is activated with generating peak-loads comparable to SMA devices.

Strengthening existing structures with the composite fibre skins is inexpensive and has the advantage that the vertical structures of buildings stay intact. Unfortunately this method is not reversible and hence cannot be applied to buildings of historical value whose façade cannot be altered.

Seismic behaviour of monumental structures (COSISMO project)
author: A. Pinto

In the framework of the COSISMO project (financed by the Portuguese General Directorate for Monuments and jointly developed by the LNEC, Lisbon, and the JRC) several tests have been carried out on a model of the cloisters of the Saõ Vicente Monastery in Lisbon. The tests on the retrofitted model have been carried out at ELSA during 1999. The test results and the subsequent

analytical studies have shown the good deformation capacity of the column-arch system commonly used in many monumental structures.

The tests on the original model have shown that satisfactory deformation and dissipation characteristics of this type of structures can be expected, provided that a rational distribution of ties exists at the floor levels. The practical design of these tie systems, using new construction techniques and advanced analysis tools, are under investigation.

The test campaign carried out on the retrofitted model showed that continuous-bond anchors are as efficient as pre-compression ties. Moreover, the cracking in the upper part of the model appeared better spread out. In fact, distributed cracks appeared in the stone-masonry wall and the cracks at the masonry-column interface were substantially reduced in comparison to the case without bonding of the ties. The tests have shown the applicability and effectiveness of such a kind of retrofitting in terms of deformation capacity and strength of the model. Another important issue was the performance of the system in the anchors overlapping zone (2 m overlapping). Neither damage nor debonding appeared in this zone. Therefore, such a system may be installed in holes of small diameters drilled from both sides of the construction. This is an important advantage. However, the irreversibility of this retrofitting solution remains a drawback. A schematic representation of the test set-up and of the applied continuous-bond retrofitting bars (anchors) is shown in Figure 2.8. Detailed analysis of the test results and related analytical/numerical developments were published [2.15,2.16].
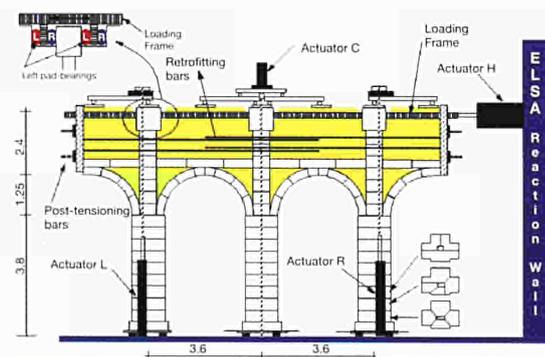
Figure 2.8: S. Vicente model - Test set-up and location of the continuous-bond retrofitting bars.

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Optical Diagnostics in Cultural Heritage Preservation

introduction: M. Zürn

Optical methods are inherently contact-less and non-destructive and as such they are pre-destined for Cultural Heritage applications, especially in the diagnostics and information collection phase. Several methods can be applied and they differ considerably in precision, resolution, measurement ranges, and cost. ISIS has developed both, full-field measurements of building complexes and detection of micro-cracks for raw approximations and sub-micron precision measurements. The experience in fibre optic sensing contributed to the use of smart materials (composites with embedded optical fibres). Work results are published under http://tintin.jrc.it.

Digital Photogrammetry
author: M. Zürn

Photogrammetry is a classical full-field measurement tool, usually applied for semi-manual retrieval of 3D CAD information from buildings. Combining high-resolution photography and top-end digitizers with modern information technology extends this traditional tool to the automatic retrieval of 3D models. Furthermore, this model retrieval can detect changes. This is useful for the documentation of degradation. In our laboratory it has found applications in the monitoring of seismic (PSD) testing as shown in Figure 9.

Full field optical metrology
authors: M. Whelan, C. Forno

Moiré interferometric techniques have been successfully introduced to monitor the deformation of cultural heritage structures. Their value has been proven in measurements on three large-scale structures. An innovation was introduced with the patented Digital Moiré Subtraction technique. The institute is proud that Prof. Colin Forno (City University, currently visiting Scientist at JRC) and Dr. Maurice Whelan (JRC) were awarded the "Metrology for World Class Manufacturing Award" (1999), sponsored by the UK Department of Trade and Industry, for the introduction of this new technique.

Structural and material behaviour measurement of a hybrid beam
Results from the application of Moiré photography to the deformation of a concrete/glass fibre/carbon fibre beam indicated that the anticipated position of the neutral axis was consistent with its measured position using surface mounted resistance gauges. However, an unexpected feature was detected and measured relating to a buckling mechanism to the side walls. This behaviour was not monitored by other methods, for example, strain gauges or LVDTs.

Figure 2.9: Photogrammetry used to monitor a model of the Portuguese Monastery São Vicente de Fora during PSD testing: During the seismic experiment the actuator connected to the upper right part of the building pushes and pulls the building until structural damage occurs.
The graphs show the trajectory of these four points marked by arrows during the experiments [2.17]. Photographs were made at the following actuator positions: 0 (actuator in neutral position), actuator pushing 20 mm to the right hand side, 40 mm to the left, 0, 60 right, 60 left, 0, 100 right. The photogrammetric (single camera) processing revealed the positions of the points at the above mentioned actuator states. As all the information is stored on photographs any other point can be chosen a posteriori to create such a trajectory graph.

Shear Measurement in a Glass Fibre Reinforced Wall

Moiré photography showed that during in-plane loading of the wall, pure body rotation was supplemented by the presence of uniform shear strain in the glass fibre wrapped region. Outside this area massive failure at the mortar joints was revealed. The effectiveness of the reinforcement was demonstrated and a mechanism for the shear was examined.

Measurement of tilting in a column of the St. Vicente de Fora monastery

Monitoring the rotation of the central column under in-plane loading was carried out by Moiré photography together with a newly developed real-time Moiré process [2.18]. This first application of the patented method, Digital Moiré Subtraction (DMS) [2.19] provided on-line results of the rotational behaviour of the separate column (Figure 2.10). This approach has potential applications in other associated disciplines and in techniques involving optical and material studies.

Grating Interferometry for specimen building material studies

The laser-based technique of grating interferometry has been applied to study cracking mechanisms in different quasi-brittle materials. Its ability to resolve sub-micron scale displacements on small components, combined with real-time measurement is an advancement on existing coherent light methods. It has provided confirmation of material behaviour modelling.

Smart materials
authors: R. Kenny, M. Whelan, E. Gutiérrez

An Exploratory Research Project in 1996-1998 initiated the development of smart materials (i.e. materials with self-monitoring capabilities) for structural applications. ISIS followed two lines of development: (A) pultruded composite beams with embedded optical sensors and (B) *tomographic* analysis of composite panels through networks of embedded fibre optic sensors. The research greatly benefited from the collaboration of the ELSA structural mechanics laboratory and the Photonics Technologies Laboratory. The activ-
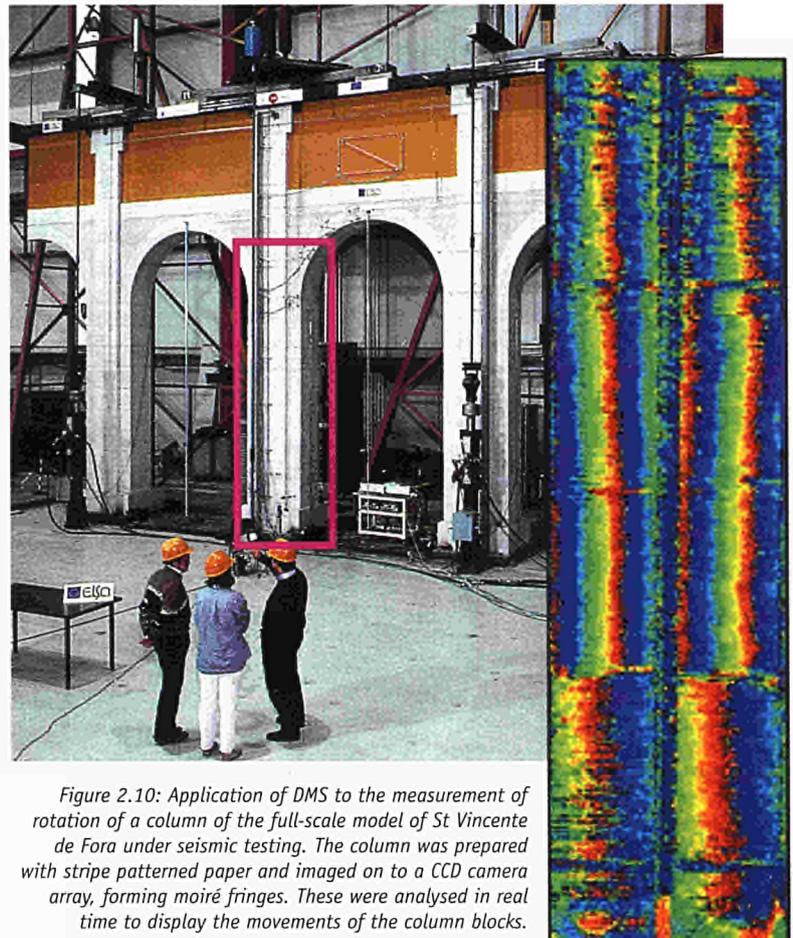
Figure 2.10: Application of DMS to the measurement of rotation of a column of the full-scale model of St Vincente de Fora under seismic testing. The column was prepared with stripe patterned paper and imaged on to a CCD camera array, forming moiré fringes. These were analysed in real time to display the movements of the column blocks.

ity generated several projects within the ISIS structural engineering research and also in support of industrial applications. These include:

- Participation in the EUREKA project "COMREHAB" on strengthening of heritage structures using composite materials.
- A technology transfer project on "Shape and Condition Monitoring of Composite Materials for Civil and Aeronautical Engineering".
- Contract research for a major European Aerospace manufacturer (Agusta) on the performance of embedded fibre optic sensors in helicopter blades.
- Founder member of the "FOS-EN" SMT Thematic Network involving over 70 European research groups, manufacturers and end-users of fibre optic sensors.

The main result is the successful demonstration of optical sensors for monitoring composite materials in civil engineering and in aerospace ap-

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Figure 2.11: Reinforced composite poltruded beam under 3-point bending alongside fibre optic test equipment. The experiment demonstrated that the imbedded fibre optic sensors characterised the mechanical performance of the beam.

Figure 2.12: Determination of vibrational shapes in flat composite plates using embedded optical sensor networks. Peaks in the frequency spectra of embedded sensors, as shown for one such sensor in the data curve, allow interpretation of how the plates vibrate under given loads. The data can be verified by measurements of Pulsed Electronic Speckle Pattern Interferometry.

Multimedia archive for sustainable tourism

author: W. Post

The JRC is presently engaged in a multimedia archiving project with the objective to provide tools for the usage, evaluation and recovery of cultural heritage. The project is performed together with the University of Basilicata and is part of an effort to develop sustainable tourism in the Basilicata region.

The AMB (Archivio Multimediale della Basilicata) is an information system using a conventional relational database, based on a knowledge model that represents the cultural heritage of the region as a multidimensional network of subjectively interconnected (and thus integrated) tourist resources. Authors of the archive can be tourist offices, communities, the region, research entities and others. Integration of the information is done over the Internet, which allows for cheap and highly available communication channels. The provided dynamic web page generator visualises the archive on the Internet following the knowledge model on which it is based. It will also serve as a template for even more advanced interrogation tools to be developed by future users of the system (Figure 2.13).

plications [2.20]. The sensors are extremely sensitive, robust against disturbances, and completely embedded within the components. Methods were developed for manufacturing and calibrating optical sensor systems at low cost, through a significant adaptation of standard telecom components. Another key result is the successful mathematical modelling of sensor networks, permitting optimised sensor placement and analysis of data to obtain deformation information in-service [2.21,2.22]. In Figure 2.11 is shown a structural test of a pultruded composite beam in progress, while in Figure 2.12 is shown results of vibrational analysis of a composite panel; in both cases fibre optic sensors were employed to obtain strain and deformation information.

Figure 2.13: HTML page for a combined search in the multimedia archive for information on cultural heritage in the region of Basilicata.

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Safety of Means of Transport

introduction: C. Albertini

The increased severity of European standards for transport safety (Frontal and side impact standards 96/27 and 96/79) and for environmental protection obliges the vehicle industry to optimise crash safety design with a simultaneous vehicle body weight reduction. New standards for injury reduction of passengers (U.S. standard No 201) drive vehicle industry to new design of vehicle interiors, while pedestrian safety requires less aggressive frontal parts of vehicle. European standard 1317-1-2 requires well-designed and tested road safety barriers assuring higher containment and redirection of uncontrolled vehicles.

New high strength and low weight materials, and optimised passive safety structures designed with the use of reliable advanced crash computer codes, is the response of industry to the requirements of safety standards. Safety authorities and industry need the support of advanced research in the field of precision measurements of energy absorption capability under impact loading of new materials and passive safety structures. The final aim is the improvement of the material and structural models under impact loading, in the crash computer codes. ISIS provides the capacity to carry out this type of research by means of its unique Large Dynamic Test Facility and its Dynamic Material Testing Laboratory, up-dated by a considerable body of original patents and supported by advanced numerical simulation.

Advances for dynamic testing

author: C. Albertini

The characterisation of new materials at high strain rate, like high strength sheet steel, was continued during 1999. Tension, compression and shear testing was performed in order to complete the data bank for the calibration of constitutive models used in the computer codes.

Important changes of the mechanical properties and energy absorption capability at the high strain rates of impact loading have been noticed; an example is shown in Figure 2.15 regarding high strength steel that the steel industry is developing and the vehicle industry attempts to implement in the vehicle body construction for increasing energy absorption by weight (thickness) reduction.

The curves of Figure 2.15 show that the strength of the steel increases under impact loading with con-

Figure 2.14: The Large Dynamic Test Facility (LDTF) at ISIS. This is the only method available for measuring the complete deformation/energy absorption history during a fast, dynamic event.

servation of the same ductility; therefore it absorbs more energy: Nevertheless the material shows a pronounced yield strength peak in the first part of the curve with the consequence of possible peak load response of the passive safety structures of vehicles like longitudinal side members.

The steel experimental data bank has been used for the calibration of material models like those of Johnson-Cook, Zerilli–Armstrong, Ludwik–Prandtl. The first two models have been implemented in the in-house developed FE code Plexis–3C; present material models are not able to handle material yield strength peaks.

Measuring the response peaks of passive safety structures is difficult. It has been tackled with success at JRC by extending for the first time the use of Hopkinson bar methodologies from material testing to structures testing. High load peaks of passive safety structures must be avoided as a possible source of injuries for passengers because of consequent deceleration peaks acting on the passenger compartment.

The Hopkinson bar structural tests are supported by the numerical simulation of the code Plexis–3C; however structure load peaks cannot presently be reliably predicted by FE codes.

Figure 2.15: True
Stress/Strain curves of
high strength steel in
tension (0.7 mm plate
thickness) show that
crash energy
absorption increases
under impact loading.
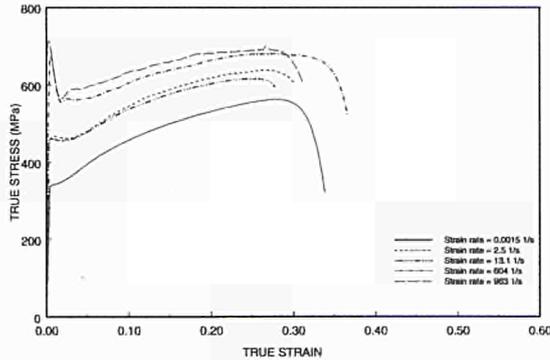
The deformation of materials of passive safety structures in real crash conditions is least biaxial. Therefore a biaxial testing apparatus based on the Hopkinson bar technique has been developed and successfully used in 1999; a special cruciform specimen for the sheet material and for composite materials testing has been also developed.

The design of safer vehicle interiors further requires the characterisation of low density energy absorbing materials under impact load, like polymeric foams. Special Hopkinson bar equipment has been conceived, designed and it is now under construction. The new apparatus will also measure the interaction between human head and limbs with vehicle interiors in simulators, where all materials involved are of low density.

Road barrier deformation tests
author: G. Solomos

Safety barriers are road vehicle restraint systems, which are installed alongside or on the central reserve of a road. They are designed to restrain and redirect errant vehicles, according to specified performance levels of containment, for the benefit of both the occupants and of other road users. The requirements that these road barriers have to meet for certification are set in the relevant standards, e.g. EN 1371-1-2, prepared recently by the Technical Committee CEN/TC226. Full-scale tests involving barriers as well as vehicles are prescribed in them.

A significant impediment to developing new road barrier systems is the high cost of performing these full-scale tests. While some full-scale crash tests will always be needed to demonstrate that the devices work correctly, it is highly desirable that numerical computer simulations enable engineers to reliably evaluate alternative designs more quickly and at less cost. This can help to drastically reduce the number of crash tests and enhance designers' understanding of the performance of the barrier.

Our research aims to tackle exactly this aspect of road barrier design by validating numerical approaches and codes with precision testing at the Large Dynamic Test Facility (LDTF). A physical model of the barrier will be established by means of precision impact tests physically equivalent to those prescribed by European Standard tests, and further allowing accurate measurements on a real size safety barrier of the parameters of resistance, deformability and absorbed energy. The physical model of the barrier will then be numerically implemented in computer codes, whose predictions of the road safety barrier behaviour will be compared with the precision impact test results.

Experiments are in preparation at the LDTF, which will reliably represent the main parameters of full-scale tests. These are: total mass of the vehicle (0.9 ton - 38 tons), impact angle (8°-20°), and impact speed (65 km/h - 110 km/h). Contacts with the experts in the field have been made (CEN/TC226, Prof. V. Giavotto, designers) and the necessary modifications of the testing apparatus have been conceptually designed. DG Enterprise finances part of the project. Within this framework, a contract has been established with the Spanish Technological Centre LABEIN for collaboration in the area of modelling and numerical simulations with Finite Element techniques. In addition, the French L.I.E.R. (Laboratoire d'essais Inrets Equipments de la Route) will conduct a small number of standard full-scale tests. Producers of deformable road barriers have finally been contacted for the procurement of the specimens, and the actual tests are planned for the first semester of 2000.

Crash worthiness
author: C. Albertini

As discussed in the introduction, the measurement of load peaks of passive safety structure response is a critical check of the structure efficiency. An example of the importance of the load peak is shown in Figure 2.16 reporting the load–displacement response of a longitudinal side member, made of the same high strength steel whose stress-strain curve is shown in Figure 15. These load peaks of safety structures response must be measured in order to take measures for their suppression or mitigation before they arrive to load the passenger compartment. (Length 500 mm, rectangular section 80x90 mm, thickness 0.7 mm) showing an excessively strong initial load peak that would cause dangerous deceleration on the passengers.

A study has been assigned by DG Enterprise to the JRC aimed to perform precision testing with

Hopkinson bar methodology on the frontal part of a car in testing conditions equivalent to those of European standards 96/27 and 96/79, and to compare the experimental results with the prediction of leading numerical crash codes. The comparison will also assess the present accuracy of code prediction of the complete crash structural response investigating the potential of code predictions as alternative/complementary and less expensive standard test.

The study has been initiated through a contract with Renault, which will deliver frontal parts of the CLIO car as well as the reference code computational predictions. These will be compared with the precision impact experiments. Furthermore, it will be possible to measure the occurrence of load peaks. Numerical modelling of load peaks of materials and structures will be attempted in order to have a refined evaluation of the accuracy of numerical code predictions. Modifications of LDTF needed for performing the experiments on the frontal part are described in [2.23].

A second project assigned to JRC in the field of crashworthiness is the development of a "Liquid Jet Crash Energy Absorber" (LJCEA), subject to a JRC patent. The project has been performed in collaboration with the Spanish laboratory LABEIN, which has provided the calculation and the construction of the first prototypes of LJCEA, successively subjected to crash tests using the large Hopkinson bar of JRC. From these precision crash tests the LJCEA performances in crash energy absorption were measured, resulting in:

- A nearly constant load versus displacement curve, which assures efficient energy absorption without peaks (Figure 2.17).
- An automatic adaptation of the energy to the severity of crash. Energy absorption increases with increasing collision speed.
- Good energy absorption also in the case of oblique impact.

On the basis of these results LABEIN has optimised the LJCEA design and new prototypes have been installed in a CLIO car. Goal is to check the implementation possibilities of LJCEA in a real vehicle structure, and the resulting safety improvements during a crash under standard conditions. Some preliminary basic research results of LJCEA have been published in [2.24].
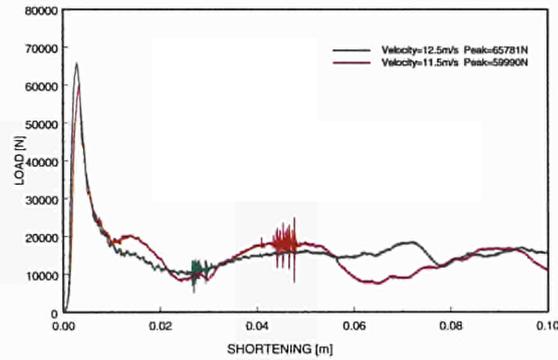
Figure 2.16: Load/Shortening curves of high strength steel longitudinal beams
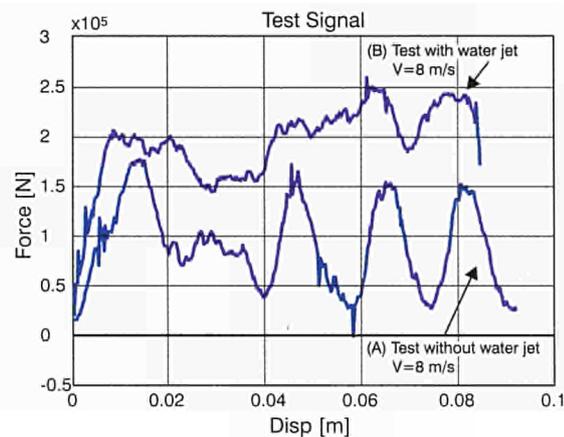
Figure 2.17: (A) Conventional crash energy absorbers exhibit deceleration peaks in regular intervals which would endanger the passengers' safety; (B) The test with the liquid water jet energy absorber shows a progressive crash energy absorption without harmful deceleration peaks.

Validation of laser welding technology

author: E. Ruiz-Morales

The LASEROBOT project supported by the Innovation Programme, aims at validating laser-welding technology on large, heavy and thick components that are commonly used in the transport sector. ISIS is in charge of integrating the heavy robotics CO_2 laser welding cell at the RIALTO facility (Figure 2.18) and of demonstrating the results to industrial partners from the transport sector. The most innovative aspects of this project are the required welding accuracy (0.3 mm), the thickness (over 12 mm) and dimensions of the work-pieces (provided and de-

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Figure 2.18: Two computer simulation views of a large pipe welding with the LASERBOT manipulator representing an example of a typical three-dimensional welding test case.
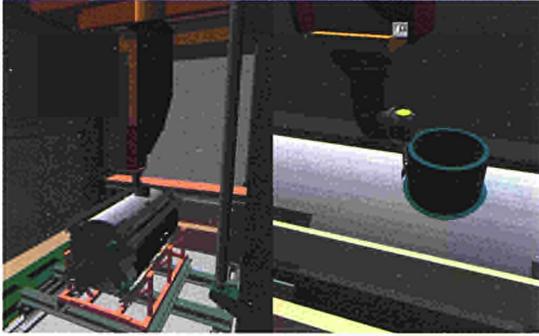
Figure 2.19: Ballasts from the new-built tanker "Theodoros", representing a typical environment in which the ROTIS ROV (see figure Figure 21) is supposed to navigate.
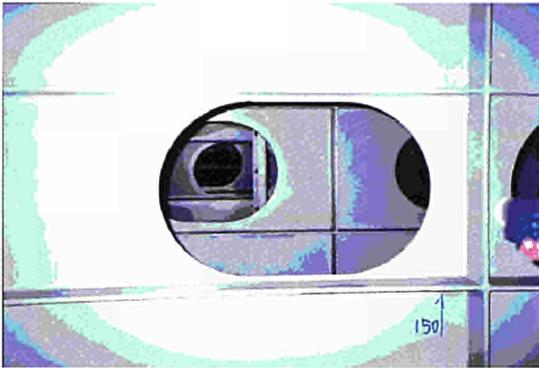
Figure 2.20: Section of the new-built tanker "Theodoros". Ballast tanks are shown in light blue colour. They give access to virtually all the plates, which have to be inspected periodically according to the International rules and regulations.
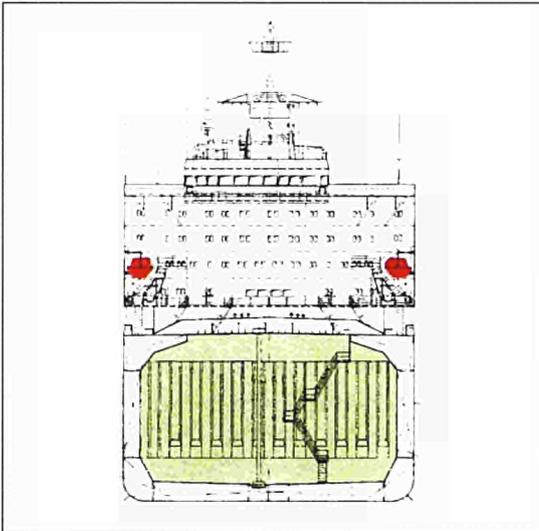
Figure 2.21: 3D model of the ROTIS ROV for remotely operated tanker inspections.

signed by FRAMATOME), and the integration of this complex laser-welding cell through GENERIS, the ISIS software control platform.

The laser-welding cell equipment consists of two robotics manipulators (RIALTO and GAER), a laser transmission system by air (from RTM), a seam tracking system (from GAER), a work-piece conveyor a 12 kW laser source power control. Several advanced tools for calibrating, simulating, programming and monitoring have also been developed and used. The year 1999 has been devoted to the RIALTO facility preparation and testing for the final integration and testing of partner's equipment scheduled for early 2000.

Remotely operated tanker inspection system
authors: F. Andritsos, M. Fenici

The ROTIS (Remotely Operated Tanker Inspection System) project deals with the design, development and testing of a novel remote inspection system for tankers. This system is based on a small ROV (Remotely Operated Vehicle) capable of navigating inside the ballast tanks of tankers and other cargo vessels, through the standard man-holes and openings and perform the close visual inspection and thickness gauging required by the classification societies during the periodic vessel inspections (Figure 2.19, 2.20, 2.21). Successful implementation of ROTIS is expected to lead to enhanced, safer and cleaner inspections, contributing to a safer and environmentally benign navigation. The JRC had initiated the project. Within the consortium, it is responsible for the requirements, the system specifications as well as for the preliminary tests and system calibration, which are due to take place in a specifically designed mock-up inside a test-pool, constructed in the RIALTO heavy robotics facility.

Automation and Integration of Processes in Shipbuilding (AIPS study)
authors: F. Andritsos, J. Perez Prat

On behalf of DG Enterprise, ISIS performs a study on *"the Automation and Integration of Processes in Shipbuilding; State-of-the-art Report"*. The purpose of this EU wide state-of-the-art study is to obtain an overview of the technology of the production processes in view of a competitive and sustainable European shipbuilding industry. The key objectives are:

- To identify the technologies in which investments are likely to be more productive in increasing the competitiveness of the European shipyards.
- To identify the actions and measures that are more appropriate in order to enhance the necessary R&D efforts.
- To identify sectors from which shipbuilding can profit in terms of Technology Transfer and the actions that would help developing the necessary synergies.

The study covers the shipbuilding technology and the related R&D, encompassing all the EU countries plus the new member states and, wherever possible, providing information on US, Japan, Korea and China. It is combined with the activities of the ROBMAR thematic network (ROBotics for the MARitime Industries – BRITE TN type 2) for which JRC-ISIS (F. Andritsos) is the scientific coordinator.

Figure 2.22: From the visit of the CESA working group on co-operation at the "Chantiers de l'Atlantique" at St Nazaire (F); the JRC was given the opportunity to participate in the activities of the above group in the frame of the AIPS study.

Computational Mechanics for Structural Safety

introduction: M. Géradin

Numerical modelling is today indispensable in any context dealing with structural safety assessment. To this end ISIS uses and develops two large computer code systems: CASTEM 2000 and PLEXIS-3C. The major part of the research carried out in Computational Mechanics is conducted as direct support to ISIS's experimental activities in structural dynamics. This includes test design, pre-calculations, monitoring aid, analysis of results and validation and calibration of structural/material models. Specific know-how is further exploited in various activities, some of which being reported hereafter and serves also as an excellent basis for independent expertise.

Fluid-structure interaction

author: F. Casadei

The activity on FSI has consisted in further refinement and generalisation of the numerical models, especially in conjunction with large in-

dustrial applications that have been solved by our industrial partners, mainly ENEL-PIS. A simulation of an electric arc in a current transformer has been performed at ENEL-PIS using PLEXIS-3C (Figure 2.23). The internal arc produces pressure waves that hit the magnetic core. When the overpressure reaches the rupture disk, this fails and the excess gas is discharged. The iron tube which supports the magnetic core is deformed plastically, and the core moves towards the metallic cap. Results have been published [2.25-2.27].

Continuous pseudo-dynamic testing with non-linear substructuring

author: P. Pegon

The European Laboratory for Structural Assessment (ELSA) has developed the new continuous PseudoDynamic (PsD) technique and has realised a
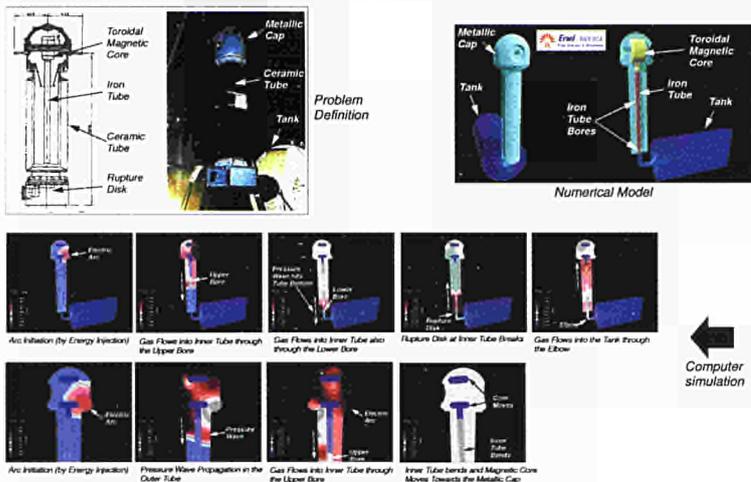
Figure 2.23: "PLEXIS-3C numerical simulation of the mechanical effects of an electric arc in a current transformer. (Courtesy of ENEL-PIS)".

system designed to perform fast non-linear substructuring pseudodynamic tests. This will open the way for accurate testing of the earthquake response of structures outfitted with various components having velocity-dependant restoring forces. The objective is to create a dynamic testing system in which only the critical components of a structure, at full or large scale, are mounted in the laboratory and loaded at high rate by the forces and displacements produced by the surrounding structure, which is modelled numerically.

Significant improvements in the PsD integration scheme, in the hardware architecture and in the control algorithm of the servo-hydraulic system are proposed to fulfil this objective.

The continuous PsD testing is implemented by means of a *synchronous* process with *short* control period (1 ms) and small time step. Some intrinsic and challenging difficulties related to the implementation of substructuring have been solved and experimental results obtained at ELSA showed the effectiveness of the new technique [2.28].

This study is realised under the execution of an EU Research Project focused on "Further Developments in Dynamic Control of Earthquake

Engineering Facilities" and involving the collaboration of the JRC , the University of Bristol (UK) and the Laboratório Nacional de Engenharia Civil (LNEC-Lisbon).

Development of numerical models for structural acoustics
author: P. Capéran

Structural acoustics is a multi-physical discipline of growing importance in engineering, with many implications in the society of today. In particular, noise reduction is a very challenging problem for which developing very accurate models, including active vibration control, is mandatory. The same, generic modelling tools can be applied successfully to a large class of environmental an/or engineering problems. Their development at ISIS is currently tested on the very specific application of particle coating.

When submitted to a sonic field, aerosol particles tend to agglomerate into bigger ones. This phenomenon can be used in various industrial processes (e.g. air filtration, particle engineering). An extensive experimental database quantitatively documenting this phenomenon (in the ultrasonic frequency range) was already available. To perform an advanced interpretation of these data, new methods and tools have been developed:
• A suitable identification technique (developed under Maple) to quantify the agglomeration coefficients between particles of different size.
• A numerical model, based on finite element discretisation, describing properly the coupling between the acoustic source (of complex geometry) and the agglomeration chamber.

For the present application, the combined use of these tools will bring a thorough understanding of acoustic coating, permitting the design of optimised acoustic processing devices.

At longer term, disposing of these tools will give to ISIS the capability to treat a relatively large class of acoustic problems.

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Safeguarding against the Proliferation of Nuclear Weapons

editor: A. Poucet

I rrespective of reduction or growth of nuclear energy, the European citizen is worried about the potential threat to public safety from the accumulated nuclear materials from nuclear weapons proliferation, and from illicit trafficking of nuclear materials and other radioactive materials. Verification and control related to non proliferation of nuclear materials is performed by the Euratom Safeguards Office (ESO) of the European Commission within the context of the Euratom treaty, and by the International Atomic Energy Agency (IAEA) within the context of the Non-Proliferation treaty.

ISIS gives scientific, technical and training support to ESO and IAEA, and supports the Russian Federation and other CIS countries in establishing a system of nuclear materials accountancy and control which is comparable with the Western standards in terms of efficiency and effectiveness. ISIS also carries out underpinning research and development in a number of areas that are relevant to nuclear materials accountancy and control, and to other verification activities in the framework of non-proliferation of weapons of mass destruction (WMD).

Mass/Volume Measurement Techniques (TAME Laboratory)

author: B. Hunt

The Mass and Volume Measurement Techniques Support Program to IAEA concerns a safeguards system for the Rokkasho Reprocessing Plant in Japan. This is a joint task carried out with the JRC, IAEA, US DOE Brookhaven National Laboratory and NMCC (Nuclear Materials Control Centre Japan). A two-week predefined experimental campaign was carried out jointly in June in Japan at the LASTAC facility, which simulates a large reprocessing input vessel. A vast amount of data relating to tank calibration, recalibration, verification and influencing plant operational parameters were collected for detailed independent analyses. A preliminary meeting to discuss the results is scheduled for January 2000. Figure 3.1 shows the JRC developed instrumentation utilised in the exercise. IAEA personnel were also trained on their recently acquired JRC portable pressure measurement instrument in May.

A support program task with ESO has been elaborated after a consultative visit to La Hague in which all the parameters have been defined to provide technical know-how and measurement equipment for the verification of 10 large tanks currently being installed in La Hague. A plan has been drawn up taking into account the operator's planning for tank availability for inspector's usage. Equipment will be prepared by the JRC ready for April 2000 with supplementary training given to ESO inspectors, scheduled for both March and May 2000. In addition, long term monitoring equipment was provided for ESO in La Hague on a temporary basis in order for their staff to acquaint themselves with installation, data gathering and eventual analysis as well as the overall performance of the equipment compared to their presently utilised system. The demonstration and setup of the equipment was carried out in November with on the spot training.

Support has continued to TACIS via a training course for Russian personnel at Ispra on mass/volume methodology in bulk handling facilities for calibrations/verifications and tank monitoring. Emphasis was also placed on support activities to the Ulba conversion and fabrication facility in Kazakstan. On the basis of an analysis made on the situation in the ULBA conversion and fabrication lines, a project plan was established to improve on:

- Mass/Volume determination of liquids in a large number of tanks
- Procedures for calibration and data evaluation for weighing scales
- Sealing and identification techniques
- Surveillance techniques

In the field of R&D a prototype instrument PIMM (Pressure Instrument Measurement Module) [3.1] has been produced at the JRC, see Figure 3.2. PIMM has been designed particularly to meet the objective of minimising interference to the plant operator whilst maintaining the requirements of an inspector. PIMM is a compact and lightweight pressure measurement acquisition device designed to perform unattended monitoring of

Figure 3.1: JRC developed instrumentation for measuring tank filling in the NMCC Japan facility.

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tanks in reprocessing and/or fabrication facilities. An EPROM and battery supply allow the system to be installed in a facility without cable connections. The only connections needed are those made in routine operations by connecting in parallel to the operator's air-flow lines, in order to measure the pressure in the level, density and reference probes of the tank. Cable connections can be made via a portable computer to start the software acquisition parameters and subsequently to download the data for analysis.

Figure 3.2: A prototype pressure instrument module was designed for accurate in-field measurement of liquid mass and volume in tanks (PIMM).

Non-Destructive Assay in the PERLA laboratory

authors: R. Berndt, B. Pedersen, M. Thornton, P. Schillebeeckx

The Non-Destructive Assay (NDA) related Safeguards activities are executed in the PERLA (PERformance LAboratory). PERLA is a unique internationally recognised facility in the European Union, housing an extensive collection of well-characterised nuclear reference materials and instrumentation. In PERLA NDA systems, methods and techniques are characterised, validated, calibrated and used for training. To achieve this aim, PERLA instrumentation and infrastructure is continually updated and improved. During 1999, new reference material was procured and the laboratory is undergoing a transition, which will more clearly define its role in nuclear measurement techniques.

Calorimetry
author: M. Thornton

In the field of calorimetry, PERLA has strengthened its instrumental base by upgrading its 150 mm-diameter plutonium calorimeter. This has resulted in a significantly improved base power stability, due to improved thermal insulation of the measuring chamber and incorporation of new low noise electronics. A new small sample calorimeter (SSCAL, see Figure 3.3) specified by ISIS in 1998 has been delivered and is undergoing extensive testing and "fine tuning", which will continue into the next year. This brings the number of calorimeters in PERLA to three, and allows samples from less than one gram to several kilograms to be measured by this technique [3.3]. The SSCAL

compliments the other two by allowing samples of less than 1 gram, with heat outputs of only a few mW, to be measured with an expected precision of less than 0.2%. This level approaches that of plutonium assay by destructive analysis. The calorimeter relies on thermopile technology for temperature measurement and control, and is a radical change from the traditional nickel sense windings, which have been used for many years.

Figure 3.3: The new Small Sample Calorimeter (SSCAL) allows the characterisation of samples as small as 1g of plutonium at 0.2% precision.

Passive neutron assay

authors: B. Pedersen, P. Schillebeeckx

Concerning the passive neutron correlation technique, data analysis for measurement campaigns in installations were improved. Results indicate the possibility to improve existing detector design. A design analysis of a new high efficiency detector was initiated using Monte Carlo simulation. The code used includes a complete pulse train analysis. The simulations of fission neutron multiplicity distributions is significantly improved [3.4]. This work is expected to result in a new prototype high efficiency counter during next year.

To improve the performance of such neutron devices, a new amplifier-discriminator circuit has been developed in collaboration with the Politecnico di Milano. The circuit has been especially designed for a better determination of the system dead-time of passive neutron counters, used for the absolute determination of the Pu mass based on the analysis of neutron signal multiplets [3.5]. In Figure 3.4 the performance of the amplifier-discriminator circuit, for three different shaping times, is compared with the performance of the Amptek board mostly used by Safeguards instrumentation manufacturers. Figure 3.4 represents the Rossi alpha distribution for a ^{241}AmLi(α,n) random neutron source. The measurement data show that, compared to the Amptek board, the time resolution is improved by a factor 2 and the new circuit is less sensitive to the loss of neutron events from double-pulsing signals. The implementation of the electronics in a passive neutron counter is foreseen in 2000.

As part of its support to the Euratom Safeguards Office, new commercial multiplicity counters underwent performance evaluation testing in PERLA before their installation in-field. Also a service is provided in which ISIS specialists accompany nuclear inspectors to deal with measurement problems during auditing. This has included physical inventory verification (PIV) measuring campaigns at one MOX and two low enriched uranium (LEU) fuel assembly fabrication plants in Europe.
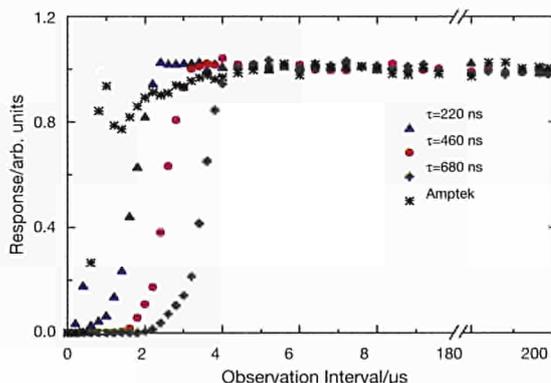
Gamma spectroscopy

author: R. Berndt

In the framework of spent fuel characterisation, efforts were made with the development of a Spent Fuel Attribute Tester.

This under water measurement system is equipped with a room temperature Cadmium Zinc Telluride detector (CZT). Compared to classic gamma radiation detectors, these detectors are still under development. New detector types appear frequently, and the users are always confronted with different properties. As a consequence, up to now there are no adequate highly developed spectrum unfolding codes available to deliver a quantitative analysis of the spectra.

The spectra obtained with the CZT detectors are complicated and their features depend strongly on the considered detector specimen. The peak shapes are not simple Gaussian due to the physics of electron and hole transport properties. They are asymmetric with a long low energy tail.

In this context, a spectrum evaluation algorithm was developed for a special large volume CZT detector type to allow characterisation of spent fuel in safeguards inspections. Its application makes possible the determination of parameters such as cooling time and burn-up of the fuel by applying a non-linear least-squares fitting procedure to the 550 - 850 keV region of the spectra (Figure 3.5). It makes implicitly use of a set of fitting parameters calibrated as a function of energy with points sources and takes into account scattered radiation from the shielding material between the fuel rod and the detector or the background radiation due to surrounding elements [3.6].

In support to the IAEA a gamma ray spectrum library was determined in PERLA using items with a wide range of isotopic composition, chemical form and total plutonium or uranium mass. This library allows the comparison of different gamma analysis codes [3.7].

Figure 3.4: The Rossi-alpha distribution for a random ^{241}AmLi(α,n) neutron source. The results of the data obtained with the new amplifier-discriminator circuit, plotted here for three different shaping times τ and compared with the Amptek board, shows that the new circuit approaches better the rectangular form of the ideal distribution for random neutron sources.
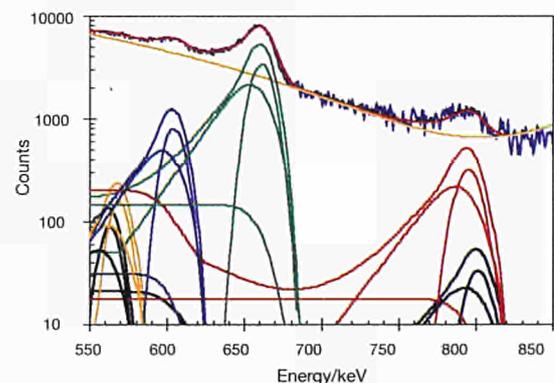

Figure 3.5: Gamma radiation spectrum measured with a CdZnTe detector and functions used for the fit.

SILab: Sealing and Identification techniques Laboratory

author: B.C. d'Agraives

SILab specialises in developing ultrasonic seals (for instance: sealing-bolts) for safeguards application which have unique marks for identification and for detecting unauthorised manipulations. Characteristic for metal seals is their raggedness against environmental influences, even in fuel ponds, and their high stability over many years.

ESO and IAEA both use sealing devices on storage containers in La Hague and Sellafield. Assistance was provided during the Physical Inventory Verification (PIV) in THORP (Sellafield) involving support to inspectors and some tests on site as well as preparing special measuring tools. Ad hoc dedicated software for both La Hague and Sellafield sites was delivered. Delivery of 40 special MK-6 seals for ESO to be applied in la Hague was prepared.

Based on requests/needs from potential customers intended at exploring the suitability of such technologies to specific applications, R&D was performed in the fields of ultrasonic and optical techniques:

- A new mechanical concept for "Sealing-Bolts" or "Sealing-Nuts", incorporating an improved mechanism for the "breakage" of the seal when it is removed (or attempted to remove); to be used, for instance, at Sellafield BNFL (UK) or La Hague COGEMA (F) storage ponds, or on dry storage containers.
- A new optical equipment was specified to build dedicated prototypes based on the SPECKLE effect of surface textures and using HeNe Lasers or Laser Diodes, in view of the Identification of valuable/sensitive items in air or underwater. Tests were very successful with high repeatability with either system, the latter being more compact and precise. A patent is pending.
- Based on promising results obtained in 1998, prototypes were built and then patented for a completely new system allowing the direct

identification of a structure, such as a container or a fuel assembly, by means of a small metallic insert (token) which embodies an ultrasonically readable "code". Such system could allow the suppression of the conventional numbers "engraved" or "painted" on the structures. Patent granted.

- As an extension of the previous, a prototype for a new Sealing-Bolt concept was built which would embody in its head two features: an analogous "fingerprint" and a digital "code", both readable with a special "double ultrasonic Reading Head". This technique would allow an inspector to directly know which seal he is verifying and avoid errors such as misreading the conventional inscriptions/numbers on containers. Patent pending.

A 230,000 Euros long term third party work contract has been negotiated and eventually signed with two Japanese companies (Hitachi and Toshiba) in which *SILab* is due to study a special FAUST (Fuel Assembly Ultrasonic Sealing Technique) suitable for the Japanese BWR MOX Fuel design. The work will start in February 2000 when the necessary mock-up will be provided to Ispra (see Figure 3.6).

A Sealing System for the UF6 drums in use by the Brazilian Navy was studied and proposed to ABACC (the Brazil Argentina Agency for Control and Accountancy).

In the framework of TACIS (Technical Assistance to Community of Independent States) a Demonstration Set was developed, destined to the IPPE (Institute of Physics and Power Engineering) Obninsk Training Centre in Russia. The delivery is planned for early 2000 and will include two reading units associated to two portable computers, specially equipped with ad-hoc ultrasonic/electronic cards, as well as a series of dummy Sealing-Bolts for training.

Figure 3.6: Left: Meeting in Tokyo with Hitachi and Toshiba Colleagues while negotiating the Contract on MOX Fuel Sealing Systems. Middle: Laboratory test mounting for the Identification of Surface Textures by "Speckle" Effect, using a Laser Diode. Right: Two "measures" of the same area are shown.

Transponder based identification

author: C. Korn
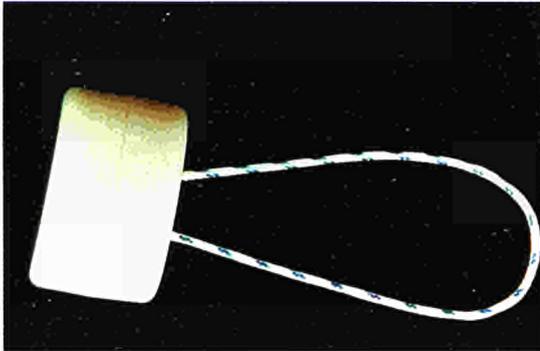
A new multipurpose passive radio-frequency transponder [3.8,3.9] seal (Figure 3.7) was developed and patented (International Patent no. 99402256.4). This new passive seal uses the same installation principle as the well-known Copper Brass (i.e. wire needed). Using a portable radio-frequency reader, it is now possible to read the two identification numbers inside the seal without detaching it and bringing it back to the headquarter. This new seal technology presents a simplification and gain of time of the inspector and headquarter jobs. 200 seals were delivered and tested by the Euratom Safeguards Office at the end of 1998 and 50 other samples were tested by the IAEA (Vienna) during 1999. Following the overall satisfaction of the end users, 4000 pieces were ordered for real field application, together with a specifically designed software for the portable reader which can be directly linked with the Headquarters' Central Data Base.

Another application of the transponder technology for Safeguards is the use of tags. In order to trace samples from the sampling plant to the analysis laboratory in reprocessing plants, 30 samples bottles were equipped with FDX passive transponders and are actually under evaluation by Euratom Safeguards Office. The identity of a bottle transported inside a pneumatic transport system is for the moment read at the entrance of the pneumatic tube and when it arrives at the glove box. The next step will be to trace the sample bottle continuously all along its trip.

The second application of passive radio-frequency transponder tags is the identification of metallic drums such as U containers. Transponders are stuck directly to the drum and read automatically with portable and/or stationary readers, specially designed (in terms of radio frequency tuning) to operate with metallic surfaces (Figure 3.8). This technology allows a quick and reliable inventory of storage rooms as well as control for the input and output of containers inside nuclear storage rooms.

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Surveillance and Monitoring

Augmented reality in surveillance

authors: V. Sequeira, J. Gonçalves

Augmented Reality techniques have been applied in Safeguards to improve the presentation of surveillance images and to ease the location and the configuration setting of surveillance cameras [3.10]. The problem in multi-camera systems arises from the difficulty for a Safeguards inspector in providing spatial context to the images from different cameras. This requires good spatial knowledge of the premises being surveyed, as well as the detailed knowledge of the location of each camera. Spatial Context can be achieved by combining live images from the environment with an "*a priori*" 3D model of the environment. Photo-realistic 3D representation of the remote environment combined with the real-time video surveillance streams provide a good spatial context for the observation of the images. The end-user can thus perceive the environment from any viewpoint. The capability of observing the environment from any position enhances the perception of the remote site, eases the interpretation of events and is considered of great importance in applications of training and/or remote surveillance.
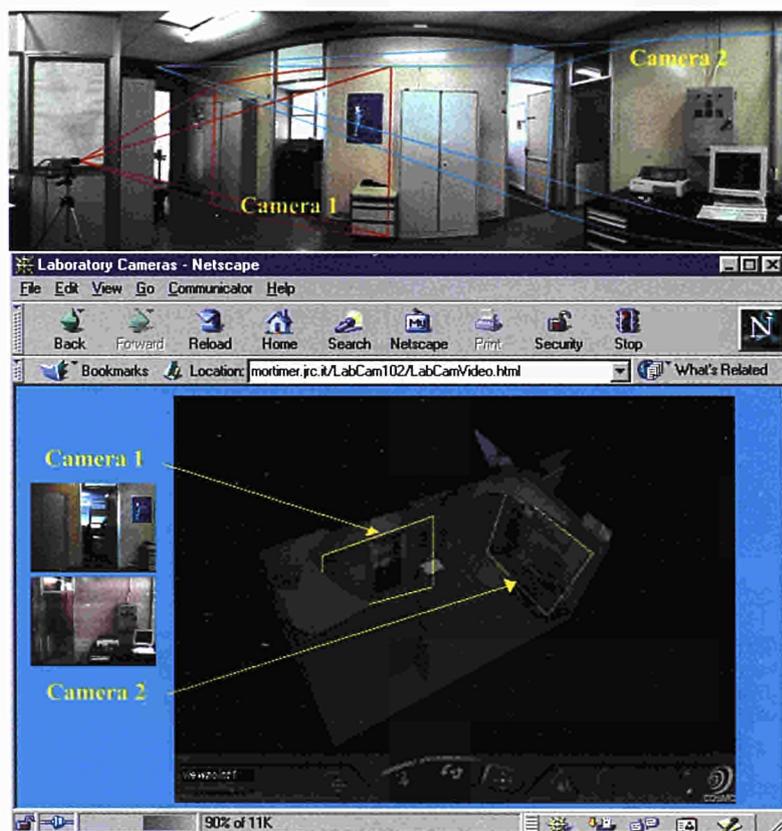
Figure 3.9: Multi-Camera Surveillance – Pilot implementation using two cameras. The 3D model of the surveyed environment is overlaid with the real-time video surveillance images. This provides spatial context for an easier interpretation.

Authentication in surveillance

author: J. Gonçalves

Safeguards applications require the authentication of scenes under video surveillance. To prevent possible scene tampering, a laser device associated to the conventional video surveillance adds the verification of the third dimension (depth). The authentication of surveyed scenes is based on the real-time analysis of distance profiles originated from a self-illuminating laser scanner [3.11]. Whenever profile discrepancies are detected, the surveillance camera is triggered. An optional infrared illuminator can be also coupled to the system to compensate for illumination blackouts. The extended level of security provided by the *Laser Surveillance System* increases the confidence in a surveillance installation (see Figure 3.10).

Figure 3.10: Laser Surveillance System constituted by a camera (1), an Infrared illuminator (2) and a laser range scanner (3).

Portable digital surveillance system (CODIS)

author: F. Sorel

CODIS is a compact digital surveillance video system built of commercially available of-the-shelf components. ISIS integrated the system and developed the application software to meet the specific safeguards requirements, in particular the security aspect of image authentication as well as the unattended recording over long periods. The system comprises mainly a standard color camera and a very compact PC based on the industry standard PC104+. It supports the connection of several acquisition stations and a review station over Ethernet. The software allows the remote configuration of the acquisition station from the review station through an easy graphical interface for the safeguards inspector. The configuration settings include the recording mode and the compression rate of the digital video images. A prototype system was tested with success by ESO staff and the test results are used to complete the software development.

Figure 3.11: The portable digital surveillance system CODIS with the very compact PC based on the industry standard PC104+.

Figure 3.12: The verification station CIVES for metal cap seals comprising the image acquisition part with the special seal illuminator and the image archive unit.

Verifier of metal cap seal images (CIVES)

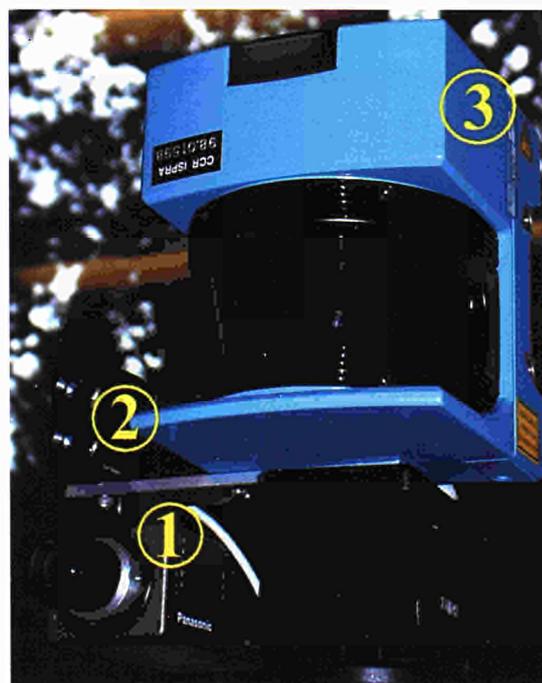*author: F. Sorel*

The last generation of the ESO verification station for metal cap seals has been completed. The major improvements are the new storage medium on high capacity DVD disks and the possibility to compare the reference and live seal images either by software or by a video mixer. The application software includes the conversion modules for copying the images recorded in the previous years on optical disks to the new storage medium. The new station can process either colour or black-and-white images recorded by the older verification stations.

Syclop Detector activities

authors: P. Guilmain, C. Korn, G. Azzalin

New developments were conducted on the Syclop detector (heat flux sensor based detector) in order to trigger a digital camera when an intrusion is monitored. The first prototypes gave very good results.

Satellite monitoring

author: A. Poucet

The recent availability of commercial high-resolution satellite images (with Ground Sampling Distance – GSD of 1-2 meter) opens new perspectives on the use of such images for safeguards purposes. A first study [3.12] was launched on the potential use to support verification of site declarations made in the context of the strengthened safeguards regime (INFCIRC/540). A prototype application was developed that allows to integrate satellite images with other geo-referenced information (road infrastructure, buildings, site maps), to represent and explore nuclear site data in a geographically oriented data base, and to verify the consistency with declared data.

In this prototype application, satellite images from 2 sources were used:

- The Indian IRS-1C satellite, PAN sensor (panchromatic single band, 6 bits radiometric
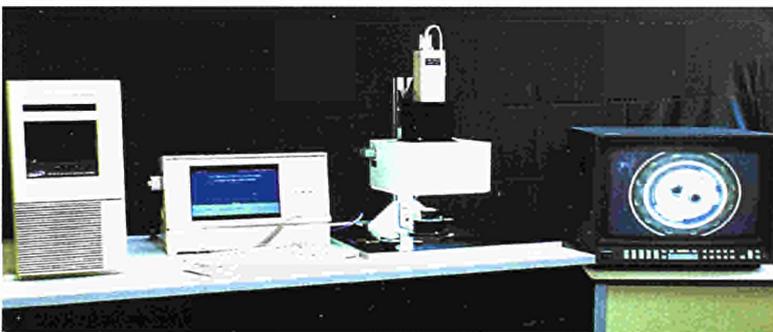
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resolution, spatial resolution 5.8 m per pixel) and the LISS sensor (multispectral).

- The Russian SPIN-2 missions using the KVR-1000 instrument (panchromatic on photographic film, spectral range of 510-760 nm, spatial resolution around 2 m per pixel).

Further work will involve the use of high-resolution images (1 m spatial resolution) from the IKONOS-2 satellite.

Secure Data Transmission

author: J. Gonçalves

A data encryption architecture was studied to allow transmission of Safeguards relevant data using public communications networks [3.13]. This architecture is based on the clear separation of encryption at all levels in the system, i.e., sensor data, data transmission and data archival. A prototype system using this encryption architecture was implemented and thoroughly tested between Ispra (Italy) and Luxembourg (see Figure 3.14).

A second activity concerned the design and development of a software package for monitoring the performance of the encrypted data transmission over ISDN network. Several statistical parameters are considered, such as: availability, time to dial, delay and throughput. Before setting up a specific Safeguards data link, it becomes thus possible to evaluate the data communication characteristics of the point-to-point connection according to different architectural aspects, including the presence of encryption devices, time-of-the-call. Figure 3.15 shows the delay and the transmission throughput of an ISDN connection depending on the presence of a hardwired encryption device.
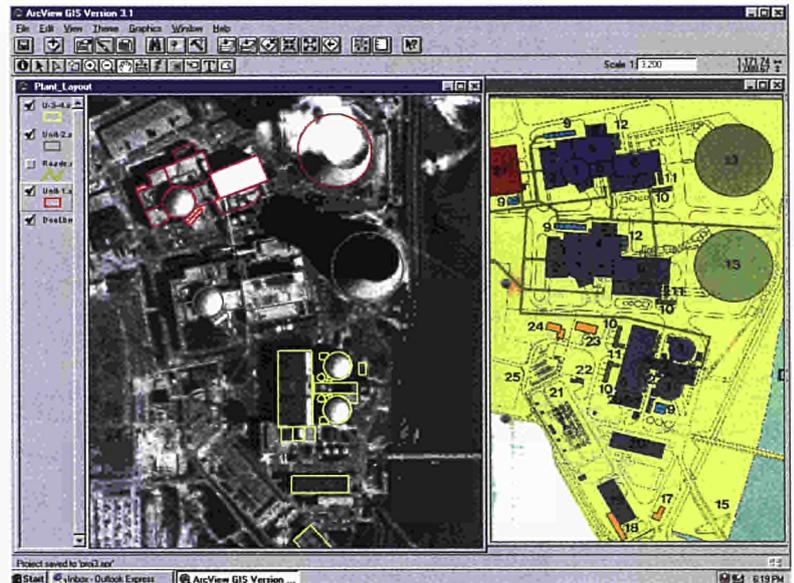
Figure 3.13: On the left side (view 1) the satellite image of a nuclear power station is shown. On the right side (view 2) the site map as given in the site description is shown. The information in the site map is vectorised to create graphical objects that represent the buildings and main infrastructure and that can easily be overlaid on the satellite image. Even minor features can be easily recognised.
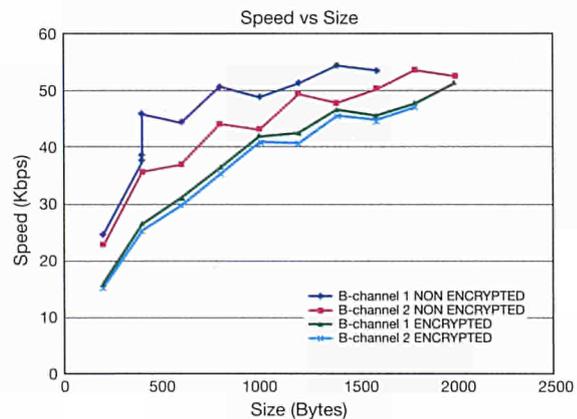
Figure 3.15: ISDN Monitoring –Measured data throughput and speed as a function of packet data size, and presence of encrypting devices.
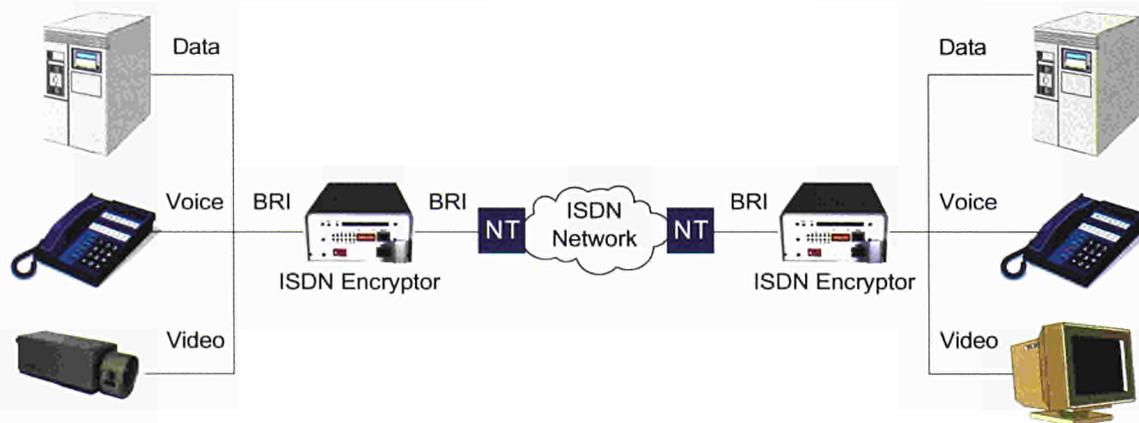
Figure 3.14: Description of the pilot secure communications system implemented between Ispra and the ESO headquarters at Luxembourg.

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Remote Inspection and Teleoperation for Advanced Storage Areas

author: E. Ruiz-Morales

Figure 3.16: 3D simulation of a robotics inspection operation.
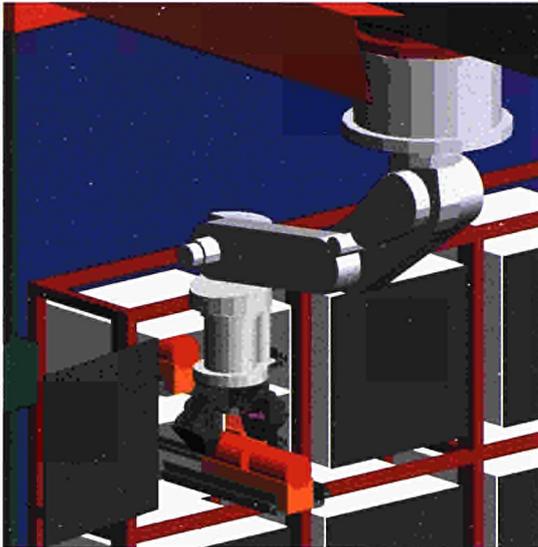
Figure 3.17: Real view of robotics handling operation.

The control of large size storage areas with very high strategic material will become an important issue after the dismantling of nuclear weapons and their probable release to the international verification regime. ISIS has undertaken a preparatory research activity dealing with the automation of these advanced storage areas that are hazardous for human inspection.

A prototype robotics system in a simulated environment is under development at the RIALTO laboratory (Figures 3.16, 3.17). The aim of the prototype system is to study and assess advanced teleoperation techniques and tools that would facilitate remote inspection and remote handling operations. For instance, the studies cover the development and use of remote real-time monitoring through computer simulation tools (as Virtual Robot), the development of safety-critical supervisory and control system architectures for robotics and automated systems, and the study of human-computer interfaces for remote inspection. The developed robotics prototype is also aimed as a training and demonstration platform for inspectors and TACIS projects in nuclear safeguards.

One important tool in this project is the software GENERIS developed for the supervision and control of robotics and automated equipment. It is an innovative real-time software package with a modular and opened architecture to control virtually any type of robotics cell. New computer simulation and programming tools are under development for complementing GENERIS to the described application in advanced storage areas.

The next step will deal with application using a reference structure of a plant. This reference structure will include vertical storage cells with (simulated) nuclear material containers of different sizes. The tests on the reference structure will allow to refine the simulation tools and prepare the future in-field tests.

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Environmental testing (TEMPEST laboratory)

author: C. Korn

The TEMPEST (Thermal, ElectroMagnetic and Physical Equipment Stress Testing) extended its activities in terms of Electromagnetic Compatibility immunity and measurement testing as well as in the field of mechanical shocks and vibrations, installing new generators and measurement instruments to be able to perform tests based on new international standards.

The accreditation process of the TEMPEST laboratory according to quality standard EN 45001 was concluded in October 1999 with an external COFRAC (COmité FRancais d'ACcréditation) audit and with its official accreditation in December 1999. TEMPEST laboratory is now the first thermal and electromagnetic test laboratory of the ISIS worldwide recognised under EN 45001 quality standard. The accreditation number is n° 1-1037. During 1999, the activity of the TEMPEST laboratory increased in terms of number of Safeguards equipment and devices tested, mainly in support to IAEA. As examples, one can speak about the electromagnetic (radiated and conducted immunity and emission) tests conducted on IAEA's DSOS [3.14], ALIS and DCM-M3 [3.15] surveillance systems, thermal, humdity and mechanical tests conducted on the JRC passive transponder seal [3.16] as well as on its reader and on the IAEA's DCM-M3 surveillance system.

The TEMPEST laboratory also set up in 1999 a new qualification test procedure [3.17] for Safeguards equipment in collaboration with the Euratom General Directorate and the IAEA (Vienna). This new Euratom/IAEA common test procedure based on various electromagntic, thermal and mechanical test standards is now the basic acceptance reference document for new developed Safeguards equipment and systems.

International Cooperation

author: C. Foggi

The European Safeguards Research and Development Association (ESARDA) is the cornerstone of the Safeguards cooperation with other organisations in Europe. In 1999, ESARDA organised its 21st Annual Meeting [3.18] in Sevilla. It was its largest symposium ever with 230 participants and 142 presentations. This is a tangible sign that the safeguards community needs, more than ever, a forum for exchanging experience and information.

The support program to the IAEA remains the principle mechanism for cooperation outside Europe. Specific coordination and information exchange meetings were held also with the US Department of Energy (DoE) and with the Brazil-Argentinean Safeguards organisation (ABACC). Through JAERI, exchange of information with Japan is maintained.

Cooperation with Russia and Kazakstan is performed in the framework of the various TACIS safeguards projects that are coordinated by ISIS. Besides the two training centers mentioned before, ISIS coordinates the projects on the implementation of nuclear material accountancy and control equipment at the Ulba fuel fabrication facility in Kazakstan, and on safeguards instrument devleopment in Russia. ISIS has started to prepare a project for enhancing safeguard systems on pilot plants in Kursk (RBMK) and Kalinin (VVER).

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Training

author: S. Guardini

Inspector training

The ISIS safeguards activities are a strong basis for providing training in the techniques of verification of accountancy for plutonium and uranium in nuclear facilities. ESO makes extensive use of the training capabilities. The ISIS training course menu includes about 15 courses covering for example, passive and active neutron measurement methods, gamma spectrometry techniques for isotopic composition, calorimetry, mass and volume measurements for liquids in accountancy tanks as well as courses dealing with the practical procedures of verifying an inventory and subsequent data processing. These courses rely heavily on ISIS specialists in nuclear instrumentation as well as of the availability of a wide range of nuclear samples in the PERLA laboratory. In most courses for ESO, the instruction is a combined effort from ISIS specialists and experienced staff from ESO itself. The Euratom Safeguards Office is not however the only client of these training courses as some of the ISIS courses for ESO are also attended by IAEA inspectors. During 1999, ISIS gave a total of eight courses of different types for ESO and IAEA participants. In the framework of ISIS support to the develop-

ment of similar training in Russia (see below), courses are also organised for Russian scientists who will be instructors in the Russian training centre. During 1999, ISIS provided four courses for Russian participants. These covered neutron collar measurements and calorimetry in the PERLA laboratory (Figure 3.18), and tank mass/volume measurements at the TAME laboratory (Figure 3.19).

Multimedia

Throughout their career, ESO inspectors need a wide range of training courses as well as the possibility of updating and refreshing what they have learned earlier. The emerging technologies of computer based learning can meet some of these needs in an appropriate way. For this reason ISIS has an on-going project of development of multimedia modules for ESO inspectors. This development is an active collaboration between ISIS and the training personnel in ESO and uses external software companies as much as possible. Most of the content is concerned with the practical use of instruments and their associated soft-

Figure 3.18: View of the PERLA Safeguards training laboratory. Inspectors have the opportunity for hands-on experience with different kinds of non-destructive instruments.
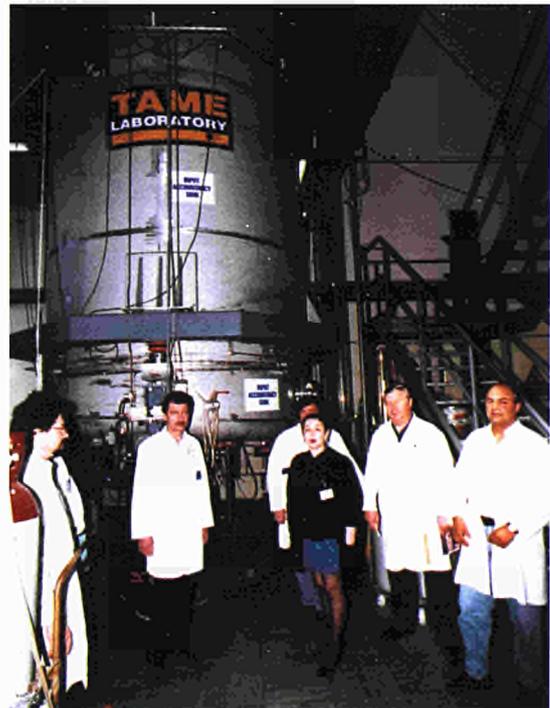
Figure 3.19: Mass and Volume measurement training session in the TAME laboratory.

ware. It is considered that these will provide an easily accessible and fairly digestible refreshment of knowledge previously acquired in training courses. These multimedia modules will be made available via network. The available modules cover active and passive neutron measurements, gamma spectrometry, as well as concepts of measurement uncertainty and measurement quality control. The content covers practical setting up of the instrumentation, use of software, theory of the measurement methods, problem solving, etc.

The Russian Methodology and Training Center (RMTC - Obinsk) and URSIMTC (Snezhinsk)

The Russian Methodology and Training Center (RMTC) is now operative and has been giving training to MINATOM and GAN officers for two years: at the end of 1999 it had organised about 100 training courses encompassing all facets of Nuclear Materials Accountancy and Controls (NMA&C), for a total of about 2000 trainees. The number of foreign and Russian specialists that have been involved in the RMTC training activities totals 113 individuals, 55 of them being Russian citizens and 58 from the USA and EU.

One quarter of Russian instructors have a doctoral degree; over 50% of them have been through special training courses offered by ISIS and the US National Labs.

Training was conducted in 25 different courses attended by over 100 Russian GAN inspectors, over 400 various specialists from Minatom and other agencies of the Russian Federation, at least 15 specialists from Newly Independent States (Kazakstan, Ukraine, Lithuania). The majority of the students have been through at least two courses.

ISIS support in setting up the RMTC has included:

- provision and calibration [3.18] of instrumentation
- provision of nuclear material standards
- modification of laboratories
- training of Russian trainers
- participation in training courses and workshops at Obninsk
- making available ISIS training documentation

The ISIS assistance to the Russian Federation in setting up the RMTC was supported by the TACIS program. In a second project, work has begun in identifying the detailed needs for a second training centre in Snezhinks in the Ural region of Russia (URSIMTC). A feasibility study on the requirements of a first laboratory dealing with the nuclear material protection, control and accountancy aspects of large plutonium storages has been performed.

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Safety Aspects of Nuclear Energy

editor: B. Worth
author: H. Weisshäupl

Nuclear safety remains a political issue of great concern within Europe, particularly in view of the impending enlargement of the European Union with the accession of new Member States from the East. The JRC, with its long-standing involvement in a wide variety of safety-related activities, provides direct and impartial support to the DG Environment, in particular to the Directorate C which is responsible for nuclear safety and civil protection. Major accidents such as Three Mile Island, Chernobyl and more recently at the Tokai Mura reprocessing plant in Japan serve as reminders of the need for scientific vigilance in all aspects of nuclear reactor technology. Also of concern is the licensing of advanced and innovative reactor systems, radioactive waste disposal and the assurance of adequate safety levels in 'ageing' nuclear installations. One fundamental approach to nuclear safety is the so-called "defense in depth" concept. This provides for a set of multiple levels of protection, aiming at progressive provisions for the prevention of incidents and accidents and, if prevention fails, a means to limit their potential consequences and prevent the possible evolution to more serious conditions. The JRC is involved in many key aspects of this concept, which is essential when addressing the assessment of the safety of nuclear power plants, ranging from materials research, in-service inspection and maintenance, to the assessment of the consequences of a severe accident with core melt down.

Research at the JRC over recent years has concentrated on the harmonisation of critical safety issues, both within the EU and in the Pre-Accession States of Eastern Europe where safety standards are under continuous review. Harmonisation requires the assessment of all potentially unsafe processes and activities relating to risk assessment, thermal-hydraulics and severe accidents. Widely used analytical techniques involving the use of probability risk assessment, fault tree analysis and reliability studies, including human factors, are being continuously improved.

Safety can be greatly enhanced when a good understanding of the basic physicochemical processes involved is available. Significant effort into model development at ISIS in the areas of fluid dynamics and thermal-hydraulic processes of severe accidents aims at addressing many fundamental problems impacting on nuclear safety. The FARO project has conducted extensive experimental and analytical studies of simulated core melt accidents using representatively scaled reactor geometries and materials. The Phebus FP experimental program provides unique data on fission product release from a reactor circuit under postulated severe accident conditions. ISIS is actively promoting the interpretation of this test data; both, 'in-house' and through international collaboration in order to improve the validation of severe accident computer codes, and with it the general safety culture within the extended EU nuclear industry.

Harmonisation on critical safety issues

Support to Commission Service
author: G. Cojazzi

ISIS promotes harmonisation on safety aspects by providing technical support to DG Environment and DG External Relations by participating in international activities, by networking laboratories, by organising benchmark exercises, and by performing research activity on safety critical issues. Specific research activity is carried out in the areas of Probabilistic Safety Assessment (PSA), Human Reliability, and Model Developments in Fluid Dynamics. Reports and publications are extensively distributed to DG Environment, DG Research and DG Information Society.

ISIS supports the Nuclear Safety and Civil Protection Directorate of the DG Environment in the implementation of the two Council Resolutions (C128-75, C172/2-92) dealing with Reactor Safety. Day-to-day contacts with the Directorate ensure close collaboration on all safety-critical issues. This includes attending the meetings of the Commission's Nuclear Regulator Working Group (NRWG), which is the permanent advisory group on reactor safety, and networking Nuclear Regulatory bodies of EU Member States. ISIS also participates actively in various NRWG taskforces. A project on safety-critical software in nuclear power plants has been monitored. Advice was provided regarding actions on 'European Safety Practices During Planned Outages at Nuclear Power Plants' and 'Developing Guidelines for Periodic Safety Review' of Russian built VVER Nuclear Power Plants (NPP). The support will be extended in the future to provide technical assistance on issues related to the enlargement process.

Participation in various international bodies, committees and associations is very important in a transnational field such as nuclear reactor safety. This concerns the OECD Nuclear Energy Agency, in particular the Committee for the Safety of Nuclear Installations (CSNI), and related working groups dealing with risk assessment, thermal-hydraulics and severe accidents. It also concerns the International Atomic Energy Agency (IAEA) and European Safety, Reliability and Data Association (ESReDA) [4.1].

One of the main concerns among EU citizens is the safety of nuclear power plants of East European design. To improve the safety of these installations, the European Commission has over recent years devoted considerable resources to technical assistance programmes. The JRC continued in 1999 to technically support the implementation of the Commission's TACIS and PHARE Assistance/Co-operation programmes with CIS and CEEC. The contribution from ISIS focused on its own areas of competence, such as thermal-hydraulics, design basis accidents, severe accidents, risk assessment and management, and structural dynamics. The support covers the design safety of industrial projects, drafting of contract Terms Of Reference, selection and evaluation of project offers, and follow-up and review of intermediate and final project reports. ISIS has given technical assistance, to the DG Environment, in the review and evaluation of PHARE and TACIS project reports related to Technical Support Organisations (TSO) regulatory assistance projects. ISIS reviewed intermediate and final TSO reports in confidence on a regular basis and grouped them periodically in synthesis reports [4.2].

Probabilistic Safety Assessment
author: G. Cojazzi

The emphasis of the Probabilistic Safety Assessment (PSA) activity has shifted to developing and using risk informed methods in support of decision making. ISIS concentrates on Expert Judgement methods, information storage for PSA studies and, more recently, on safety critical information systems in nuclear plants.

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Expert Judgement involves how judgements derived from experts on safety relevant issues, together with their relative uncertainties, can be collected from experts in a disciplined way, properly documented and, if necessary, suitably aggregated in order to provide an uncertainty quantification of the relevant issues in a PSA study. For the quantification of severe accident phenomena, ISIS designed and coordinated an international benchmark exercise, collecting information about the use of structured Expert Judgement techniques among Level 2 PSA researchers and practitioners and to compare methods. PSAs of Level 2 aim at the quantification of accident progression sequences, which start from a damaged reactor core and progress up to the release of radionuclides to the environment. The problems considered in the exercise were fuel coolant interaction and the transient event of hydrogen deflagration/detonation in a pressurised water reactor of evolutionary design [4.3,4.4]. Figure 4.1 shows the event tree that has been constructed from the knowledge elicited from two domain experts. The analysis and valorisation of the results of the overall benchmark project have also been performed.

The development of the ISIS code ASTRA for fault tree analysis has been continued in synergy with other research lines of the Institute. A basic feature of ASTRA is to employ the powerful Binary Decision Diagram Technique. Extensive documentation about the ASTRA tool for fault tree analysis has been issued in 1999 with reference to the logic analysis algorithms, sensitivity and time dependent analysis modules (see also the section on tools for Reliability and Safety Analysis in the chapter Risk Management and Decision Support).

The storage of large amount of technical information and subsequent intelligent retrieval for Level 2 PSA studies was carried within a Shared-Cost Action project (FI4S-CT96-0034). The prototype database has been completed with reference to the hydrogen problem. About 300 references are contained, dealing with topics related to hydrogen generation, distribution and mitigation measures in NPPs [4.5,4.6].

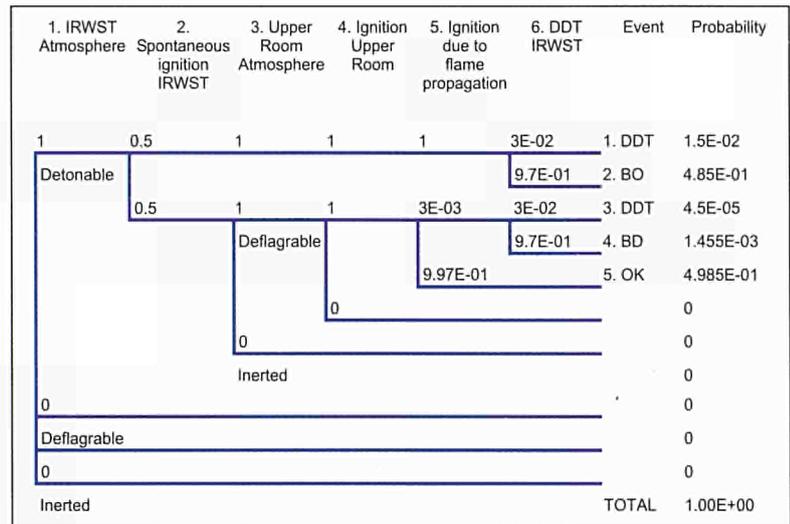| 1. IRWST Atmosphere	2. Spontaneous ignition IRWST	3. Upper Room Atmosphere	4. Ignition Upper Room	5. Ignition due to flame propagation	6. DDT IRWST	Event	Probability
1	0.5	1	1	1	3E-02	1. DDT	1.5E-02
Detonable					9.7E-01	2. BO	4.85E-01
	0.5	1	1	3E-03	3E-02	3. DDT	4.5E-05
	Deflagrable				9.7E-01	4. BD	1.455E-03
				9.97E-01		5. OK	4.985E-01
			0				0
		0					0
	Inerted						0
0							0
Deflagrable							0
0							0
Inerted						TOTAL	1.00E+00

Figure 4.1: Accident progression event tree for the evaluation of the hydrogen deflagration-detonation issue in the Incontainment Refuelling Water Storage Tank (IRWST) in an evolutionary pressurised water reactor as a follow-up to a hypothetical loss-of-external-power accident. Consequences for each branch are indicated together with estimated probabilities. The event tree is conditioned to the occurrence of the initiating event (loss of off-site power) whose frequency (yr^{-1}) was not quantified. Key: BD=Burn Downward, BO=Burn Other, DDT=Deflagration-to-Detonation Transition, OK=No ignition event.

An emerging topic in the safety of NPPs is related to the development and spreading of digital technologies, and to their use in safety-critical and safety-related systems, leading to the so-called 'safety critical software' issue. The subject is of relevance to both existing installations, due to the changeover from analogue to digital control systems, and for new installations, which will make full use of digital technologies. A survey study was conducted summarising the main international ongoing activities in the field of the assessment of Safety-Critical Software in Nuclear Power Plants [4.7]. The study shows that assessment and comparison of methods for assessing the dependability of safety critical software would be of scientific and practical interest for the nuclear safety community. To this aim, a project for an international benchmark study has been outlined and proposed to DG Research.

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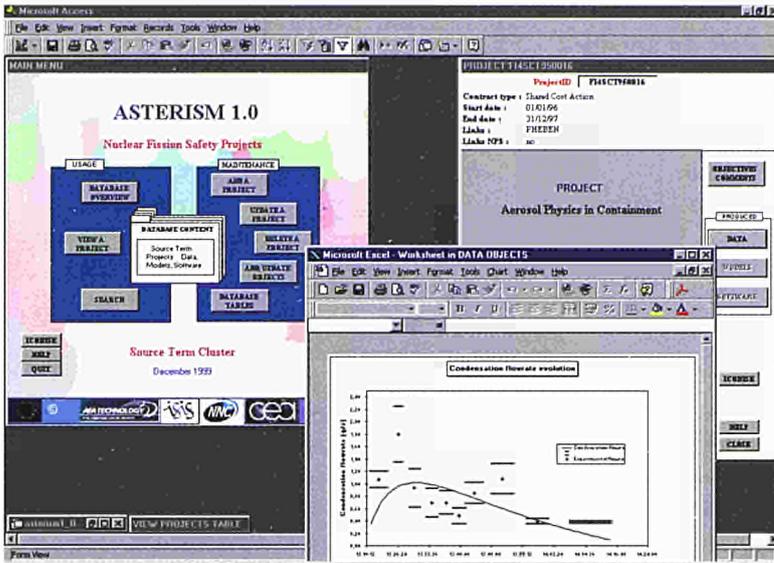
Figure 4.2: This view portrays the main menu of the 'ASTERISM' database, the cover page simulation of the APC project (Grey area) and a specific graphic from the corresponding final report.

A Database for Nuclear Fission Safety Projects (ASTERISM)

authors: A. Jones, M. Delaval

An 'Archive for Source Term Information and System Models (ASTERISM)' was developed to provide a catalogue of results, from ten projects of the source term cluster and a pilot database containing a representative sub-set of the source term cluster data and models, taken from the APC, IC and CHEM projects. Most of the projects of the source term cluster produce information of two kinds: data (calculated, experimental), models (equations) and/or functioning sections of computer code (software). The catalogue of information was issued in March 1999 and the database prototype was released in December 1999. The user interface is shown in Figure 4.2.

Model Development in Fluid Dynamics: Two-phase flow

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

Computational fluid dynamics (CFD), in all its guises, is nowadays widely used for the simulation of generic thermal-hydraulic flow processes.

However, progress made over the last two decades in the development of so-called 'advanced systems codes', i.e. codes used routinely for many if not all reactor safety calculations, has been sporadic. Moreover, it has largely failed to address the complexities of *localised* two-phase flow phenomena and processes of importance in the design and safety aspects of nuclear reactor systems. Consequently, most existing thermal-hydraulics codes like RELAP5, CATHARE and ATHLET, whilst giving perfectly satisfactory prediction results for the overall 'averaged' system behaviour, find difficulty in modelling localised processes in which strong parameter gradients exist. Wall heat transfer associated with mixture level formation in the core can be a strongly 3-dimensional phenomenon, where use is often made of specific sub-models of somewhat limited capabilities. Moreover, these codes, based as they are on largely outdated numerical schemes, suffer from serious deficiencies in terms of unwanted numerical viscosity. This originates from the coarse averaging procedures used in all finite difference schemes, and which effectively precludes these codes from being used to solve problems of a very local nature, such as boil-off in a partially uncovered core, or in 'Navier Stokes type' problems where physical viscosity effects are important.

The advanced two-phase flow (ATPF) code [4.8,4.9] developed within ISIS provides one such approach for the numerical simulation of transient two-phase flow processes. Supported partly through EC-funded shared-cost activities, the ATPF pilot code is based on a two-fluid model for the simulation of non-equilibrium inhomogeneous two-phase flow. A finite-volume numerical scheme makes direct use of the eigen-structure of the underlying conservation equations for mass, momentum and energy. This provides the mathematical basis for a solution scheme in which wave-like information characterising the flow can be propagated along the characteristic lines defined by the eigenvectors. A second-order interpolation technique allows a high-resolution simulation of two-phase flow with very low inherent numerical viscosity. Real fluid viscosity can then be included to give a physically realistic simulation of viscous flow problems.

The ATPF code has been successfully used for typical problems of the nuclear and process industries. The simulation of two-phase mixture levels

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in a reactor pressure vessel during 'blowdown' events leads to situations with rapid core uncovery, dryout of the fuel bundle and possibly 'meltdown'. An accurate prediction of in-core temperature variation is possible only if the wetted regions of the core can be computed from knowledge of the (two-phase) mixture levels (Figure 4.3). Another problem of interest is the critical 'choked' flow with strong pressure gradients near the break, fast depressurisation, slow gravity-induced phase separation and the simulation of two-phase flow processes at low pressure.

Explosion Models: REACFLOW contributions to the Nuclear Safety Programme
authors: T. Huld, H. Wilkening

Hydrogen formation during a severe nuclear accident could be caused by hot core melts interacting with the cooling water. The subject of study is an ignition of the hydrogen cloud which could start a severe explosion inside the reactor containment.

Due to the large-scale complex phenomena involved, studies of these explosions necessarily involve numerical simulations. For this task the 3D Computational Fluid Dynamics software REACFLOW has been developed in ISIS. REACFLOW allows automatic dynamic grid adaption to resolve the explosion fronts. This is essential to model explosions on large 3D scale. The method has been applied successfully to a number of small-to-medium scale problems relevant to attain a better understanding of the underlying phenomena.

During 1999 a number of new developments and improvements [4.10,4.11] have been implemented in REACFLOW, including:

- Improvements in the combustion models
- Improvements in the grid adaptation algorithms
- Implementation of a 3D graphics subsystem, as well as improved diagnostics.

Calibration calculations have been carried out for the turbulent combustion models in 3D, comparing obtained results with experimental data, obtained from our collaborators at the FZ Karlsruhe, Germany.

(A) (B)
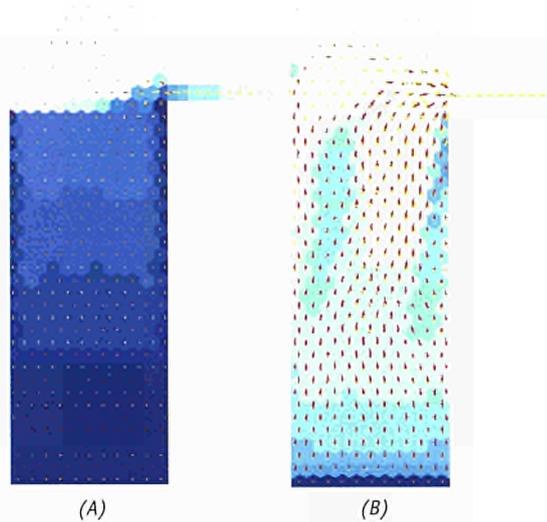
Figure 4.3: Computer simulated discharge of a steam and water mixture from a cylindrical pressure vessel via a horizontal outlet pipe, at two time intervals: (A) t=4 sec, (B) t=14 sec, showing complex two-phase flow phenomena. Simulation made with the ISIS 'ATPF' pilot code.

(A)

(B)
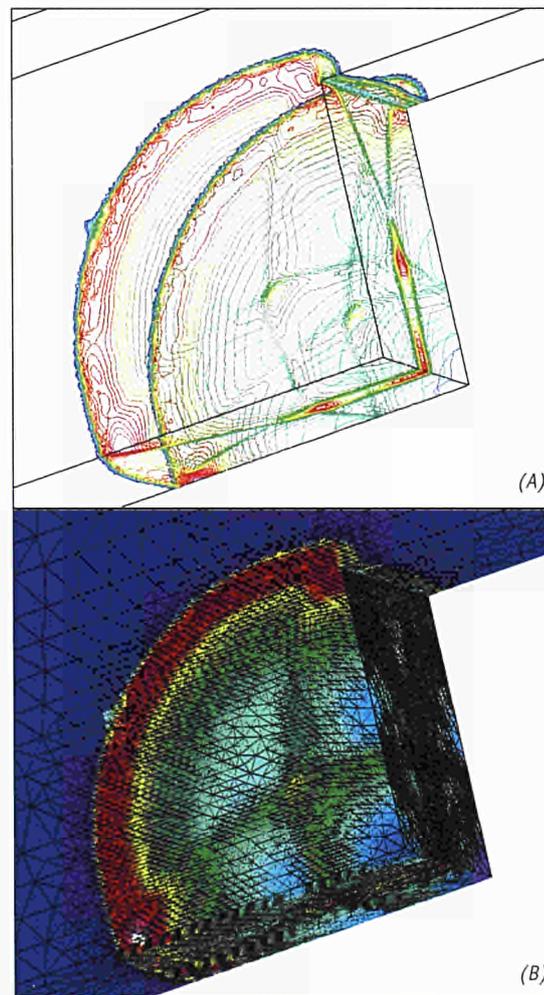
Figure 4.4: Simulated pressure results of a hydrogen explosion in the Russian RUT test channel which is 28 m long and has a cross-section of up to 2.5 m by 6 m. Both pictures give instant pressure distribution on the surface at 2.5 ms after triggering a detonation by a high explosive.
(A) shows isolines between 1 and 15 bar (blue to red). The initial spherical detonation has interacted with the channel walls, which generates a complex system of pressure waves. Highest gradients occur right at the detonation front. (B) shows the same situation using isocolours (1-15 bar from blue to read) with the surface grid. The grid resolution is highest where the pressure gradients are high due to the automatic adaptation procedure.

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Severe Accidents
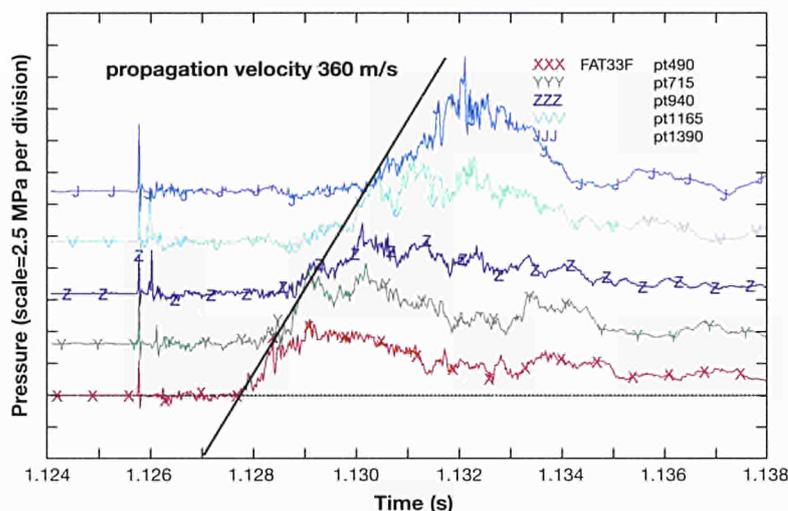
Figure 4.5: Upward propagation of the energetic event triggered in FARO test L-33; water depth 1.62 m, subcooling 122 K; pt=pressure transducer in water located on the wall of the test vessel at xxx mm from bottom as indicated; pressure scale=2.5 MPa per division.

Figure 4.6: Analysing molten reactor core material helps to assess the heat transfer for long term debris cooling after a severe nuclear accident. The above debris was generated in a FARO spreading test from ca. 200 kg corium material molten at 3,000 °C.

FARO/KROTOS Experiments

authors: D. Magallon, I. Huhtiniemi

The general scope of the FARO programme was to provide reference data to assess the reactor plant response to core melt relocation, and to verify design solutions and accident management strategies for core melt cooling and retention in the containment. The specific objective of the FARO tests was to determine experimentally the corium melt quenching characteristics at large scale. A series of fuel-coolant interaction (FCI) and spreading tests has been performed over recent years in the FARO facility involving up to 177 kg of 80 w% UO2+20 w% ZrO$_2$ corium melt. Smaller fuel-coolant interaction tests have been performed in the KROTOS facility with a few kilograms of Al$_2$O$_3$ and 80 w% UO$_2$+20 w% ZrO$_2$ melts in various conditions, to understand the specific behaviour of corium melt and its propensity for producing steam explosions. Data from both FARO and KROTOS have been and are being extensively used throughout the world as reference data to verify code and model capabilities in predicting severe accident FCI sequences.

The most significant accomplishment in 1999 [4.12,4.13] was the triggering of a steam explosion involving a quantity of melt around 40 kg in FARO test L-33. It was the first-of-a-kind steam explosion ever obtained experimentally with such a large quantity of prototypical corium in a reactor-like unconstrained geometry, moderate pressure (0.4 MPa) and water at ambient temperature. Figure 4.5 shows the dynamic load experienced by the interaction vessel walls at 300 mm from the explosion. The maximum impulse was 20 kPa.s and the explosion efficiency around 0.2%. The test vessel was slightly damaged and the 4 m^3, 10 MPa designed pressure vessel jumped physically a few millimetres. The test confirmed at large scale the KROTOS finding that steam explosion efficiency with corium is low and does not induce any damage to the load bearing structures in the unconstrained configuration.

References

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An important accomplishment was the execution of the first ever corium melt spreading test on a substrate covered with a thin layer of water. The FARO results demonstrated that the presence of the water improved the cooling of the substrate and did not induce a steam explosion.

FARO test L-33 was performed on July 1999, concluding the series of severe accident experiments at Ispra. Test analysis and documentation continue. The description and documentation of 14 FARO tests and 36 KROTOS tests are published at http://asa2.jrc.it/stresa/.

Accident Simulation and Analysis

authors: A. Annunziato, C. Addabbo

Severe accident analysis at ISIS focused on accident melt coolant interaction as well as to reactor primary cooling system behaviour during the evolution of precursory events such as design basis accidents and transients. The tool is the successful in-house code development used for providing analytical support to the experimental programme (FARO/KROTOS) as well as for applications to real reactor plant.

Severe Accident Melt Coolant Interaction Thermal-Hydraulics

The in-house developed COMETA (Core Melt Thermohydraulic Analysis) code [4.14] has been extensively applied for FARO test design calculations, pre- and post-test analyses, and for sensitivity calculations assessing the influence of major parameters, such as system pressure and subcooling, on the potential for energetic escalation. COMETA post-test calculations of system pressure evolution in FARO Test L-33, which exhibited an energetic interaction using an external trigger, is shown in Figure 4.7. The results of the calculation indicate that the code was able to reproduce the basic phenomena, although the pressure level, at the highest elevation, was difficult to be correctly reproduced. Considering the state-of-the-art of these type of codes this calculation is quite satis-
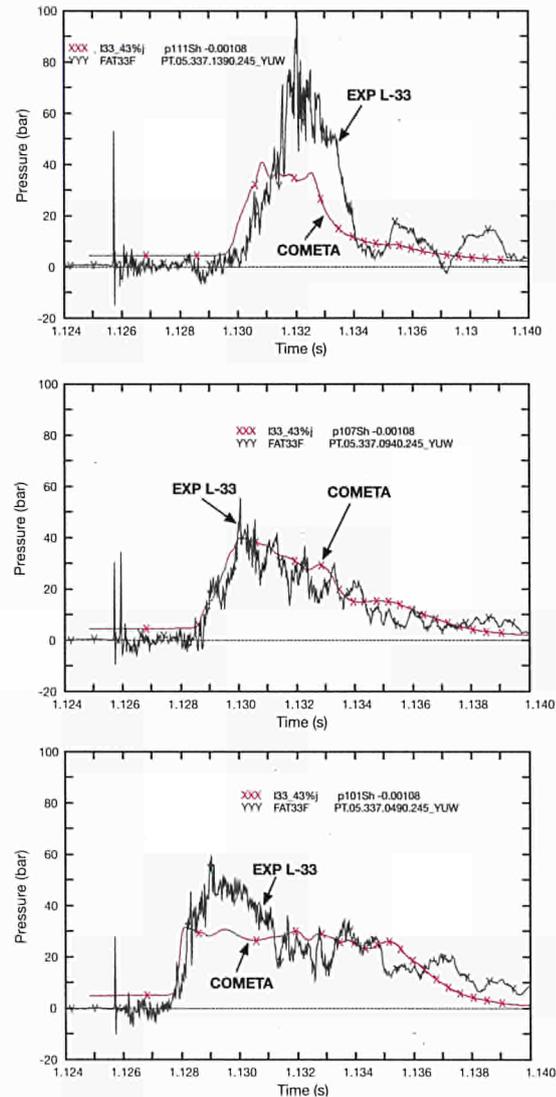
Figure 4.7: COMETA Post Test Calculation of FARO Test L-33 showing the good agreement between prediction and measurement results.

factory. In order to predict structural deformations that may result from an energetic interaction, the code has been coupled through an off-line routine to the hydrodynamic-structural mechanics code SEURBNUK/-EURDYN; prediction calculations of the energetic KROTOS 44 test have been performed using the coupled code version [4.15].

In the evaluation of reactor safety margins, there is an emerging need to quantify, insofar as possible or practical, the uncertainties associated with the code predicted results in full size reactor calculations. Within this context, COMETA full-size reactor calculations have been performed for the ASCO-NPP, a 3-loop 966 MWe PWR, and for the

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Figure 4.8: COMETA nodalization of the TMI-2 pressurised water reactor with indication of the void distribution around the primary circuit as calculated with SCDAP/RELAP5; on the right the result of the COMETA calculation.
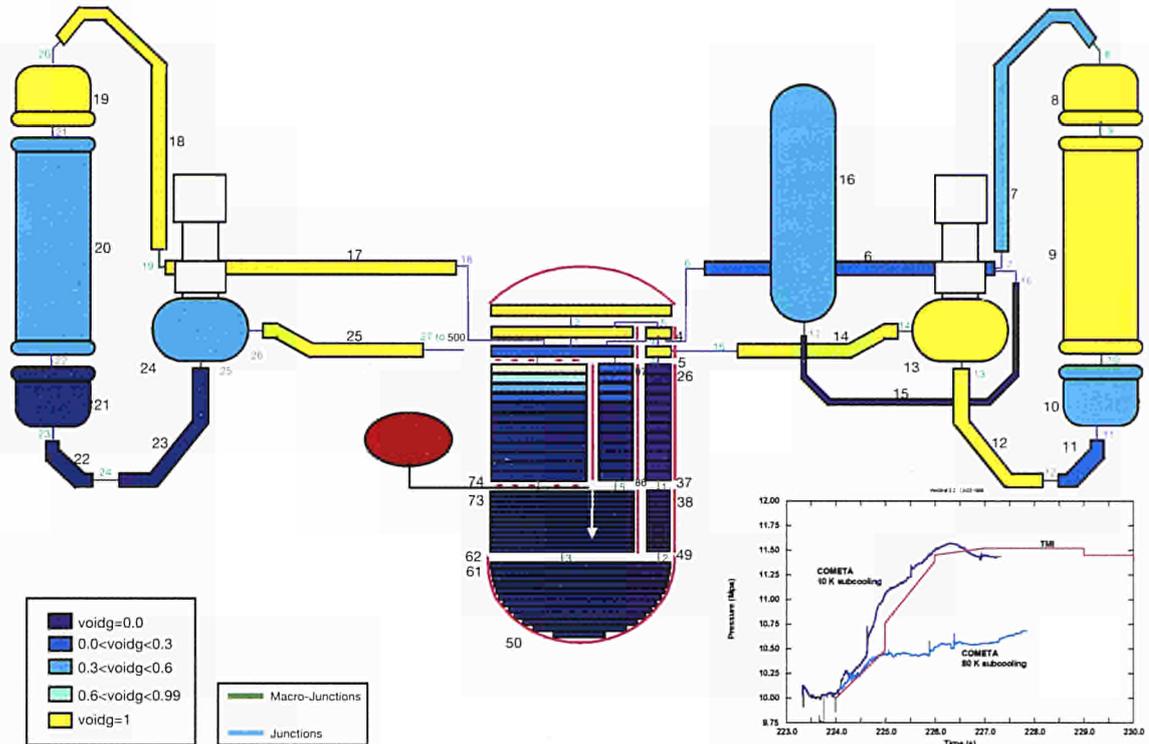
simulation of the TMI accident sequence [4.16]. A RELAP5/SCDAP calculation was performed in order to determine the conditions of the plant at the time of melt relocation. Figure 4.8 shows the void fraction distribution as calculated by this code and demonstrates that the vessel was full of water a the time of melt relocation.

These conditions were imposed in the COMETA code to calculate the release sequence; the insert in Figure 4.8 shows the pressure obtained with this code. The COMETA calculations indicate that the results strongly depend on the initial water subcooling degree.

COMETA is an integral system computer code coupling thermal-hydraulic and melt fragmentation modules for the simulation of melt coolant interaction and quenching. The code is composed of a Eulerian two-phase flow field with non-condensables and a Lagrangian melt field representing the jet, the droplets and the debris components. Melt coolant interaction and fragmentation is described by an original model which provides the local erosion rate on the basis of an interpolated 'jet break-up length' correlation (i.e. L/Dj = f(We, Fr,...) with melt droplets diameter calculated on the basis of the Weber number and Froude number criteria. The eventual unfragmented melt relocates on the vessel bottom plate forming a fused debris bed agglomerate. The code includes models for hydrogen generation from metallic as well as oxide components and heat transfer from the debris-bed to the coolant.

Design Basis Accident Thermal-Hydraulics

Following the establishment of Technical Exchange Agreements, the LOBI data is now available to several research organisations from Central and East European Countries (CEEC) and the New Independent States (NIS) to benchmark safety codes used in VVER safety analysis. The LOBI data base comprises 70 integral system experiments covering a wide range of pressurised water reactor accidents and transients. It has been widely used to identify and/or verify safety-relevant thermal-hydraulic phenomena and to provide reference information for the development and assessment of reactor safety codes such as CATHARE, ATHLET and RELAP.

Expert advice was provided to ENEA (I) for establishing an experimental programme on innovative reactor concepts to be conducted in the SPES test facility operated by SIET in Piacenza (I).

Enlargement

Since the safety aspects connected with reactors operating in Central and Eastern European Countries (CEEC) and in the New Independent States (NIS) are at the forefront of international concern, and have high priority in the EU enlargement agenda, ISIS started the exchange of information on VVER and RBMK safety with CEEC

and NIS research organisations. A technical exchange agreement in the field of reactor design basis and severe accident studies was concluded with the Electrogorsk Research and Engineering Centre (EREC) of the Russian Federation.

On the basis of this agreement, ISIS will provide expert advice for the execution of the Russian experimental programmes PSB and ISB, dedicated to the investigation of design basis accidents and transients in VVER reactors. Collaborative activities are envisaged in the field of melt coolant interaction analytical studies, which will focus on the development/refinement of the COMETA and VAPEX codes and on the complementary experimental programme which EREC will conduct in collaboration with the All-Russian Scientific Research Institute of Experimental Physics (IEP).

Reactor Vessel Integrity in Severe Accidents

author: G. Solomos

A possible scenario of a severe accident is that of the impact of a slug of molten corium (=reactor core material) and debris on the upper vessel head caused by a steam explosion and dynamic pressure loading in the lower part of the reactor vessel. Theoretical investigations and modelling have produced strongly differing and unreliable results concerning the integrity of the structure. Therefore, experiments with detailed structural mock-ups have been deemed necessary (BERDA and FLIPPER experiments of the Forschungszentrum Karlsruhe, FZK). These impact problems 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 of size, strain rate, and temperature are adequately simulated.

ISIS has been assigned to carry out such dynamic tests for material characterisation, in the Large Dynamic Test Facility (LDTF), which allows the testing of large specimens under well-defined strain rates. Uniaxial and biaxial tension tests are performed on the materials used for the pressure vessel and its internal structures. These include: ferritic steel 20MnMoNi55 (vessel head), austenitic steel X6CrNiNb1810 (Upper Internal Structure), ferritic steel 26NiCr Mo146 (bolting). Cylindrical
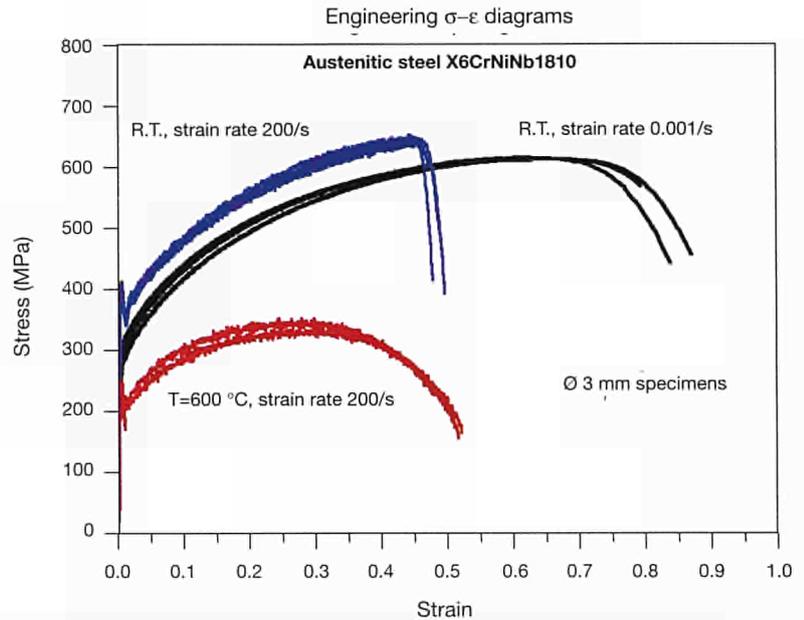
Figure 4.9: Stress-strain curves to be considered when assessing the reactor vessel structural safety under severe accident conditions. The measurements show a drastic effect of the speed of deformation (strain rate) and of temperature on the behaviour of the austenitic steel as used in the Reactor Pressure Vessels of the Upper Internal Structure.

tension specimens of diameters 3 mm, 9 mm and 30 mm have been tested at room temperature and higher temperatures (400 °C - 600 °C), and at strain rates ranging from quasi-static (10-3/sec) to dynamic (200/sec) conditions, Figure 4.9.

Strain rate and temperature effects have been adequately assessed through the stress-strain diagrams obtained [4.17]. The size effect issue has demonstrated to be more sensitive: it appeared to be minor with respect to resistances and concentrated mainly to local deformation parameters near fracture [4.18]. A series of tests with notched specimens, where strain gradient effects and local phenomena are more accentuated, are in progress for further investigation of these interesting size effect trends.

This activity is carried out within the framework of two shared-cost action projects belonging to the "In-vessel Core Degradation and Coolability" cluster of the Nuclear Fission Safety/ Reactor Safety programme. They are: `(a) RPVSA (EU Project FI4S-CT95-0002) "Behaviour of the Reactor Pressure Vessel under Mechanical and Thermal Loadings caused by Core Melt-Down and Steam Explosion Accidents", and (b) REVISA (EU Project FI4S-CT96-0024) "Reactor Vessel Integrity in Severe Accidents".

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The PHEBUS FP (Fission Product) Release Experimental Programme

author: R. Zeyen

The Phebus international FP (= fission product) release programme includes five in-pile bundle degradation experiments with special emphasis on circuit transport and containment chemistry. While this latest and third experiment in the Phebus series (FPT4) has yet to be evaluated (its final report is expected for 2002), this year was also marked by the release of significant consolidated data from previous experiments FPT0 and FPT1. Several unexpected phenomena have been clearly identified:

- fuel degradation: rather low melting temperature and a high degree of fuel liquefaction,
- iodine release: substantial amount of gaseous iodine from the circuit, significant iodine retention in the sump due to the presence of silver from the Ag, In, Cd control material in the melting process,
- faster than expected hydrogen release kinetics during the cladding oxidation process.

Several reactor safety authorities around the world are re-evaluating their severe accident source term and their accident management procedures linked to these scenarios. Test interpretation is performed together with the preparation future tests, largely within the ISIS-coordinated PhebusNet (see below).

Test FPT2 is in its final preparation stage. It will be another bundle test, this time in hydrogen-rich degradation conditions. Boric acid is introduced into the steam cooling and catalyst specimens from hydrogen recombiners will be tested against potential poisoning by real fission products from a degraded reactor core, and any effects on the fission product chemistry in the containment.

After long international discussions, test FPT3 is now clearly defined as the boron carbide test; the Ag, In, Cd control rod will be replaced by B4C, more typical of BWRs but also for more modern French PWRs.
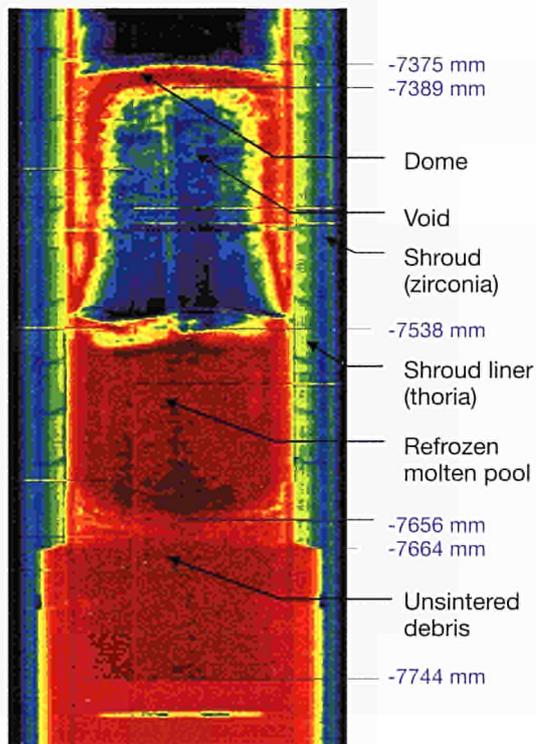
Test FPT4 (Figure 4.10) was successfully performed on July 22nd, 1999 during about 5 hours of tight teamwork involving about thirty experimenters and reactor operators, executing the complicated operations of the power transient and the evaluation of numerous test termination criteria. Preliminary results show the formation of a perfect crucible, comprising the molten (solidified) pool region, the void region and a top vault. The thorium oxide (thoria) liner containing the melt during the experiment performed extremely well. No obvious cracks or holes formed, which could have led to an early shut down of the test.

Test FPT4 melted down 6 kg of corium debris bed by neutronic heating. This bed was composed of 33 GWd/t enriched UO_2 from the Graveline power plant, mixed with 20% of ZrO_2 from oxidised cladding tubes. Downstream of the fuel, a battery of five sequential filters retained characteristic aerosols from the various release phases of the severe accident scenario; i.e. the volatile FP release phase (Cs, I, Te,...), the non-volatiles (Ru, Ba, Sr,...) release phase, and two phases at very high temperature just before and after the melting process. These last phases should compare release rates for a debris bed versus molten corium in a late accident phase. One highly significant first conclusion from the downstream filter retention is that a clear "low release scenario" was observed, without the often-predicted massive release of uranium oxide and its associated fission products.

FPT5 will probably be a bundle degradation test including an air ingress phase.

The EC/ISIS participates as a joint leader in all Phebus executive working groups and steering committee meetings. Its presence supports the day-to-day management of a number of technical and organisational matters in this important programme, such as the development of improved aerosol sizing instruments for the Phebus circuit. International contributions to the Phebus programme from different countries are directly managed by ISIS scientific personnel.

Figure 4.10: Radiograph of the final bundle state of the Phebus FPT4 experiment. The colours indicate the density of the test section, from red=high to purple=low.

-7375 mm
-7389 mm

Dome

Void

Shroud (zirconia)

-7538 mm

Shroud liner (thoria)

Refrozen molten pool

-7656 mm
-7664 mm

Unsintered debris

-7744 mm

The PHEBUS FP Network

author: A. Jones

ISIS participates actively in the interpretation of Phebus FP test results, in the preparation of future tests, and in the validation of LWR severe accident computer codes and models against Phebus data. This involvement concerns both in-vessel phenomena of core degradation and fission product release (described later), and, as regards the source term issues of fission product transport in the reactor circuit, aerosol removal in the containment and both short-term and long-term fission product chemistry. It also promotes European and international cooperation on these themes through the Phebus scientific analysis working group (SAWG) and its interpretation circles on degradation/release, aerosols and chemistry. These groups continue to meet regularly (twice in 1999), with a large number of participants, not only serving the Phebus project but acting as a focus for severe accident research across Europe.

ISIS has also coordinated and participated in several SCAs and other projects in the same general area, and in the interests of rationalising the various actions and exploiting the synergies between them, the first steps have been taken to create an umbrella organisation called 'PhebusNet'. The objectives of the network are to promote the coordinated interpretation and analysis of data from the Phebus FP, to provide input to the definition of Phebus tests and the post-test studies and separate-effect tests associated with them, and to act as a general forum for information exchange in the severe accident area and an interface to Commission services and SCA projects. At the last count there were 18 participating EU organisations and 9 from other states with nuclear programmes including the USA, Japan, Canada, Korea and Switzerland. The most recent meetings featured not only analyses of the various aspects of Phebus tests FPT0 and FPT1 and precalculations of test FPT2, but also presentations about new experimental facilities for containment thermal-hydraulics/aerosol studies and model developments for aerosol transport in turbulent flow, chemical speciation and non-equilibrium effects, and silver-iodine interactions. Presentations were also made on past and future SCAs relevant to PhebusNet including PHEBEN, ICHEMM, REVAP, and forthcoming projects on code validation against Phebus, iodine chemistry, validation of the ASTEC code, and a database of 4th Framework Programme results in the source term area.

ISIS has presented within PhebusNet and also at international meetings some significant model developments in 1999. One [4.19] used a model combining fission product transport with non-equilibrium chemistry to calculate the volatile iodine fraction entering the containment in Phebus tests FPT 0 and FPT 1. The theory accounted both for the observed fraction and for the fact that this was lower in test FPT1 with irradiated fuel than in FPT0 with fresh fuel. A second development [4.20] incorporated a multi-layer model for silver-iodine reactions in the code IMPAIR, commonly used for plant source term evaluations [4.21], and obtained reasonable agreement with the corresponding Phebus data. In a third development, a simple analytic model developed by ISIS has been applied to aerosol flow in containment leakage paths, revealing the dependence of trapping in the paths on the changing flow and thermal boundary conditions. A fourth development captures in one simple model the particle resuspension information coming from Phebus FP, STORM, and other experimental programmes. In a collaboration with IPSN the model is currently being incorporated in the circuit code SOPHAEROS.

The PHEBEN activity

authors: T. Haste, A. Jones

The PHEBEN concerted action, coordinated by ISIS with eleven partners, was successfully concluded in 1999 [4.23]. It benchmarked modelling codes against fission product release, circuit

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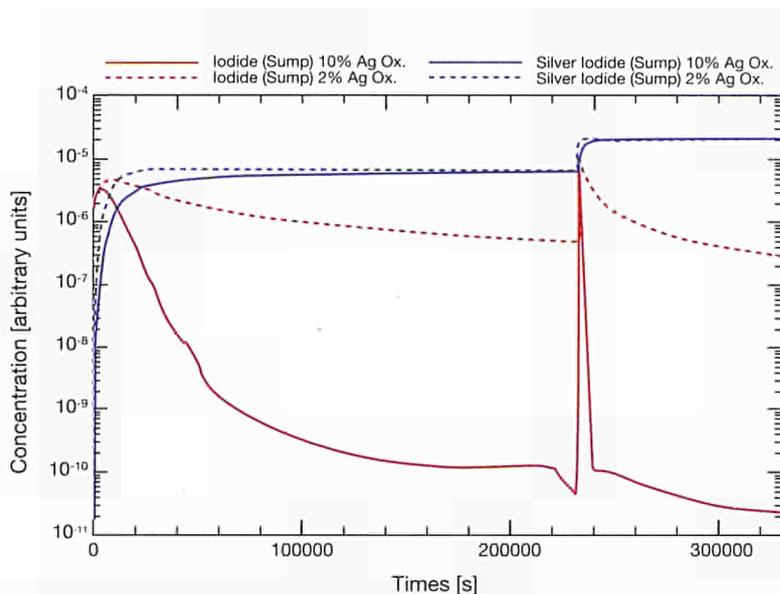
Figure 4.11: IMPAIR3 calculation of sump iodine in Phebus FPT1, showing non-volatile silver iodide (top curves) as the dominant species.

haviour in the containment volume is generally well simulated. Containment chemistry models for silver/iodine reactions, which can trap iodine in the sump water, so reducing its presence in the atmosphere and potentially reducing the source term, have been successfully developed and validated [4.24,4.25]. ISIS, in collaboration with PSI Switzerland, played a leading role in this area, developing and validating detailed models for these reactions [4.20] (Figure 4.11). Overall, the focus of severe accident research is being significantly affected by Phebus results and effort in this area is expected to continue, for example in the follow-on project PHEBEN2 that has been approved for the next four years.

In-vessel phenomena in severe accidents

authors: I. Shepherd, T. Haste

transport, containment aerosol physics and containment chemistry data from the in-pile experimental programme Phebus-FP. This work helps to reduce the uncertainties in calculating radioactive fission product release into the environment in the unlikely event of a severe accident in a light water reactor.

The codes gave a satisfactory overall picture of the first two Phebus tests FPT-0 and FPT-1, with generally good predictions of containment thermal hydraulics and aerosol physics. Models for the release of fission products from the fuel performed quite well, although the predicted release of semi-volatiles was too great and the observed effect of changing fuel geometry (rod-like to melt pool) is not considered. In the circuit, codes now predict correctly that most elements are in aerosol form; but, while the zone of greatest deposition is well predicted, the amount of deposition is not. Studies continue on the time and spatial variation of chemical speciation in the primary circuit [4.19]. Thermal hydraulic be-

During 1999 the two projects Core Behaviour (COBE) [4.26,4.27] and Oxidation Phenomena in Severe Accidents (OPSA) [4.28], coordinated by ISIS and involving 12 different partners came to a successful conclusion.

COBE dealt with issues of concern to accident management - the quenching of fuel rods and late-phase phenomena – debris bed molten pool phenomena and the movement of material to the lower head. The QUENCH facility at Karlsruhe was designed and commissioned on the basis of calculations performed by a private company, two universities and a national research organisation. All the partners of COBE were given the opportunity of influencing test parameters. Both pre- and post-test calculations were cross-checked by different organisations using different computer codes. The lessons learnt from the QUENCH calculations were shared by all participants who were able to go on and calibrate their computer codes for better estimation of hydrogen production during quenching in reactors.

References

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Some emphasis was given within the project to modelling late phase behaviour. Prompted by the forthcoming Phebus FPT-4 test better code models for the behaviour of molten pools were developed. Increased understanding of other processes was also reached including the influence of control rods, the degradation of BWRs, relocation to the lower head and the swelling of irradiated fuel [4.29]. Because this understanding has not yet been fed into system code models, the impact on accident management procedures is hard to quantify.

The OPSA project marked the first serious attempt world-wide to improve understanding of the impact of air ingress on core degradation, with efforts to demonstrate the relevance of air ingress scenarios being combined with experiments and their analytical treatment. The highlight of the project was undoubtedly the successful execution of two bundle air ingress tests in the CODEX facility at AEKI, Hungary (Figure 4.12). ISIS took the lead in pre-and post-test calculational support and in the aerosol measurements [4.30]. The broad thermal behaviour of the test sections was modelled using the ICARE2 code, and the data were shown to be consistent. The aerosol particles produced and the final states of the degraded fuel rods were analysed (for results of the second test see Figure 4.13). The consistency of the experimental findings amongst the small-scale and bundle tests and the possibility of their preliminary description by simplified correlations was demonstrated, but additional separate-effects tests and more fundamental model development will be needed if the complex phenomena exhibited are to be fully explained. Developing these models and tools is the essential next step if we are to acquire prediction capability for this type of accident.

ISIS continued to coordinate the Phebus-FP Bundle Interpretation Circle. The lessons learned in analysing the first Phebus-FP experiment, FPT-0, have been fed into analyses of the second test – FPT-1. Measurement-simulation comparisons showed better agreement - particularly for hydrogen generation - that should result in less uncertainty in estimating the impact of accidents in real plants. Attention is turning to understanding the fission product behaviour where the release of low volatile products – in both the first tests – was less than that observed under similar conditions in separate effect experiments.

In parallel with the quench studies performed in the COBE project, a Status Report [4.31] on the

quenching of a degraded core was produced at the request of CSNI Principal Working Group 2. This report summarises the state-of-the art in this field, and indicates areas such as quench of debris beds where additional work might help towards risk reduction in accident management of light water reactors. In addition, a start has been made on an update of an In-Vessel Core Degradation Code Validation Matrix in collaboration with GRS Garching, Germany.

Figure 4.12: Schematic Diagram of the CODEX-AIT facility at AEKI Budapest for the Conduct of Core Degradation Experiments in Air.
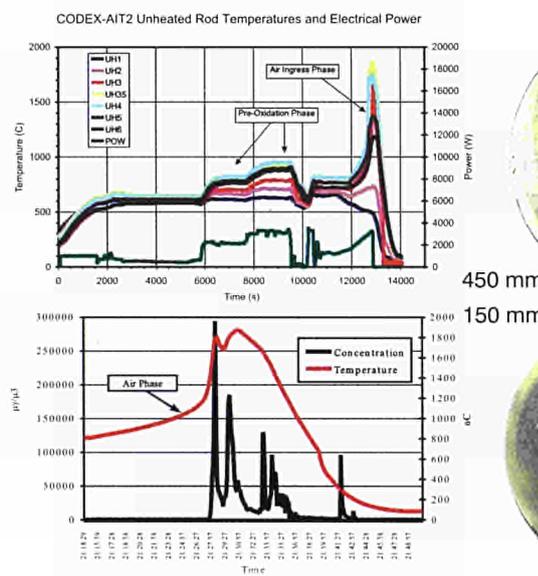
Figure 4.13: Air Ingress Experiment CODEX AIT2 Unheated Rod Temperature Histories, Aerosol Production in Air Phase and Cross-Sections showing Rod Degradation and Material Relocation.

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Figure 4.14: Code predicted coolant temperatures and velocities after 64 hrs in a small experimental ADS facility with a simulated blocked beam.

09-Dec-99
Temperature
Absolute
Kelvin
Time=232040
Local MX=1244
Local MN=1203

1244
1241
1238
1235
1232
1229
1226
1223
1220
1217
1215
1212
1209
1206
1203

Safety of Innovative Reactor Concepts

author: H.U. Wider

Safety calculations on lead/bismuth-cooled Accelerator-Driven Systems (ADS) have been continued [4.31-4.34] and first comparisons with gas-cooled ADSs have been made. We have also started looking into potential fission product release and transport aspects in the innovative direct-cycle High Temperature Gas-cooled Reactor (HTR). We applied for shared-cost actions for both ADS and HTR.

The first comparison of Pb/Bi and gas–cooled ADSs showed that the gas-cooled variant has disadvantages regarding accident occurrence probability because of its high-pressure coolant. It also has weaknesses considering accident mitigation because it has a low heat capacity; ex-vessel passive emergency decay heat removal by air is not possible, and if fuel melting occurred, coolabilty and re-criticality problems are likely.

Investigations of emergency decay heat removal in a Pb/Bi-cooled ADS with a Reactor Vessel Auxiliary Cooling System (RVACS) for the case of a station blackout were made with the 3D thermal hydraulics code STAR-CD. It was shown that a larger system with 800 MWth or more may require additional cooling measures beyond pure air cooling. It was also shown for larger systems that the combined use of water spray cooling on the outside of the guard vessel and filling the air gap between the reactor vessel and the guard vessel with molten Pb/Bi, can easily remove the decay heat.

Calculations of a combined Loss-of-Heat Sink and Loss-of-Flow scenario without beam shut-off (although highly unlikely) were also done with STAR-CD. This was to investigate the functioning of the melt-rupture disc (for which we have been granted a patent in 1998). After melting the solder material around the melt rupture disk, the coolant streams into the beam pipe and blocks the proton beam (In ADS type reactors the chain reaction is maintained by an external proton beam, which must be switched off or blocked in safety critical situations). A new spallation heat source appears high up in the vessel. This leads to an interesting natural convection problem with a heat source at the top and air cooling at the side wall. The decay heat of the core is after tens of hours much smaller than the spallation source high up in the vessel. The results show that the blocking of the beam leads to long term coolable conditions only for the small Ansaldo demonstration facility design (80 MWth) which can be see in Figure 4.14 The maximum vessel temperature in this case is 1170K. For larger ADSs, the vessel reaches this temperature already after a few hours and then rises further. It seems unlikely that the beam would remain operative for such long times, however.

References

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Fight Against Fraud

editor: S. Arsenis

ISIS further advanced or launched new research projects with the aim to develop or apply technologies for identification, controls and audits, and information management, computer communications, data analysis, and risk analysis for anti-fraud. These activities are:

- Project IDEA for the electronic identification of farm animals, a major feasibility study on applying electronics and database technologies to identify and register farm animals.
- Control technologies for fishing, comprising two feasibility studies for monitoring fishing vessels and using information technology to identify fish stocks.
- Information management and computer communications for anti-fraud, to develop prototype solutions and demonstrate use of available technologies in various fields like information retrieval, data mining and visualisation, language engineering, and workflow and document management.
- Data analysis and risk analysis to develop and apply statistical methods for estimating fraud and extracting signals, patterns and trends from relevant databases.
- Advanced statistics for the clearance of accounts, a new project to provide a valid scientific basis for choosing appropriate sampling and estimation methods for conducting audits and estimating total overpayment in payment populations.

While the expected research results are of potential interest to other Institutions of the Union and Member States, the primary customers for the activities are the Directorates General for Agriculture and Fisheries, and the European Anti-Fraud Office (OLAF).

Electronic Identification of Farm Animals, project IDEA

authors: C. Korn, O. Ribo

The objective of project IDEA (*Identification Electronique des Animaux*) is to assess the feasibility of the electronic identification for farm animals and to validate identification systems in real field conditions. IDEA is a three year project (1998-2000) and was launched by the Directorate General for Agriculture (DG AGRI). ISIS gives technical support in testing the performance of electronic identification devices, quality control of equipment, definition and establishment of the central database, data transmission and recording during the project, and global evaluation of results obtained.

Approximately one million animals from three species (440.000 cattle, 490.000 sheep, 30.000 goats) in 6 EU Member States (France, Germany, Italy, Netherlands, Portugal and Spain) will be identified applying 3 different types of electronic tags: eartag, ruminal bolus and injectable transponder. The performance of electronic identification devices and the necessary organisational structure in a real EU livestock scenario will be evaluated. The analysis will determine whether electronic identification is a feasible system to trace animals individually from birth to the slaughterhouse. It is important to identify the appropriate technologies for electronic tags and reader types for full-scale implementation to EU livestock.

In 1999, the definitive version of the "Guide Procedures for the IDEA Project" (v. 5.3) was prepared and distributed to all IDEA participants [5.1]. The Procedures Guide gives recommendations on identification, reading, recovery, data recording and transmission, etc., and specifies all data that should be recorded by the participants and transmitted to the JRC.

The IDEA Central Data Base was designed and developed with the analysis of all data types (animal, people, electronic identification devices, etc.) and of all activities to be performed during the project (tagging, reading, and recovery). From these, the Data Dictionary (v. 1.1) was written [5.2], which contains all data to be recorded and registered in the data base with their codification and format (numeric or alphanumeric, length, etc.). The JRC IDEA Central Data Base was implemented and tested, and is operational since September 1999.

A document has been prepared defining data transmission between the IDEA participants and the Central Data Base using the EDIFACT (Electronic Data Interchange for Administration Commerce and Transport) Standard [5.3]. EDIFACT conversion software was installed to permit electronic data interchange with the participants' regional databases. X-400 connections between the JRC and all IDEA participant organisations have been put into place. The data stream from the IDEA participants to the JRC started in December 1999.

During 1999, six new electronic identification devices (electronic tags, and portable and static read-

Figure 5.1: Reading station for electronic animal identification.

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ers) have been certified in the TEMPEST (Thermal, Electromagnetic and Physical Equipment Stress Testing) Laboratory. Thus, since 1996, 72 pieces of equipment have been certified and 225 certificate updates have been produced [5.4].

The electronic identification of animals within the IDEA project began in September 1998. During 1999 IDEA participants have supplied data from 300.000 electronically identified animals. It is expected that in year 2000 this will reach about 800.000 animals, or 80% of the total.

Preliminary analysis of the results indicates a global better performance of the ruminal bolus compared to electronic eartags and injectable transponders [5.5]. However, this conclusion is drawn only from a fraction of the data to be collected. Also, detailed data on loss, breakage, electronic failures by animal type, tagging and reading data, equipment, etc. will have to be analysed.

Control Technologies for Fishing

Two activities pertaining to control and inspection mechanisms for the Fisheries policy were conducted in 1999. These are: using synthetic aperture radar imagery for monitoring fishing vessels and applying of information technology to identify fish stocks.

Monitoring Fishing Vessels
authors: N. Kourti, I. Shepherd

This project started in January 1999 and aimed to determine whether spaceborne synthetic aperture radar (SAR) could be an element in fisheries control. The test zone selected by the Fisheries Directorate General was the Flemish Cap area of the North Atlantic. This is on the continental shelf but outside Canada's territorial limit. Contracting parties to the North Atlantic Fisheries Organisation, including the European Union, negotiate annual fishing quotas for a number of species including prawns, American plaice and Greenland halibut. The Cap is not on a navigation lane so most vessels in the area are engaged in fishing.

60 images were analysed for the period April–September 1999 – this period had been chosen on the basis of the statistical likelihood of favourable weather conditions. These images were predominantly RADARSAT ScanSar Narrow with a resolution of 50 metres and a swath width of 300 km. It was felt that the combination of a wide swath and the frequent images offered the best possibilities for vessel monitoring in the Flemish cap area. A number of other images with different resolutions, polarisations and incidence

angles were also analysed in order to test the sensitivity of the method to these parameters. An image interpretation algorithm to detect the fishing vessels was developed and tuned to optimally detect vessels against a noisy background and automatically remove false positives.

Figure 5.2: SAR signatures of the same vessel captured on three different days.
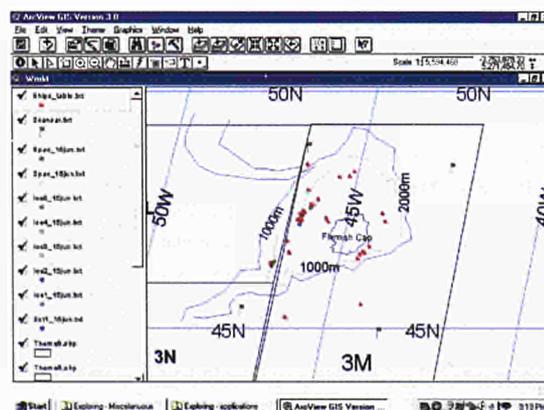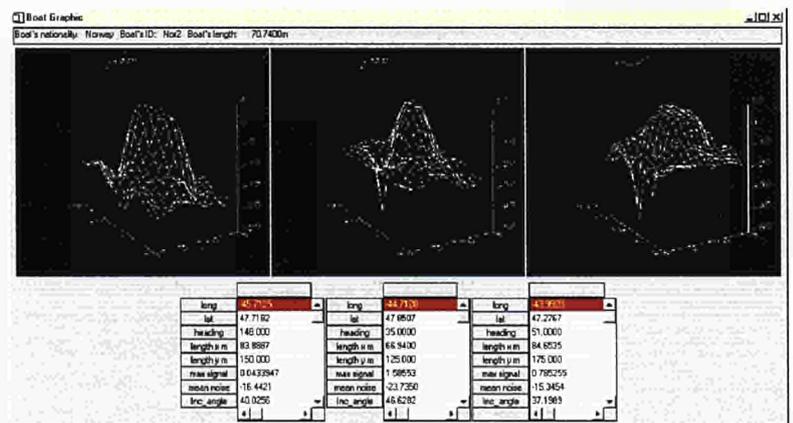

Figure 5.3: Geographical information system (ArcView) used to display results. Users can make queries such as "display all the vessels detected with the SAR together with the VMS records". This image uses vessels detected by RADARSAT ScanSar narrow on 15 June, 1999 in the Flemish cap area. The flags mark the corners of the image.

Contacts with the Spanish, Portuguese, Norwegian and Icelandic Fisheries Inspectorates helped to obtain information from their on-board GPS-based Vessel Monitoring Systems (VMS). The VMS information was stored in a database and analysed to determine the position of vessels on image acquisition times. The positions of the vessels detected on the SAR images were cross-checked with this VMS information and also with the "HAIL" messaging system, with the European Union inspectors' log-books, and with images obtained from Canadian aircraft over-flights.

Analysis showed that the ScanSar Narrow images were indeed very suitable for detecting vessels. Except under very adverse weather conditions it was possible to find all the vessels within one image frame and the positions deduced were consistent with the ancillary information. Following an invitation from the Fisheries Directorate General, the results were shown at a meeting of EU Inspectors in Gothenbourg. There was general agreement that SAR imagery could usefully complement the VMS system by detecting vessels whose on-board systems were not functioning correctly.

Fish Stock Identification

authors: J.M. Zaldívar, H. Hardy, A. Imsiridou

A substantial amount of research at national and international level has been devoted to develop genetic methods for the characterisation of different fish stocks. These studies are based on the collection of samples at different locations and the use of various methods for examining the genetic structure of the stock. There are a number of AIR, FAIR and BIOTECH projects aiming at the generation of such data sets and the literature describes many such studies.

The generation of the data is time-consuming and costly, but it is not evident how this data can be used for control purposes by national molecular biology laboratories interested in assessing the origin of a particular fish species. Consequently, there is a need to store the data in a database easily accessible to researchers and control authorities.

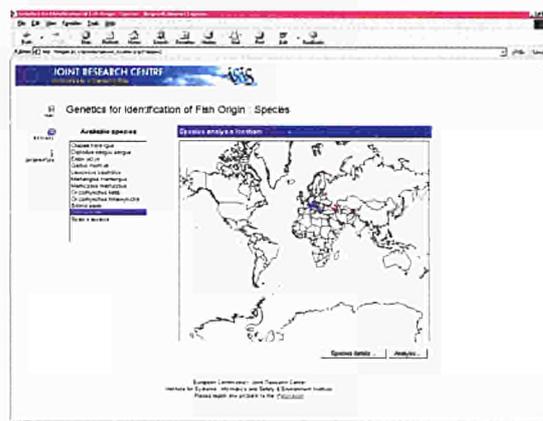ISIS developed a prototype database concerning

Figure 5.4: Fishgen database indicating analysis type - Allozyme (red), RFLP (green), sequencing (blue), microsatellites (pink)- and location for Sea trout. By clicking on the points, data concerning the specific sites is obtained.

exclusively the different genetic data from fish studies. This web database (http://fishgen.jrc.it) is accessible to researchers and control authorities through the Internet, see Figure 5.4, and should serve as a repository of information about genetic differentiation of stocks of commercially important fish species [5.6,5.7]. It contains data from studies involving different methodologies and techniques applied in fish genetics [5.8], e.g. allozyme electrophoresis, Restriction Fragment Length Polymorphisms (RFLPs), sequencing data, and microsatellites data.

The database should allow molecular biologists working in genetic fish identification to access rapidly and efficiently the existing information about materials, methods and results obtained for the desired species. The database has been developed in a way that new information can be inserted easily by researchers in the field submitting their own data [5.9]. As a specific case study, allozyme analysis to differentiate between one Atlantic and one Mediterranean Hake population have been carried out [5.10].

The database may be the essential first step in establishing a systematic European capability in determining the origin and species of a fish or a part of a fish from its DNA. It is a promising forensic tool to support conservation, anti-fraud and consumer protection policies.

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Information Management and Computer Communications for Anti-Fraud

authors: A. Garg, T. Barbas, R. Steinberger

R&D in information management and computer communications is rapidly expanding to include various new research fields - like information retrieval, data mining, data visualisation, language engineering, workflow and document management. Work is also expanding to include development of prototype solutions and delivering consultancy for specific real-world problems and issues. The year 1999 saw both the initiation and completion of various projects that are given below. Lessons learnt and know-how for these projects was disseminated via presentations. These tasks were implemented through projects, using both institutional and external funding; the main customer or beneficiary of which was the European Anti-Fraud Office (OLAF).

Prototypes of selected *workflows* are expected to benefit OLAF in formalising some important business processes [5.11]. Methodological aspects of this work were presented at an international conference [5.12]. The web-based prototype applications are based on ActionWorks Metro software of Action Technologies.

ISIS developments have shown how Geographical Information Systems help to analyse and visualise OLAF's Early Warning System's (EWS) transit data for sensitive goods. New developments included the possibility for predefined queries to an EWS database (via ODBC), spatial analysis capabilities, a rebuilt user interface to enhance usability, and the automation of some visualisation functions for the casual user.

Analysis of a number of relevant data sources and associated problems was carried out on behalf of OLAF. First, we looked into the feasibility of combining EWS transit transactions and IRENE fraud case data. Then, in the area of *data warehousing* for the textiles sector, an in-house development of "outlier detection" software was demonstrated and tested on data coming from the COMEXT and GSP systems [5.13]. OLAF has now requested further developments to make the tool useful to casual users. In addition, an analysis of IRENE data was performed to establish the feasibility of integrating this data into a data warehousing environment in OLAF [5.14]. An expert study on behalf of DG AGRI, Clearance of Accounts (ex DG VI.A.I.3) about data warehousing technology for *paying agencies data* [5.15] was completed in June and presented in September 1999. Finally, a problem statement on networks of entities for VAT fraud accompanied by demonstrator software

was delivered following a request from OLAF.
Research in information retrieval and distributed systems theory brought new results on theoretical problems of distributed systems (including coordination theory) [5.16] and on the implementation of a new algebraic model for information retrieval systems [5.17].

A new project called *INTOOLS-2* (Tools for Intelligence) has the ambitious aim to complete two software tools, DOCTUM and IIIMS, and to make these tools a part of OLAF's every-day working practice. DOCTUM is an approximate string matching application for database cleaning. New string matching algorithms and a redesign of the user interface will be the main results of the project. IIIMS (Integrated Information and Intelligence Management System) is a system to retrieve, gather, organise and access relevant sources of information in the context of antifraud. The system features a structure to organise sources of information according to a subject classification (thesaurus) and a standardised system description. The main contribution will be to implement IIIMS as an information portal for OLAF's horizontal fraud-control functions using Internet-based technologies [5.18].

New technologies are needed to obtain fraud-related information through *automatic intelligence gathering from the* World Wide Web (WWW). For a first application focusing on movements of ships and containers, the intention is to harvest and utilise the large amounts of data available via the web. Work is in a phase where a draft statement of the requirements has been produced [5.19] and feedback from potential users is being incorporated.

Language Engineering, the field in which computers are used to process written text, makes it possible to automatically analyse and process large amounts of textual information written in a variety of European languages. Its technology replies to some common needs of anti-fraud agencies, such as the requirement to find documents relevant to current interests, to assess the contents of documents quickly, to extract the relevant bits of information, to present them in an informative manner and, possibly, to derive some meta-knowledge from texts (such as ways in which fraud develops over time and countries becoming involved with specific products) [5.20]. Language Engineering at ISIS concentrates on providing a combined multilingual system, which

retrieves relevant documents, extracts several types of information, and visualises the contents of individual documents and document collections [5.21]. Project *Modus Operandi* aims to automatically recognise the language in which texts are written [5.22], identify their keywords, and group the documents according to their similarity with each other [5.23]. The motivation for the grouping is to display main issues discussed in a document collection, to verify whether the identified clusters of fraud-related texts can be used to derive a fraud case classification, and to eventually classify new texts using this classification. Multilinguality is a serious concern. For this reason, all Language Engineering activities aim at finding multilingual solutions that summarise main aspects of the contents of documents (originally written in a variety of languages) in the mother tongue of the user. These information aspects include a collection of automatically assigned keywords, a list of the concrete objects referred to in the text, geographical references made in the text, the subject areas to which each text can be attributed, and others.

Computer communication security was assessed regarding some proposed European networks as the European Judicial Network, and the New Excise Movement and Control System. ISIS also initiated a study on security architectures for OLAF based on a public-key infrastructure (PKI).

Figure 5.5: Language engineering for multilingual document retrieval, information extraction and visualisation.
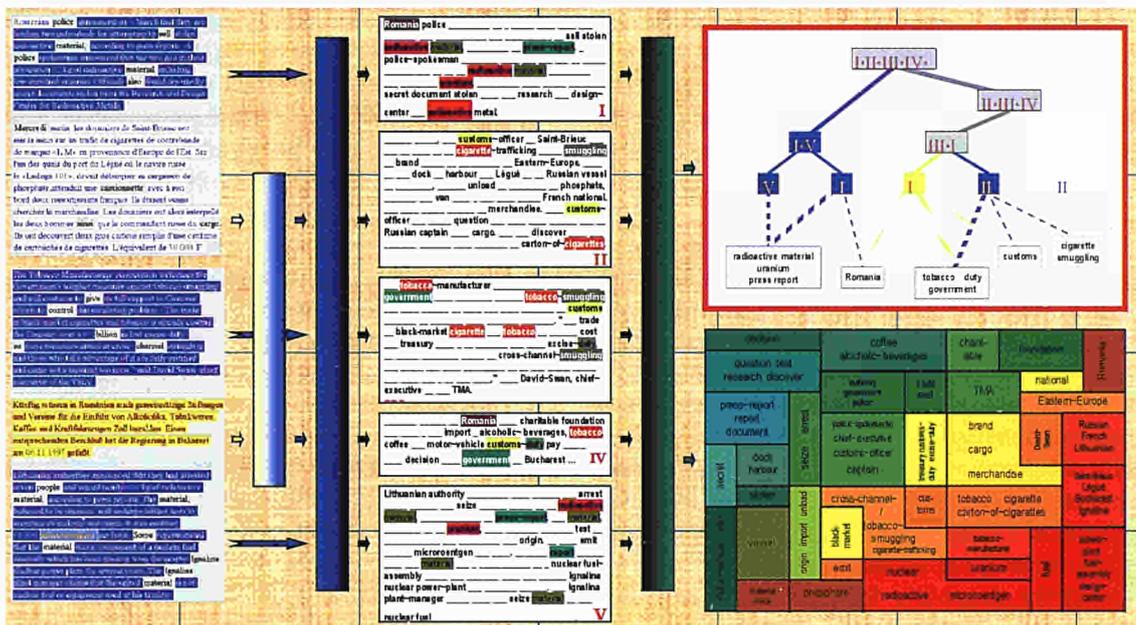
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Data Analysis and Risk Analysis for Anti-Fraud

authors: S. Arsenis, T. Rosolin

In 1999 ISIS continued work on data analysis and risk analysis issues pertaining to the exploitation of data on irregularities and frauds committed against the budget of the EU and reported by Member States to the Commission.

Exploratory Analysis of data stored in IRENE-95 was conducted on data transcoding from IRENE-3. IRENE-95 is the new habitat where reports on irregularities are currently stored. This work, reported in [5.24], aimed to examine how data supplied on cases reported to the Commission are stored in the new database in comparison to its previous architecture, and to provide feedback on the design of the database. Emphasis was given to data transcoding, duplications, omissions and on the *quality of the data* stored. Appropriate descriptive statistics were developed to highlight systematic or random errors present in the downloaded data [5.25].

An examination of cases reported by Member States has been done on the basis of subject matter knowledge to *differentiate between frauds and irregularities*. Reporting Member States and amounts reported have been taken into consideration. Robust statistical tests have been applied to bring out Member States reporting significantly large or small cases, and combinations of Member States and irregularity types that appear to give rise to populations of cases which are significantly large or small. The issue of cases reported with zero amounts defrauded was given particular attention. We applied a 5% sampling on a subset of such cases to infer that relatively infrequent combinations of variable categories in the database are due to errors that may in principle be corrected. Reporting practices by Member States with regard to irregularities reported were also highlighted by applying statistical tests and accounting for the large number of comparisons done. These findings are reported in detail in [5.26].

Data Collection and Analysis with Particular Emphasis on the Taintings for Reported Fraud and Irregularity Cases and Data Quality

The monetary amounts stored in the free text of cases reported against the Structural Funds include, in addition to amounts defrauded, the total payments made for each individual case. These data were retrieved from the free text of all reported cases. The data are used for quality assurance of the data previously encoded. They highlight some conceptual clarifications needed in reporting of cases and allow the comparison of fractions defrauded against the National (Member State) budgets and the Community budget by

Member State and budgetary line. In satisfaction of the data prerequisites for estimating the tip of the iceberg problem, a literature review and compilation of total payments by year, Member State and budgetary line has been made [5.27].

The aim of a project called *"Clusters of IRENE Cases"* is to find out whether cases reported against the European Agricultural Guidance and Guarantee Fund (GAR) can be grouped into clusters. Existing statistical methods had to be adapted to particular features of the data: the large number of observations, and the presence of categorical variables with a large number of categories. Two approaches have been adopted: multidimensional scaling and hierarchical clustering.

Multidimensional scaling represents the distances between the cases as distances of points in a 2-dimensional Euclidean space. This procedure provides a simple aid in detecting the presence of groups which are formed heuristically, see Figure 5.6. The three clusters clearly shown in the figure correspond to cases against aid, restitutions and storage measures.

Two criteria have been developed to help selecting the number of clusters produced by hierarchical clustering. The first one is based on compar-

Figure 5.6: Representation of a sample of 1000 GAR (European Agricultural Guidance and Guarantee Fund) cases after multidimensional scaling with dissimilarities calculated by unweighted and weighted indexes shown on the left and right plots.
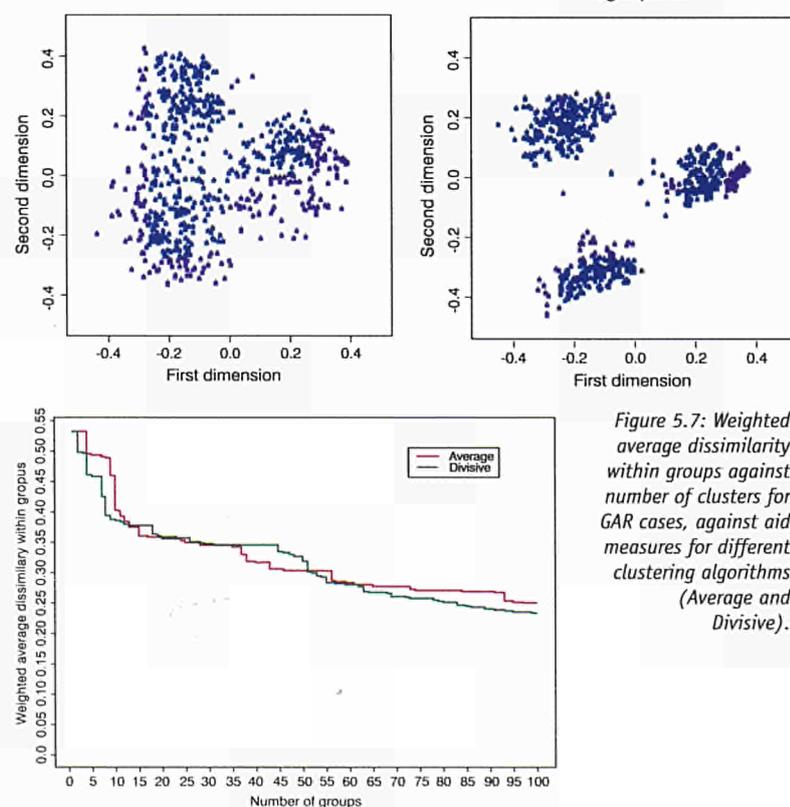

Figure 5.7: Weighted average dissimilarity within groups against number of clusters for GAR cases, against aid measures for different clustering algorithms (Average and Divisive).

ing clusters obtained by different algorithms. The second one measures the dissimilarities between cases in each cluster by an index called weighted average dissimilarity within group. As expected, the index is decreasing as the number of clusters increases. Figure 5.7 shows the weighted average dissimilarity within a group vs. the number of clusters for aid measures. A sharp drop in the index is indicative of the number of clusters in the data. Hence, Figure 5.7 suggests the presence of five to ten outspoken clusters in the data. Reports [5.24-5.26] and [5.28] contain partially confidential data and will not be disseminated freely.

Advanced Statistics for the Clearance of Accounts

author: S. Arsenis

In 1999 ISIS launched a four-year project which aims to provide a valid scientific basis for the choice of the sampling and estimation methods for conducting audits to estimate overpayment in payment populations. The methods should consider control costs and prior knowledge on total overpayment. The primary customer for this project is the DG Agriculture. OLAF, the European Anti-Fraud Office is the secondary customer.

Data analysis of payments and auditors' data provided the Institute's "wear-in" for this new project. It comprised all payments made by the paying agency of a Member State in 1994-1997 for export refunds on a major budgetary line together with the results of an audit conducted on the payment data. The final report on the data [5.29] elaborates on requirements that are to be satisfied by payments with particular reference to duplications and dates, highlights violations of these requirements in the payment populations and compares the data furnished to those required Community Legislation. Characteristics of the error populations are also studied and a new estimator of total overpayment is proposed.

We have reviewed two confidential reports of certifying bodies on payments made in 1998 by two payment agencies in one of the major Member States in the Union's agricultural policy. The reports examine payment procedures and/or samples of payments in 19 budgetary lines. Our analysis has revealed that for some budgetary lines the reports provide highly relevant information that may be conceived as prior knowledge for Bayesian estimation and definition of sample size. In addition, we discovered that operators reported by certifying bodies to have entered in irregularities in 1998, had extensively been reported earlier by Member State authorities to have committed frauds and irregularities against the EU budget. Our findings on the exploitation of the reports of certifying bodies are in preparation to be submitted to the appropriate Commission services.

As part of the development of *Bayesian approaches* for the clearance of accounts, the exact distribution for the total number of payments in error observed in Monetary Unit Sampling from finite populations has been derived [5.30]. Some extensions of the Bayesian approach proposed in the classic work of Cox and Snell have been done [5.31], and numerical comparisons of alternative estimators for total overpayment are reported in [5.32]. Report [5.29] contains partially confidential data and will not be disseminated freely.

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Risk Management and Decision Support

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author: A.C. Lucia

This chapter reports the main results of projects belonging to the fields of:
• risk and emergency management for natural and technological hazards;
• sustainable development;
The research and development activities relevant to these two fields are often strictly interrelated and synergistic and, in some cases, share methodologies and information and communication technology tools for the management of information and the support to decision making.

Some facts are strongly contributing to raise the attention on the above fields:

the complexity of technological systems has strongly increased in the last decade, as well as the number of "operational units" (e.g. number of flights per day in civil aviation); societal and environmental structures seem to show a rather unsatisfying degree of preparedness to face disasters and mitigate consequences; there is a diffused concern about the possible effects of global change on the probability of occurrence of natural disasters; citizens are paying an ever increasing attention to decisions, taken at any political level, that may have consequences on their health, their safety, the quality of their life or the state of the environment.

Risk management (analysis, reduction, perception and communication), management of emergency situations, sustainability assessment, and decision support are topics dealt with to respond to the above problems, together with a more general reflection on the science and governance.

Beside the Institutional activities (Major Accident Hazards Bureau; Natural and Environmental Disasters Information Exchange System; European Co-ordination Centre for Aircraft Incident mandatory Reporting Systems; Integrated assessment), a non-negligible part of work has been done in a competitive frame (mainly Shared-Cost Actions) or as a support to national authorities.

Risk and Governance

authors: S. Funtowicz, I. Shepherd

The mission of the Joint Research Centre is to provide scientific and technical support for the conception, development, implementation and monitoring of EU policies. Much of its work programme concerns security in a broad sense including the safety of individuals and the protection of the environment. As part of its mission JRC is active in raising awareness and participating in the debate on the changing nature of the relationship between science, government and the public. There are a number of reasons why such a debate is timely.

Firstly, there is the progress in science itself. For instance, developments in life sciences, triggered by an increased understanding of biological processes and rapid developments in technology, are producing new products and services for the market. These products are bringing undoubted benefits to the lifestyle of consumers and offer unprecedented promise for the future. But their impact needs to be understood and regulated and we must learn how to cope with innovations which could have effects that are long-term, unpredictable, and possibly irreversible.

Secondly, there has been an evolution in European institutions. The development of an Internal Market with common European standards and regulations, together with the emergence of the European Union as a representative of the Member States in trade discussions, such as those at Seattle, or environmental negotiations such as those at Kyoto, means that a debate at a European level is appropriate. The particular responsibilities of Member States, Council, Commission, Parliament, Agencies, Scientific Committees and courts are unique to Europe and the mechanisms for scientific advice to policy are not, in general, the same as elsewhere. The enlargement of the Union to include countries from the former Soviet-bloc is imminent and this is sure to bring new challenges and opportunities. Given this common commitment, it will be necessary to provide guidance for the provision of scientific advice on matters of relevance at the EU level. This work will necessarily be based on examples of experience both within Europe and outside.

Thirdly, an increased understanding of the complexity of the natural world has led to a realisation that scientific certainty in a number of important areas will not be achieved in the near future. Examples include the impact of particular greenhouse gases on global climate change, the impact of pollution on human health, or the possible hazards of the release into the environment of new chemical species, such as Xeno-oestrogens or genetically modified organisms. Where such risks are involved, some sort of "precautionary principle" needs to be explicitly invoked rather than implicitly assumed in the practice of research or regulation. This might be accomplished by (for example) exhibiting the consequences of different value judgements and problem-framing assumptions. Assessment of risks in a quantitative, technical style needs to be complemented by the contextual aspects of the complex systems in which hazards arise.

A lack of trust has recently characterised the debate on policy issues. Trust is essential for the proper functioning of science and governance alike, and is paradoxically more vulnerable in a literate, sophisticated society where citizens are able to assess the quality of performance of their institutions. The solidity and acceptability of the decision making system depends to a large extent on its ability to show that it can be fair and transparent and takes into account all the legitimate interests and opinions. There is a general agreement that the failed trade preparatory meeting of WTO in Seattle highlighted a growing influence of citizens' groups on global policies. Locating science within an interactive, reflexive and recursive process of governance can provide the means whereby public trust in science and confidence in the policy-making process can be restored and maintained.

The JRC is engaged in a number of initiatives and events for the achievement of these goals. The main goals are firstly to identify the policy concerns that require a scientific advice, secondly to determine the balance between technocratic and participatory approaches in delivering the advice, thirdly to manage risk and uncertainty and finally to enhance the mutual trust among the public and the institutions involved with science and governance.

Man Made Hazards

introduction: J.S. Duffield

Man's continual pursuit of technological development poses a small but inevitable risk to society in general. The public acceptance of this risk is closely linked to the balance between the benefit and the potential undesired consequences arising from such activities. Two industries which play a central role in creating our present day life-style, are the chemical process industry and air transportation industry; and it would be difficult to imagine our society functioning without them. It is therefore of paramount importance that the safety of these industries is assured, and much of the Institute's efforts related to man-made hazards concentrate on this.

The Major Accident Hazards Bureau (MAHB) supports EU policy on the control of major hazards involving dangerous substances and the prevention and mitigation of major accidents from fixed installations, and closely coupled to this is the support given to the upcoming Directive concerning the carriage of dangerous substances in pipelines. Other activities have been carried out supporting Regional Policies in the field of Civil Protection. Central amongst these is the development and installation of an integrated system for environmental pollution monitoring, accident detection, emergency management and support to land use planning and recovery. In parallel reliability and safety software tools have been developed. Regarding air transportation safety the European Co-ordination Centre for Aircraft Incident Reporting Systems (ECCAIRS) has been located within the Institute. This system collects mandatory information on aircraft incidents and allows civil aviation authorities to exchange information amongst themselves. By analysing these data and identifying "root causes" the expectation is that air transportation will be continually improved.

Major Accident Hazards Bureau

authors: J.S. Duffield, N. Mitchison, C. Kirchsteiger

The Major Accident Hazards Bureau (MAHB) gives independent scientific and technical support to the Commission in the field of EU policy on the control of major hazards involving dangerous substances and the prevention and mitigation of major accidents. This most notably concerns the successful implementation and monitoring the "Seveso II" Directive 96/82/EC for the control of major hazards in fixed installations. Furthermore, in order to fulfil its information exchange obligations towards the Member States, the Commission established the Major Accident Reporting System (MARS) and the Community Documentation Centre on Industrial Risks (CDCIR) which are managed and maintained by MAHB.

The principal customers of the MAHB are the Commission, particularly DG Environment, and all actors concerned with process plant safety including the legislative and regulatory process; these customers include national and local authorities, industry, research organisations, safety consultants and trade unions. The transposition of the "Seveso II" Directive into Member States' national law was due to take place by February 1999. This introduced significant changes to policy related to the control of major hazards, and it is these changes and their consequences, which were the focus of much of the Bureau's work in 1999.

Member States are legally obliged to notify the occurrence of major accidents to the Commission, and significant effort is devoted to the analysis of these accidents and to extract and distribute lessons learnt. To this end, the Bureau operates and maintains an *accident reporting system* called MARS. Using this system, Member State authorities have a local data logging system, which they use to prepare accident reports. These reports are then submitted in electronic form to the central MARS system run by the MAHB, where advanced analysis tools have been developed to facilitate in-depth analysis of the accidents notified. To enhance transparency it is intended that much of this data will be made generally available through the MAHB web site.

The *Community Documentation Centre on Industrial Risk* now holds over 3500 documents and is a very important source of knowledge on process safety and industrial risk. This library holds, in addition to documents conventionally published, a wide range of "grey literature", such as company reports, codes of practice, accident reports, safety studies, etc. A new web-based facility has been prepared in 1999 holding indexing information, abstracts, authors, keywords etc., for all these documents thereby enabling on-line access to the CDCIR through the MAHB web site.

During 1999 a prototype of a European wide, GIS-based, accident analysis package specifically ori-

Figure 6.1: Consequences of an uncontrolled runaway reaction in a batch chemical production plant. (Courtesy of The Examiner, Cork, Ireland)

ented towards "Seveso" industrial plant was developed. This software, the *Seveso Plant Information Retrieval System (SPIRS)*, has the goal of containing all relevant data on industrial plant throughout Europe which has to comply with the Directive. It will enable the Commission to perform hazard potential and risk categorisation assessments on a uniform basis.

The Bureau, in close collaboration with DG Environment, runs a number of Technical Working Groups. In most cases the primary objective of these groups is to develop guidance to ensure a coherent and correct implementation of the Seveso II Directive. It was a major achievement that, as a compendium to the Directive and prior to the transposition of the Directive into Member States' national law, a full set of "guidance" documents has been completed, published and widely distributed by MAHB. Guidance documents are available on "Information to the Public",

"Inspection Systems", "Safety Reports", "Safety Management Systems", "Major Hazard and Land-use Planning" and "Harmonized Criteria for Limiting the Information in a Safety Report". All can be viewed and downloaded from the MAHB web site. Further work, as requested by the Council of Ministers and the European Parliament, concerning "Substances Dangerous to the Environment" (TWG7); and "Carcinogenic Substances" (TWG8) is ongoing. The outcome from these working groups will be in the form on an amendment to the Directive. Similarly, preparative work has been undertaken this year on the formulation of a draft directive on the hazards associated with the transportation of dangerous substances through pipelines. The Bureau has a long tradition in organising international seminars on themes related to industrial risk. In 1999, in view of the transposition of the Seveso II Directive, an important international conference was organised in Athens entitled "Seveso 2000", in which delegates from competent authorities, industry research organisations and academia were able to present their views on the worth, practicalities and functioning of the Directive. Over 250 delegated from 33 countries attended. A related more restricted seminar was also organised in Turku, linked to the committee meeting of the Competent Authorities, in which software relevant to the Directive was presented.

The Directive and the functioning of the Major Accident Hazards Bureau can also be viewed as a model on which the Pre-Accession States, the Central and Eastern European States (CEE) and the Newly Independent States (NIS) can base their own policies on the control of major hazards and the prevention and mitigation of major accidents. The growing importance of the internet has been recognised and MAHB maintains an active and dedicated web site "http://mahbsrv.jrc.it" from which documentation, software tools, MAHB publications and relevant information can be readily downloaded by interested parties. A selected list of MAHB publications for 1999 is given in [6.1 – 6.12].

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ECCAIRS: European Co-ordination Centre for mandatory Aircraft Incident Reporting Systems

author: W. Post

ECCAIRS is a network of collaborating EU aviation authorities with the objective to collect and assess aviation incident information from EU Member States. Authorities exchange information amongst them and contribute to the EU information system in the ECCAIRS central office, located at the JRC in Ispra. The project's objective is to have all Member States participa-ting actively in the ECCAIRS network by the end of the Fifth Framework Programme. From the central office, data and assessments are disseminated to the national aviation authorities and other autho-rised organisations.

The ECCAIRS project has designed and implemented the tools that are at the basis of the proposal (prepared by DG Transport) for an EU Council Directive: "Establishing a co-ordinated system of national mandatory occurrence reporting schemes in civil aviation". This directive is based on the conviction that the establishment, at Community level, of a mandatory reporting system is feasible and that a suitable tool (ECCA-IRS) has already been developed. It is expected that this directive will be adopted and activated before the end of 2003.

In 1999 the ECCAIRS steering committee has been created, in which representatives of all EU Member States have taken a seat. Other European aviation authorities (Iceland and Norway) as well as ICAO, ECAC and JAA are represented. The list of steering committee members comprises about 25 organisations. From 1999 onwards, this committee will decide on how the ECCAIRS network and tools will evolve. To support the committee, the ECCAIRS website has been extended with a collaboration forum, which the steering committee can use to exchange opinions and information.
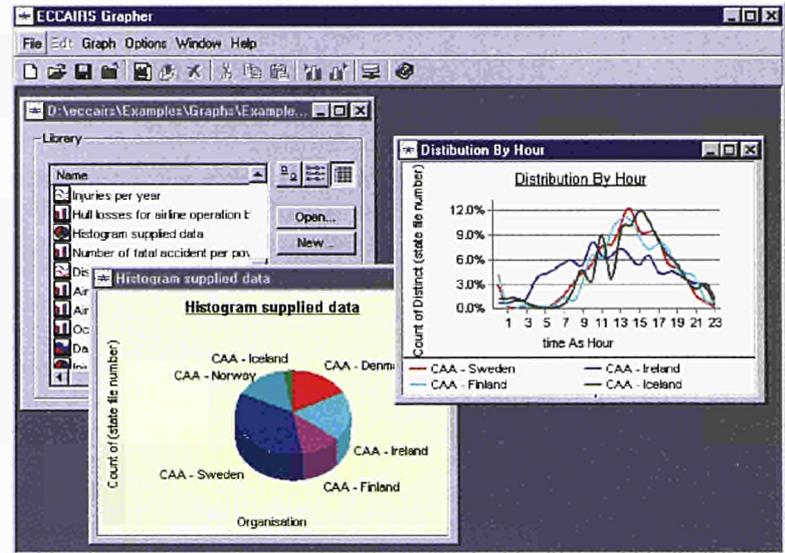

Figure 6.2: The ECCAIRS Grapher application in action.

In October 1999 release 3.3 of the ECCAIRS Reporting System software has been presented to the newly erected steering committee. This new version of the software is now distributed to forty-three aviation authorities (or related organisations) in Europe, the United States, New Zealand, Canada and Africa. The reporting system allows the authorities to collect civil aviation incidents and accidents data following an internationally well accepted standard (ICAO-ADREP). New is a facility to graphically analyse the contents of the databases (see Figure 6.2). Data from the national information systems can be sent electronically to the ECCAIRS central office, to peer organisations in other countries, and potentially also to ICAO (International Civil Aviation Organisa-tions, the UN authority for civil aviation).

Eurocontrol plans introducing incident reporting for Air Traffic Management at European level. The strategy is to base the electronic reporting tool on the ECCAIRS database structure and technology. During 2000 the tool will be developed in a collaborative effort with ICAO and the JRC.

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Risk Monitoring and Emergency Management

authors: J.P. Nordvik, A.C. Lucia

The Italian Ministry for the Environment entrusted ISIS with the SIMAGE project to establish a national integrated system for environmental monitoring, risk management, and environmental end technological emergency management.
Objectives are:
• to create harmonized air-quality networks for the industrial areas of Brindisi and Taranto, including the integration and optimization of existing air-quality networks, the installation of new monitoring stations and air pollutants instruments, and the definition of quality-control procedures and associated control laboratories;

Figure 6.3: One major objective of the SIMAGE Framework Agreement with the Italian Ministry for the Environment is the development of an integrated information exchange network that covers the main existing Italian risk areas.

Figure 6.4: Here the HARIA-GIS displays combined information about the affected industry, the area of interest for the emergency, traffic density and the available resources.
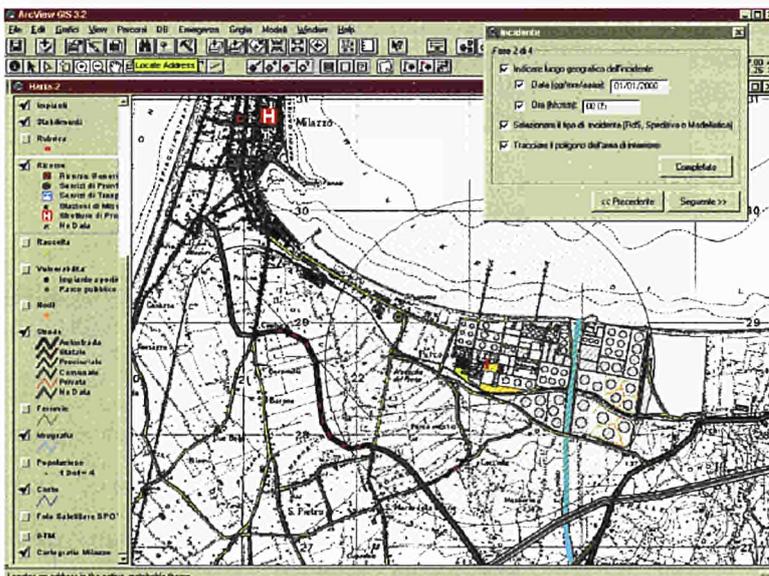
• to design and establish a national coordination centre for environmental information exchange concerning air, water and soil quality; networked with the major existing Italian risk areas, in particular, the areas of Brindisi, Taranto, Porto Marghera, Priolo-Augusta, Gela, Milazzo, Genova, Ravenna e Livorno-Piombino;
• to develop a pilot system for the monitoring and control of the transportation of dangerous substances via road, railway, and sea, including a benchmark exercise of tracking and mobile communication technologies, and the realization of local systems in Brindisi, Taranto and Porto Marghera for traffic control and emergency management;
• to define a set of indicators for the assessment of the environmental sustainability of highly industrialized areas, their evaluation for the Brindisi and Taranto areas, as well as their use for the development of decision support tools for effective land management and restoration policies.

SIMAGE started effectively in Autumn 1999 with ISIS in charge of the design, realization and effective establishment of the- integrated system, as well as of the overall project coordination.

HARIA-GIS: a Support Tool for Emergency Planning

author: S. Contini

The HARIA-2 project provides a methodology for supporting the emergency planning in hazardous chemical/petrochemical industries as well as for training decision-makers. HARIA-2 is an initiative supported by the Italian National Research Council in co-operation with the Civil Protection Department. The project is performed jointly with the University of Pisa (Co-ordinator), the University of Trieste, the International Institute of Sociology (Gorizia), and the Centro Studi Esperienze of the National Fire Brigade Corp of Italy. The research presents various interesting aspects, namely:
• The consideration of the probable behaviour of the population depending on the type and frequency of the information received;
• The simulation of the emergency taking into consideration the road traffic evolution and the movement of rescue services (e.g. accident type, road traffic, resources availability) and the actions taken by the user (e.g. closure of roads, evacuation of a vulnerable centre or of a residential area);
• Improving knowledge on the characteristics of the industrial activities taking place in the area of interest and the potential for damage in case of accident;

- Identifying the necessary resources to face emergency situations;
- Evaluation of intervention times of rescue services, depending on the status of the road network and of the traffic density;
- Comparison of evacuation against staying indoors;
- Comparison of different intervention strategies;
- Plotting of the number of people at risk vs. time;

HARIA-GIS represents the prototype software tool implementing the methodology, which will finally be validated on a real case.

The ASTRA Toolset for Systems Dependability Analysis

author: S. Contini

ASTRA is a powerful tool, based on the fault tree technique, for complex systems dependability analysis. At the current stage of development, ASTRA is composed of the following modules:

- Project Manager (Desktop), to efficiently manage the large amount of data generated during the analysis;
- Fault Tree Analysis (Basic tool), implementing a powerful analysis method, based on Binary Decision Diagrams, able to completely quantify very complex fault trees (which were not possible to quantify before without adopting crude approximations);
- Fault Tree editor and Reliability database for supporting the fault tree construction and editing (add-on module);
- Probabilistic Time Dependent Analysis allowing the simulation of any type of testing and inspection policy (add-on module);
- Sensitivity and Trade-off analysis for system design improvement based on the concurrent analysis of the whole set of fault trees describing system failure states (add-on module);

Other modules will be added soon, covering aspects such as uncertainty, event trees and Markovian stochastic processes. Information on ASTRA is available at http://dsa-isis.jrc.it/astra.

Cipratech

author: J.P. Nordvik

The principle aim of Cipratech is the transfer of risk evaluation technologies from the nuclear engineering sector to the capital investment sector. The CIPRATECH concept is based on a suite of methodologies, services and tools that will facilitate the evaluation of risk for venture capital initiatives, and for mutual and pension funds management. This new and rapidly growing business area includes high-tech start-ups, which need extra funding to start the production of innovative products, and SMEs which want to increase and renovate their production facilities. Many of such venture capital initiatives fail because of insufficient access to information and funding.

CIPRATECH provides a new perspective of risk, extended to a business area for which existing evaluation tools do not address all aspects of risks in a systematic way. The technology transfer opportunity is offered by software technologies developed and copyrighted by ISIS for Industrial Probabilistic Risk Assessment (PRA) and in particular the software platform called Stars Studio. CIPRATECH's output will be a risk assessment report which should assist the capital investor/manager in his evaluation process. It also gives recommendations to the seeker/entrepreneur for a better chance of success. The main contribution of ISIS in this project has been the adaptation of the

Figure 6.5: Event tree analysis of a scenario that would result from the failure of the Marketing and Sales aspect of a venture capital business proposal. The scenario considers mitigating and degrading events, showing their respective probabilities of occurrence. At the end of each scenario path is a quantification of the path frequency, its consequence (in terms of financial cost) and the overall risk.
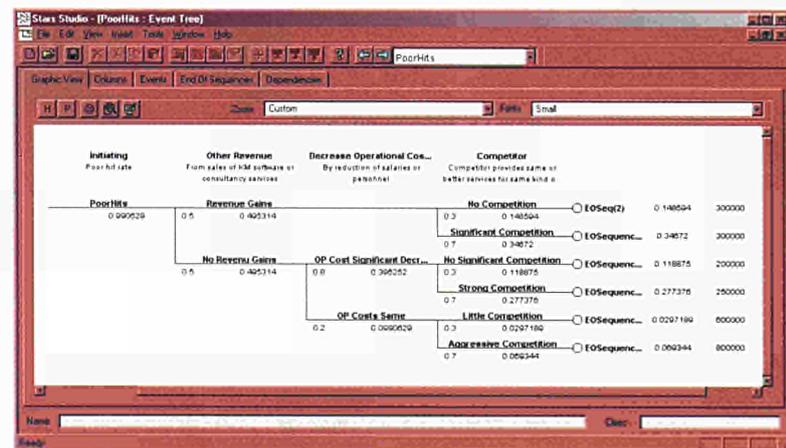
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underlying PRA methodology of Stars Studio for the Venture Capital domain. This included the identification of the PRA techniques, and the definition of the associated methodological tasks together with the information that should be solicited from the Venture Capital experts. The Stars Studio platform now has an automatic report generator. This new functionality generates a Microsoft Word document that incorporates configurable selection modelling and analysis information.

A "test business case" has been modelled and analysed using Stars Studio. The case started with a Business Proposal, a typical document that is presented to Venture Capitalists. This business proposal was abstracted into a Stars Studio System model. A preliminary Hazard Operability (HAZOP) analysis was performed using Risk Matrix techniques to identify prominent dangers to the proposal. These prominent dangers were then analysed in greater detail using Event Tree and Fault Tree analysis. The transfer of PRA techniques to the Venture Capital domain has shown promising results so far. The Cipratech project is ongoing and is scheduled for completion at the end of the year 2000.

HARSNET: Thematic network on hazard assessment of highly reactive systems

authors: J.M. Zaldívar, J.S. Duffield

HarsNet is a Brite-EuRam thematic network on hazard assessment of highly reactive systems.

The main objective of this network is to transfer the safety knowledge, procedures and best available practices from big companies and research centres to small and medium size chemical industries. The Network has been running one year and it is fully operational. The following projects are running:
- Harsbase: A database on publications related to European and national projects, with information on thermal hazard assessment, research groups and safety laboratories with details of their abilities;
- HarsWeb: http://www.harsnet.de/ contains information concerning the different tasks and last developments;
- HarsGuide: A guide containing best available practices for safety assessment of reactive chemicals outlining not only the methodologies but also the current discrepancies. This guide is addressed to experts in the field but the idea is to develop further a common methodology (HarsMeth) addressed to everybody responsible for supervising and controlling chemical processes;
- HarsSMEs: Dissemination of the information to SMEs through the organisation of national forums where chemical industries are invited (forums have already been organised in Italy, England, Germany, Greece and Spain);
- HarsRes: to propose research projects supporting HarsNet methodologies. Three research proposals have already been submitted;

HarsEdu: Review and standardise the contents of the different national educational programs for teaching technical safety at universities and technical institutions.

Natural Hazards

introduction: A.G. Colombo

This section presents four contributions:
- The NEDIES project, which provides scientific and technical assistance to Member State civil protection services and organisations involved in the management of natural and environmental disasters;
- An exploratory research study on the dynamics of earthquake faults;

- Activities performed in co-operation with IIASA (International Institute for Applied Systems Analysis) in the area of catastrophic risk management;
- An application of geographic information system and spatial analysis techniques to the problem of harmonising the European map of snow loads for structural engineering design codes.

Natural and Environmental Disaster Information Exchange System (NEDIES)

authors: A.G. Colombo, C. Theophili

The project NEDIES (Natural and Environmental Disaster Information Exchange System) was launched to support DG Environment. The main aim of the project is to provide scientific and technical assistance to Member State Civil Protection Services and Organisations involved in the management of natural and environmental disasters, and help in the exchange of experiences at European level. The overall project has been split in two phases: the pilot phase and the operational phase. The pilot phase started in January 1997 and was dedicated to the design, development and testing of the overall methodology which now is being implemented in the operational phase; the activity focused on few types of natural disasters, mainly floods and earthquakes [6.16]. The operational phase of the project started in the mid 1999, extending main types of natural disasters (e.g. floods, earthquakes, avalanches, landslides, forest fires) and considering also environmental disasters. The project deals with disasters on the territory of the Union and associated countries (EEA) and, in less priority, with outside disasters of significant interest for the Member States.

A first meeting on "Analysis of Catastrophic Avalanches occurred in the EU and Proposal for Concrete Measures" was held at the JRC Ispra on 4 and 5 October 1999. The meeting was attended by experts from Austria, Finland, France, Iceland, Italy, Luxembourg, Norway and Switzerland. Four avalanche disasters occurred in Europe and two avalanche disasters occurred in Iceland were presented and discussed. A "lessons learnt report" is being prepared, based on the contributions presented at the meeting. At the same meeting, four working groups were created, with the aim of producing recommendations on how to face an avalanche disaster. The working group areas have been defined according to the main management phases of a disaster, i.e.: prediction and mitigation, prevention (including risk assessment), preparedness and intervention (immediate response measures), and information to the public. Each working group is preparing recommendations to deal with the problems arising in the respective area of competence.

Earthquakes predictability

authors: P. Haehner, Y. Drossinos

Exploratory research on the dynamics of earthquake faults extended ISIS expertise on structural dynamics (ELSA) and on risk of complex systems. The emphasis of the project was earthquake predictability, and the associated hazard estimation, via a careful analysis of a physically motivated, non-trivial model of fault dynamics.

The new model is based on the slider-block, stick-slip Burridge-Knopoff model of fault dynamics. Specifically, a new variable was introduced to describe fault creep, thereby allowing for both plastic deformation of the fault interface and rigid sliding [6.17, 6.18]. The new creep-slip model was shown numerically to reproduce salient features of earthquake phenomenology; specifically, the event-size distribution (the distribution of number of seismic events as a function of their sizes) was found to simulate the experimentally observed Gutenberg-Richter relation. Numerical results are presented in Figure 6.6. Moreover, the creep-slip model was approximated by a cellular automaton algorithm that reproduced the algebraic correlations [6.19].

Analytical results demonstrated that the creep-slip model, as does the original Burridge-Knopoff model, exhibits a Hopf bifurcation in the velocity softening regime. It was argued that this analysis had implication on earthquake predictability. In
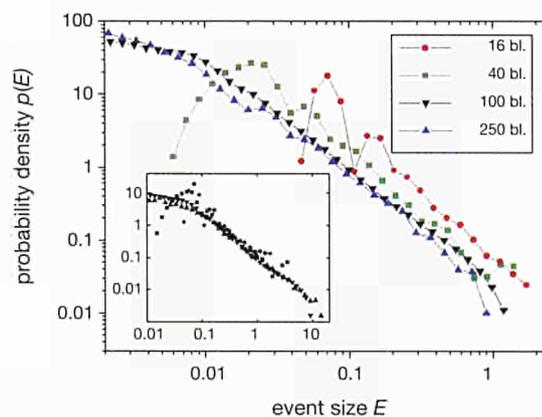
Figure 6.6: Event-size probability density for chains of 16, 40, 100, and 250 blocks. Total number of seismic events was approximately 50 000 (100 blocks). Inset: finite-size scaling plot. The numerically determined fractal distribution is consistent with the Gutenbeg-Richter relation for the frequency-magnitude statistics of earthquakes (a power-law dependence of the number on the size).

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particular, it suggests that aftershocks dynamics may be deterministically chaotic. Thus, provided low dimensional chaos may be identified, non-linear time series analysis could allow short-term forecasting of aftershock dynamics. However, this short-term predictability (related to the largest Lyapunov exponent) would still be limited by the sensitive dependence on initial conditions.

Detailed analyses of model-generated time series showed that if a spatial average is performed over the whole system, the probability of occurrence of a large event follows Poisson statistics. Namely, according to the numerical analysis of the model, spatially averaged seismic events are asymptotically (for large time separations) uncorrelated in time. However, single-site time series showed a well-defined characteristic time scale related to the tectonic drift. Hence, if precursory phenomena are to be correlated to the main event, both temporal and spatial correlations should be analysed concurrently. Alternatively, the spatial distribution of seismicity is coupled to its temporal variation.

The outcome of this project was the development of a new model of fault dynamics and the associated software tools for the analysis of synthetic-earthquake statistics, and in general of fractal distributions. The acquired expertise can be constructively applied to risk analysis of other complex interconnected systems describable by power-law distributions, for example engineering systems.

Catastrophic Risk Management
author: A. Amendola

The cooperation with IIASA (International Institute for Applied Systems Analysis) on CRM (Catastrophic Risk Management) is continuing. The management of catastrophic risks requires their assessment via hazard and vulnerability analysis; allocation of resources for their prevention and mitigation; and, strategies for risk burden sharing (insurance and other financial instruments). Global change, natural disasters and is-

sues of efficiency and equity in loss sharing have been analysed and discussed in an article being published in the Geneva Papers of Studies on Risk and Insurance.

As far as modelling is concerned, IIASA has developed a spatial-dynamic, stochastic optimisation model to support decision making processes on management of catastrophic risks. The model is based on Monte Carlo simulations of catastrophic events in the selected regions. The key feature of the model is the stochastic search technique enabling adaptive adjustments of decision variables towards desirable outcomes on the basis of sequential simulations. The model can account for the interplay between ex ante investment in prevention/mitigation measures (on the part of the public authorities, the citizens and the insurance industry) and policies for sharing the financial costs ex post to the disaster. Insurance and other financial instruments can be viewed as reducing catastrophic losses to a community by spreading these losses over a wider region, and therefore as decreasing individual catastrophic exposure. Such instruments come into play when the costs for further prevention/mitigation are prohibitive. The model is useful to national/regional authorities in informing decisions on overall catastrophic risk management. For this a comprehensive case study concerning earthquake risk has been designed together with the Institute of Seismic Risk Research of CNR in Milan. In 1999 an earthquake loss simulator has been implemented. The risk management results will be available mid 2000, and presented at a jointly organised Euro Conference, supported by the EC - TMR program on July 6-8, 2000 at IIASA. The conference on "Global Change and Flood Risk Management In Europe" was held in June 1999 (http://www.iiasa.ac.at/Research/RMP/june99/index.html). One objective was to examine the possible influence of global change phenomena on the potential future losses from flood events in Europe. A second purpose was to examine risk management issues to mitigate flood damage and to improve the spread of the losses. From the presentations on climatic issues, the primary conclusion was that increases in precipitation associated with global warming will probably have little effect on future flood losses in Europe, even if locally flash floods might be enhanced by sea surface temperature increase (Italian Riviera) or coincidence with earlier snowmelt and spring rainfalls in mountain regions. The greater contribution to such losses will likely come from the increased movement of population, capital, and infrastructure into vulnerable regions. The most effective regulatory response to potential disasters appears to be to enhance preparedness, and, at the same time, mitigation by non-structural

Figure 6.7: Flood interventionism.

measures (structural measures might decrease the frequency but increase the potential for losses). Insurance and other financial instruments (such catastrophe bonds) for risk sharing could play an important role in managing the associated financial risk. In the industrialised countries, the extent of insurance coverage for these events is remarkably low. Exceptions in the EU are countries such as France in which the government plays a major role in co-operation with private insurers. Turning to issues of risk sharing and mitigation, the conference participants examined particularly the role of pre-disaster measures, such as insurance and mitigation, with post-disaster financing measures for relief and response. Whereas the repair of public infrastructure is a clear responsibility of governments, the socially desired role of the government in compensation and disaster aid to the victims is controversial. The main (but not the only) argument underlying this position is the failure of ex post public disaster aid to provide incentives for the socially optimal reduction of the damages from natural disasters. This is an efficiency argument, where the goal is to optimise the overall social risk level given the costs of its reduction. It is important to balance efficiency arguments with ideas of what is fair in sharing the risks. The challenge is to design policies for resource allocation between ex ante and ex post measures, both in prevention/mitigation and risk sharing provisions, which include the public and the private sectors in a way that the two objectives of risk sharing and committing to prevention can be pursued.

Figure 6.8:
Harmonising the European map of snow loads: an example of the zoning map derived for the Alps region.

Harmonising the European Map of Snow Loads

authors: B. Eiselt, R.J. Peckham, G. Solomos

ISIS has been applying a Geographic Information System and Spatial Analysis Techniques to the problem of harmonising the European Map of Snow Loads for structural engineering design codes. The project was financed by DG Enterprise. The project consortium was led by the University of Pisa, has partners in Italy, Germany, France, UK, Norway and Switzerland, while the countries covered and mapped include the 18 members of CEN, the European Committee for Standardisation. The project was aimed at improving the scientific knowledge and models for the determination of snow loads on buildings, and producing a sound common scientific basis which can be accepted by all European countries involved in the drafting of European codes for Structural Engineering. In the past, different countries have used different approaches to the statistical analysis and map-
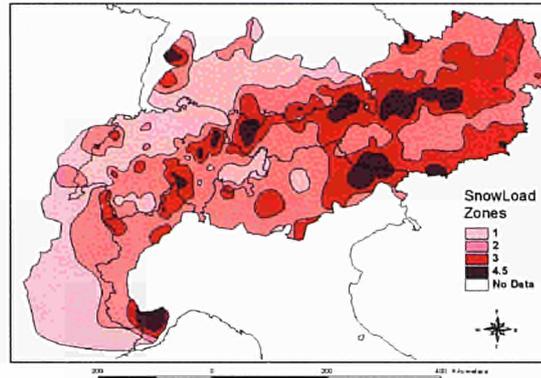
ping procedures as well as different return periods in their characteristic snow load values. It has therefore been necessary to set up and apply harmonised procedures for both statistical and spatial analysis.

Individual project partners have been responsible for collecting the data on snow loads on the ground for the countries concerned (typically several hundred weather stations per country) and determining the characteristic values of the snow loads, with 50 years return period, using agreed harmonised statistical procedures. ISIS has been responsible for setting up an integrated GIS database using the results supplied by the partners, and applying harmonised techniques of spatial analysis to develop the snow loads maps.

The approach used for the mapping aimed to identify zones where specific relationships between snow load and altitude apply. It involved several stages including the definition of climatic regions and the evaluation of the data for every climatic region in order to define distinct snow load zones. Finally a validation procedure was used to check that differences occurring at region boundaries lie within acceptable limits.

As a result of this work, a first harmonised snow load zone map has been developed for all the climatic regions in the 18 CEN countries. The use of GIS and spatial analysis has proved to be indispensable for structuring, and analysing the data as well as visualising and interpreting results. For the majority of regions the map is based on snow load-altitude relationships, while for Iceland and Norway the value interpolated is directly snow load, as in these countries there is no identifiable snow load-altitude relationship. Here other factors, like distance from coast and special microclimatic characteristics have a strong influence, and much more detailed work is still required to map all such local effects. Local knowledge of special climatic aspects should be taken into account where meteorological data is missing. Also the map will eventually need to be extended in order to include other central and eastern European countries which are foreseen to enter the European Union.

Interregional Migration Modelling

authors: B. Eiselt, N. Giglioli, R.J. Peckham

On behalf of EUROSTAT, we explored the possibility of using European socio-economic data available in the REGIO database to model interregional migration flows. The aim was to look for correlations between migration and other socio-economic statistics available at European level, and to assess whether they could be used in simulations related to European Spatial Development Policy (ESDP).

The work made use of Spatial Interaction Models (otherwise know as Gravity Models) and, after an initial assessment of the data quality and availability, it followed the classical steps of exploratory analysis, model formulation, model fitting and finally testing the use of the model for prediction. A GIS based tool for visualisation of the actual, modelled and predicted migration flows was also developed as an aid to exploring and understanding the migration flows, and as a means to visualise the results of model predictions (see Figure 6.9).

Figure 6.9: Visualisation of migration flows using the GIS based tool developed in the study on interregional migration modelling; modelled net flow for Saarland (Germany) in 1991.
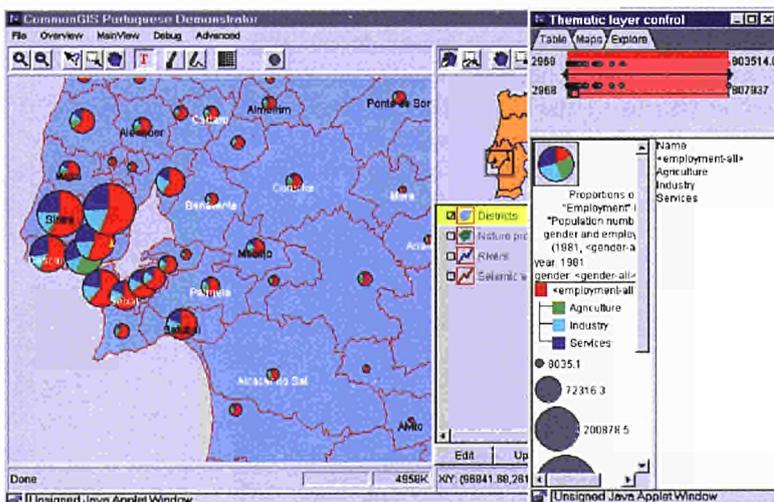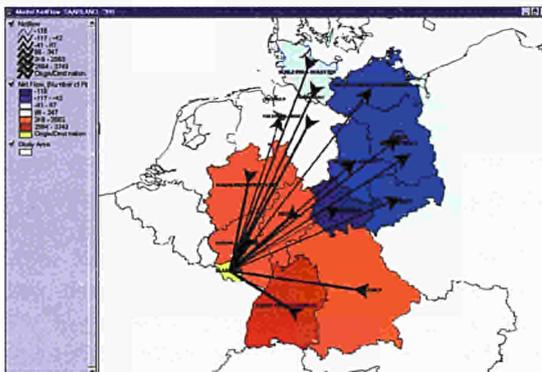
Some useful correlations were found, in particular between migration and GDP, and between migration and unemployment rate. The main findings of the study can be summarised as follows:

- The REGIO database has been successfully used for interregional migration modelling with some limitations due to availability and the level of detail of the data.
- REGIO database has been successfully used for Cluster analysis based on the values of *total inflow divided by population, total outflow divided by population, GDP per inhabitant, and unemployment rate* (percentage of unemployed out of total workforce). The identified clusters agree with our perception of the political/economical/social situation in the three countries.
- A range of different log linear models have been considered. Comparing the fits of all these models, it is found that several models yield good fits for the countries and years considered. However, a model with real world explanatory variables is more useful for simulation purposes than a model with lumped parameters; based on this criterion a single model could be selected that includes total GDP and unemployment rate as explanatory variables.
- The final model has been tested by applying it to predicting migration flow in past years for which flow data are available, with satisfactory results.
- Although the REGIO database contains useful data for this kind of modelling, this work points to the need for inclusion of the *Age structure* and the *Educational structure* of the migration flows.

Results were presented at the SIMILOR conference in the Netherlands, on simulating land use change, (http://www.econ.vu.nl/re/similor/) where interregional migration was seen as one of the important driving forces behind changes in land use.

The CommonGIS Project

authors: R.J. Peckham

Throughout 1999, ISIS participated in the CommonGIS Project, which has the motto "GIS for everyone, everywhere". This is a shared-cost action (SCA) to develop the means to access GIS based visualisations of statistical data via an internet browser, in a user friendly way, accessible to everyone. A range of possible applications are foreseen including web based visualisations of EUROSTAT's statistical data on population, employment, education, energy production etc; visualisation of election results or cadastral data. The first prototype of CommonGIS can be viewed and tested at http://commongis.jrc.it/.

Figure 6.10: Screenshot from the first prototype of CommonGIS; visualising employment data for Portugal through a www browser.

Software for Process Industries

author: B. Worth

Software and computer models developed in support of ongoing activities within ISIS are finding useful outlets in a range of industrial applications. Process engineering benefits from software developed variously for emergency pressure relief and venting systems, industrial gas-liquid chemical reactors, and the simulation of gas cloud explosions in complex geometries. These tools are allowing improvements to process safety and design as well providing the computational means for improving performance and efficiency for a range of industrial processes.

RELIEF: Emergency pressure refief simulation

author: J.S. Duffield

The RELIEF software models the phenomena associated with emergency pressure relief of chemical plant when an uncontrolled thermal runaway reaction occurs. These types of accidents occur all too frequently and their relevance is strongly related to the EU Seveso II 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 important accidents which have resulted in significant loss of life, and adverse impact on the environment. Recognising that the underlying physical phenomena are complex and difficult to understand, RELIEF has been specially developed to be user friendly and to ease the task of designing relief devices and disposal systems. Further information documentation and demonstration packages can be downloaded at http://mahb.jrc.it/RelatedProjects.html/.

ADMIRE: Advanced Design Methodologies for Improved Performance of Gas-Liquid Reactors

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

The ADMIRE shared-cost action develops advanced methodologies for designing gas-liquid

chemical reactors which are used for gas production in chemical and petrochemical industries. The Computational Fluid Dynamics (CFD) tools developed allow detailed calculations of complex local flow and related turbulent phenomena. It is expected that these techniques will replace in the near future the highly empirical design methods used today, which rely heavily on expensive experimental verifications.

Recent advances in ADMIRE led to the improved modelling of the governing two-phase flow processes; including the description of fluid-particle interaction such as bubble coalescence and break-up, the ability to treat bubble size distributions, two-phase dispersion and turbulence phenomena, and their coupling with heterogeneous chemical reactions. ISIS developed and assessed a new model for the transport of Interfacial Area Concentration (IAC) - a flow parameter which largely governs the coupling of the two phases and the chemical reaction kinetics. The IAC model has been implemented into the JRC 2-D Advanced Two-Phase Flow (ATPF) code (see also chapter 4) and a number of assessment calculations have been performed for the model verification.

PIOWC: Performance Improvement of an Oscillating Water Column Power Plant

authors: F. Andritsos, I. Vakalis

An OWC Power Plant produces electricity from wave energy. It consists of a chamber constructed along coastlines where the sea is quite rough. The incoming waves produce an oscillating free surface of the water inside the chamber causing, via a piston effect, an oscillating pressure of the air on the upper part of the chamber. A Wells turbine (i.e. with symmetric blades assuring a rotational direction independent from the air flow direction), on the top part of the chamber, converts the resulting air flux into electric energy (Figure 6.11). A pilot OWC plant has been constructed in Pico, Azores, equipped with such a Wells turbine. The PIOWC project proposes the substitution of the 'conventional' Wells turbine by an innovative variable angle, actively controlled blade turbine. Measurements, done on the existing plant, as well

Figure 6.11:
Schematic design of
an Oscillating Walter
Column (OWC) power
plant.
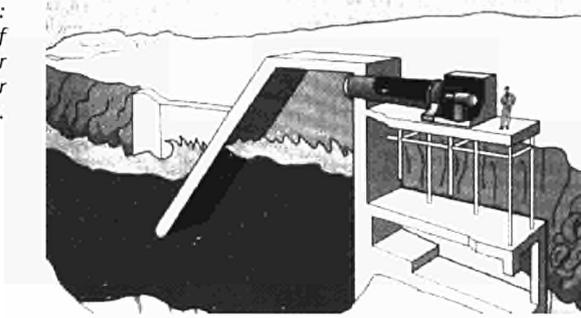
as computer simulations have indicated a significant potential for improvement in the plant efficiency. This implies a real-time blade-angle control according to one or more optimising strategies. JRC's task, within PIOWC, is to design and build the real-time control system for the turbine blade angle control of an innovative, variable pitch turbine that will allow the performance improvement in the existing OWC power plant.

REACFLOW work in the field of Industrial Hazards
authors: T. Huld, H. Wilkening

The REACFLOW software (for details see page 67) was applied to study accident scenarios in a road tunnel for a car with a hydrogen fuel tank (Figure 6.12). The tunnel calculations were performed with the new 3D compressible solver, using dynamic grid adaptation for improved accuracy. These calculations were performed in collaboration with Demokritos Research Centre, who calculated the initial hydrogen distributions that formed the basis for the explosion simulations made with REACFLOW.
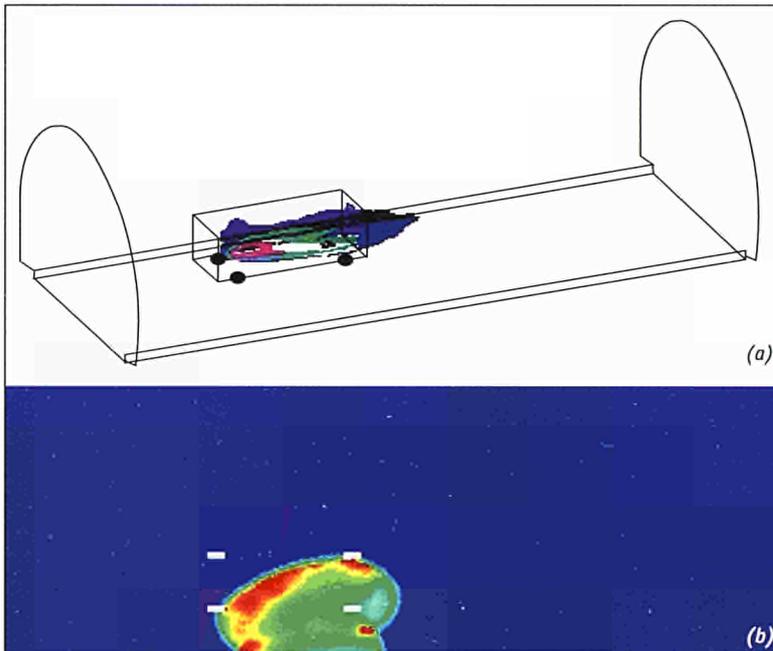

(a)

(b)

Figure 6.12: Validation calculation for the 3D reactive compressible solver of REACFLOW.
(a) The domain is a 20m section of a two-lane road tunnel, with a single stationary car. The simulation is of an explosion in a hypothetical hydrogen cloud around the car: the outline of the tunnel domain together with iso-surface plots of the hydrogen concentration, showing surfaces with hydrogen concen-trations of 8% (blue), 15% (green), and 29% (red) volume fraction.
(b) Pressure isocolour plot in a horizontal plane positioned at 15cm above the ground at a time t = 1ms. The four white rectangles represent the wheels of the car. At this time the explosion is propagating in the space between the car and the ground.

STARS STUDIO for Reliability, Availability, Maintenance and Safety Analyses
author: J.P. Nordvik

ISIS delivered the final release of the STARS STUDIO software package for Reliability, Availability, Maintenance and Safety analyses of complex technological systems. STARS Studio offers a unique integrated solution to support on normal PC-platforms both quantitative and qualitative analyses including: Preliminary Hazard Analysis, Hazard and Operability Analysis, Failure Mode, Effect and Criticality Analysis, Fault Tree and Event Tree analyses and Component Criticality Analysis.
The software integrates powerful applications for reliability data management, industrial system representation, advanced import/export procedures with traditional CAD systems, and a report generator to MS Word and Excel Office Applications.

Sustainable development and Integrated Assessment

Water Management
authors: R. Wolfer Calvo, M. Paruccini

La.TI.BI is a demonstration project for using decision support systems in strategic regional water management. The region of Basilicata expects to rationalise its water allocations through the project; involving several departments of the Basilicata University, regional authorities, ISIS and JRC's Environment Institute. La.TI.BI, which stands for "Laboratorio di Tecnologia Informativa nella Pianificazione dei Bacini Idrografici", has installed an operational center: three rooms in the University building in Potenza. The center advises the region for its strategic water management.

ISIS developed the decision support system (DSS) and part of the distributed information system. The DSS aids the local decision makers in defining effective management policies for water distribution through multicriteria analysis techniques; taking into consideration economic, environmental and social issues.

The system comprises three modules:
- "AquaRoute" for defining the hydraulic net, optimising the definition of operational rules, and simulation for calculation of hydrologic indices .
- Criteria Assessment
- NAIADE for multicriteria analysis.

AquaRoute reduces the huge number of possible feasible solutions to a subset of solutions relevant and promising for the decision-makers (see Figure 6.13). It takes into account as objective function only the minimisation of the gap between the demand and the amount of water actually provided during the time horizon selected. The module for criteria assessment receives, as input, the water flow alternatives calculating the value of the criteria considered. The multicriteria analysis supports the stakeholders in the *decision making* process to select the "best compromise". NAIADE is a multicriteria software, implementing a methodology developed in-house (see Figure 6.14).

The project achieved important results:
- all regional water data is available in the operational center and the project is fully integrated in the regions water management actions,
- the installation is complete including the GIS based decision support tools,
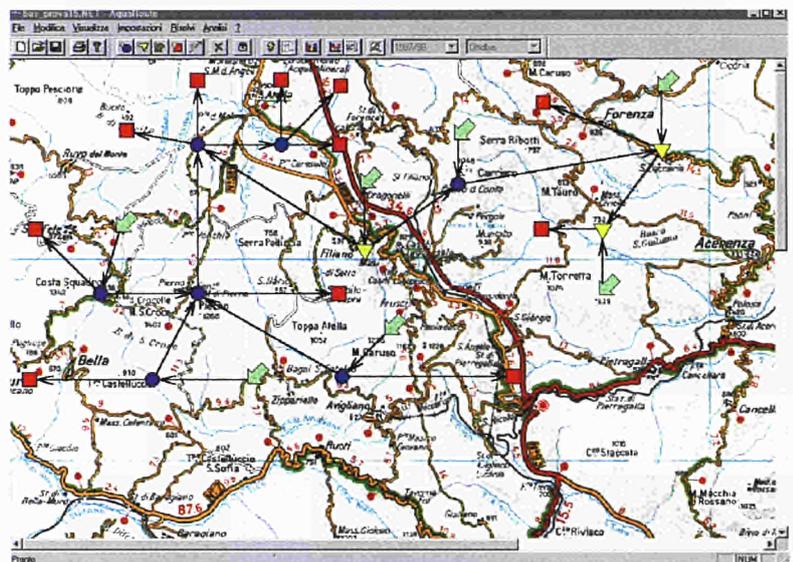- mathematical models can optimise the water network flow,

Figure 6.13: GIS model of regional water distribution in the Acquaroute model of La.TI.BI.
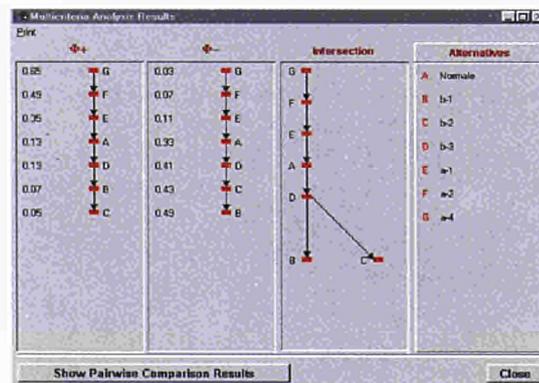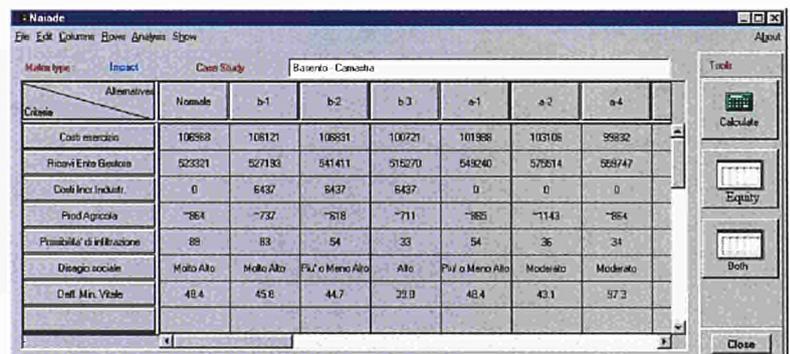

Figure 6.14: The NAIADE decision matrix allows to present a multicriteria decision problem. The output ranks the alternative solutions (here used in the La.TI.BI project for regional water management).

- the NAIADE software is a suitable operational tool,
- the public is well informed about the water situation via a public web site.

La.TI.BI already reduced conflicts related to water distribution in the Basilicata region. An important finding was that several users had requested higher supplies than what they needed. Recognising and quantifying the real needs helped to reduce wasteful and unnecessary distribution. In addition, the University of Basilicata has developed a solid know-how on integrated water management, which is available for the benefit of other regions.

Sustainable mobility

authors: D. Bain, C. Boehner, M. Mattarelli,
R. Wolfler Calvo

Decision Enhancement Technology (DET) can contribute to improved decision-making in the field of transport and mobility policy. The rationale for this is the belief that much of the knowledge necessary to achieve sustainable mobility is already available, but that management of this knowledge is often fragmented, partial and characterised by intense disagreement among stakeholders. Decision-makers require aids which address the multi-criteria reality of almost all policy decisions affecting mobility and which can cope with both the heterogeneity of the data available and the large uncertainties which are invariably present.

During 1999, the focus of this activity lay in the continued development of NAIADE and its application in a number of sustainable mobility projects. NAIADE (which stands for Novel Approach to Imprecise Assessment in Decision Environments) is a tool developed by ISIS in collaboration with the Free University of Amsterdam and initially deployed in environmental management projects. It uses sophisticated software engineering to allow decision-makers to navigate their way within a multi-criteria decision context, making full use of all the different kinds of information (crisp, stochastic, linguistic and "fuzzy") necessary for a balanced policy, but without being forced to rely on "black box" models.

Transferring NAIADE to sustainable mobility applications is a challenging task for a number of reasons. For one thing the very concept of sustainable mobility is under constant discussion, to a much greater degree than environmental management, and with the accepted aims in a continuous process of renegotiation. For another, the policy conflicts, especially as regards transport issues, are generally much more immediate and politically very sensitive.

This has both positive and negative consequences. On the negative side the passions aroused by transport policy decisions are worrying to researchers concerned with giving neutral scientific support to decision-makers. On the other hand NAIADE is particularly well-suited to conflict resolution in that it gives a common structure and data core to policy debates, makes very explicit the values underpinning different viewpoints and provides an "equity matrix" which helps the various stake-holders to identify possible policy solutions which meet some of the desires of all parties.

> **STEEDS,** *(Strategic Transport-Energy-Environment Decision Support) consists of a series of interlinked models which simulate the effects, over all EU countries and for every year to 2030, of new technologies entering the transport system and of a wide range of policy options. The NAIADE-based Decision Support System, which ISIS contributed to the project, allows decision-makers to investigate "What if...?" policy packages within this extremely large and detailed modelling exercise.*
>
> *Following favourable reactions from a number of possible users, STEEDS is now on the threshold of being used for broad-brush appraisal of European mobility policy in the medium- to long-term.*

The other two sustainable mobility projects in which ISIS is using NAIADE are the DG Transport Shared Cost Action UTOPIA and another JOULE-funded SCA called MATADOR. Both are scheduled to finish in 2000.

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UTOPIA *(Urban Transport: Options for Propulsion Systems and Instruments for their Analysis) is a multi-partner project aimed at providing city-level decision-makers with a series of tools for assessing the likely outcome of introducing new transport technologies and systems. In addition to providing city-specific aids to transport policy analysis, UTOPIA provides assessments of previous case studies, allowing more systematic access to past experience with new technologies and systems than has previously been possible. The NAIADE-based decision support tool will help city planners to assess the range of possibilities open to them, on the basis of various economic, environmental and social criteria, and guide them towards appropriate experiments carried out elsewhere.*

MATADOR *(Management Tool for the Assessment of Driveline TechnOlogies and Research) is, in some respects, a less ambitious project. Its aim is to provide fleet managers with a decision tool helping them assess the implications for their operations of adopting novel driveline technologies (such as electricity, LNG, hybrids, etc.). Most of the other partners in this project are involved in the testing of innovative vehicles. The ISIS contribution, known as MIG (for MATADOR Interactive Guide), serves partly as means by which the data generated from testing and standards research can be made available to the transport industry. Initial testing of the MIG on potential clients had positive responses.*

These projects provide important contacts with other European researchers, in industry, public policy research, universities and research laboratories, and with decision-makers at local national and EU level. The lessons learned are used both to improve the tools themselves (which are, in any event, constantly evolving in the light of new ICT developments) but also to assist their applications to other parts of the sustainable mobility *problematique*.

Integrated air quality assessment via remote observation

authors: D. Sarigiannis, M. Moula, M. Saisana, G. Triacchini, L. van Wijk

The ICAROS project assimilates various data sources (in situ measurements, Earth observation and simulation modelling) to develop an open-ended computational environment for the integrated assessment of air quality [6.22]. Various environmental information sources integrate into a unique and optimally managed environmental information processing tool. Applications are air pollution monitoring, extreme incident forecasting and strategic environmental assessment at the urban and conurban, up to regional scales. Progress was made regarding statistical correlation between atmospheric chemistry and transport model results, ground-based measurements and the output of satellite image processing algorithms. These indicate the good agreement be-
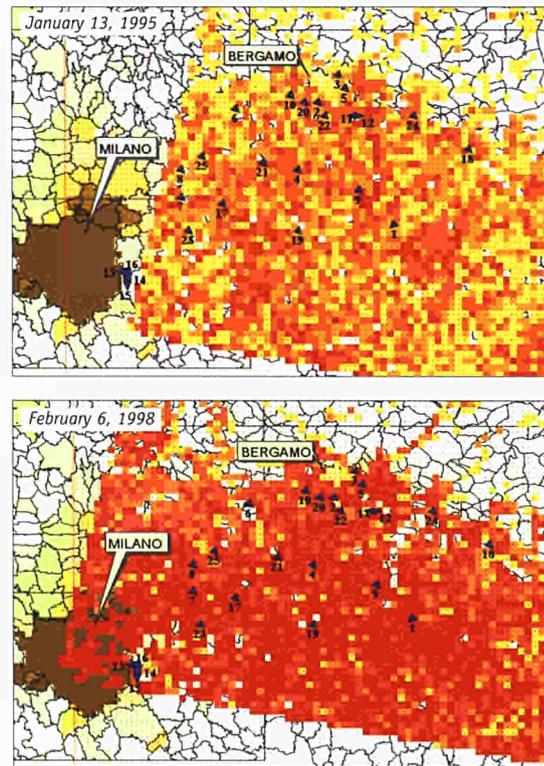
Figure 6.15: Evolution of aerosol optical thickness in the central Po valley from 1995 to 1998 and optimal configuration of the regional air quality monitoring network.

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tween pollutant measurements on the ground and reckoned optical thickness of atmospheric aerosol, based on satellite-derived images [6.23]. Correlations between aerosol optical thickness and the normalised difference vegetation index (NDVI), derived from SPOT and Landsat TM high spatial resolution images have shown that the proposed method may provide valuable insight regarding the effects of air quality on natural vegetation at the regional scale.

The ICAROS platform may serve as input for the multi-objective optimisation of ground-based air quality monitoring networks extended over large areas. State-of-the-art information tools for emissions inventory development was integrated in the platform. The ad hoc decision support system developed in the frame of the MOON project (Multi-Objective Optimisation of Networks) [6.24]. It follows EU guidelines for air quality monitoring networks and handles efficiently various information classes including pollution distribution, land use, as well as cultural and social-economic data. During 1999, MOON was implemented in the ICAROS platform and first pilot applications in the monitoring network of the extended area of Brescia and the Central Po Plain in Lombardy, northern Italy, were completed. The results of the respective studies are being used in the Regional Plan for Air Quality in Lombardy (see Figure 6.15).

Impact of Common Agricultural Policy
author: D.H.A. Al-Khudhairy

Agriculture is the biggest land user in the European Union. Over the centuries, European agriculture has given rise to unique landscapes with a rich variety of semi-natural habitats and species. However, in the last few decades agriculture has also been viewed as a major source of pollution and a driving force behind the degradation of Europe's landscape and "natural" environment. This is because European agriculture has changed notably in the last four decades. It has become a complex "high tech" industry that has increased agricultural production, thanks to rapid application of new technology and the encouragement of generous support under the Common

Agricultural Policy (CAP), by rates that far exceed those in other industries. It was not until the 1992 CAP reform, by the provision of accompanying measures (e.g. voluntary agri-environment measures), that the environmental dimension was seriously taken into consideration. Five years have elapsed since the majority of national agri-environment schemes were adopted in Member States. The aim of this project is to establish a framework for analysing the environmental and economic impacts of specific components of the new CAP reform under Agenda 2000. An assessment of numerous empirical and modelling studies, conducted in Member States by various research groups to examine the linkages between the 1992 CAP reform and the environment, was carried out [6.25]. The salient conclusions are: first the 1992 CAP reform package has not been in place long enough to yield a profound positive influence on the environment in the EU and moreover the 1992 reform package was introduced over several years. Second, insufficient comprehensive survey information exists relating changes in farming practices and the environmental impacts. Third, the 1992 CAP reform was also accompanied by buoyant world commodity markets, which influenced farmers' decisions. Fourth, fluctuations in agricultural practices are also sensitive to advances in technology, climatic conditions, and pest or disease incidence. Fifth, the agri-environment regulation is only a minor element of the 1992 CAP reform package (4% of the European Agricultural Guarantee Guidance Fund). However, its take-up is highly influenced by the level of common market organisation payments and its coverage varies widely amongst Member States. These factors make it very difficult to ascertain the environmental benefits of the 1992 CAP reform package. In other words, it is still difficult to appease the critics who argue that the 1992 CAP reform did not go far enough in terms of integrating the environmental dimension in the agricultural policy area. Moreover, the studies show that a redirection of the CAP towards a stronger inclusion of environmental considerations is needed to enhance the correlation between policy changes and the control of environmental impacts. The next few years will reveal whether the new CAP reforms under AGENDA 2000 have been sufficiently reformed with regards to integrating the environmental dimension.

References

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Carbon Dioxide exchange between EU forests

author: P.H. Martin

Part of the work accomplished consisted in spelling out (using the cartographic model in Figure 6.16), analysing, and appraising the method that led us to estimate the net exchange of carbon dioxide between forests in the European Union and the atmosphere in 1997 to 0.17 to 0.34. Following a brief review of the objectives of the study, we presented the data and the methods used. We then issued a series of caveats. We closed with a discussion of the main assumptions made in the calculation and a summary of the principal conclusions. The detailed description of our approach aims at providing something akin to a worked-out example, at encouraging alternative uses of the method, and at stimulating further methodological developments. This work is currently being published [6.26]. An interactive database system for forest sink analysis constitutes another completed project. This system interconnects a database containing a wide variety of data as well as models operating at different scales. This could serve as a template for future JRC Global Change cluster efforts. Figure 6.17 provides a graphical representation of the prototype.

Information Technologies for Sustainable Development

author: A. Guimarães Pereira

Integrated Assessment (IA) aims at the integration of knowledge from diverse sources as part of the policy making process. Frequently, IA deploys computer models and other Information and Communication Technology (ICT) in ways that are accessible to and used by only a limited range of scientists or within expert circles. Recent developments of ICT open up new possibilities for an extended participation to face the critical problems of our local and planetary co-existence. Policies for a "sustainable development" of our societies, i.e. a shared future that affirms the virtues of a *co-existence in diversity* (diversity of cultures, life forms and ecosystems), can be promoted through convivial forms of information sharing and social communication.

Cartographic Model for the Calculation of NEE per Country

Figure 6.16: Cartographic model for the calculation of national carbon dioxide next exchange in forests.
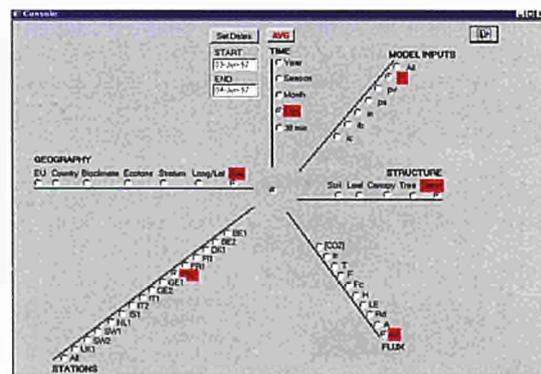
Figure 6.17: Graphical presentation of the ISIS developed prototype for Global Change Clustering.

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[6.26] Ceulemans R.J.M., Veroustraete F., Gond V., and Van Rensbergen J.B.H.F., Forest ecosystem modelling, upscaling & remote sensing, *SPB Academic Publishing bv*, The Hague, The Netherlands, 1999.
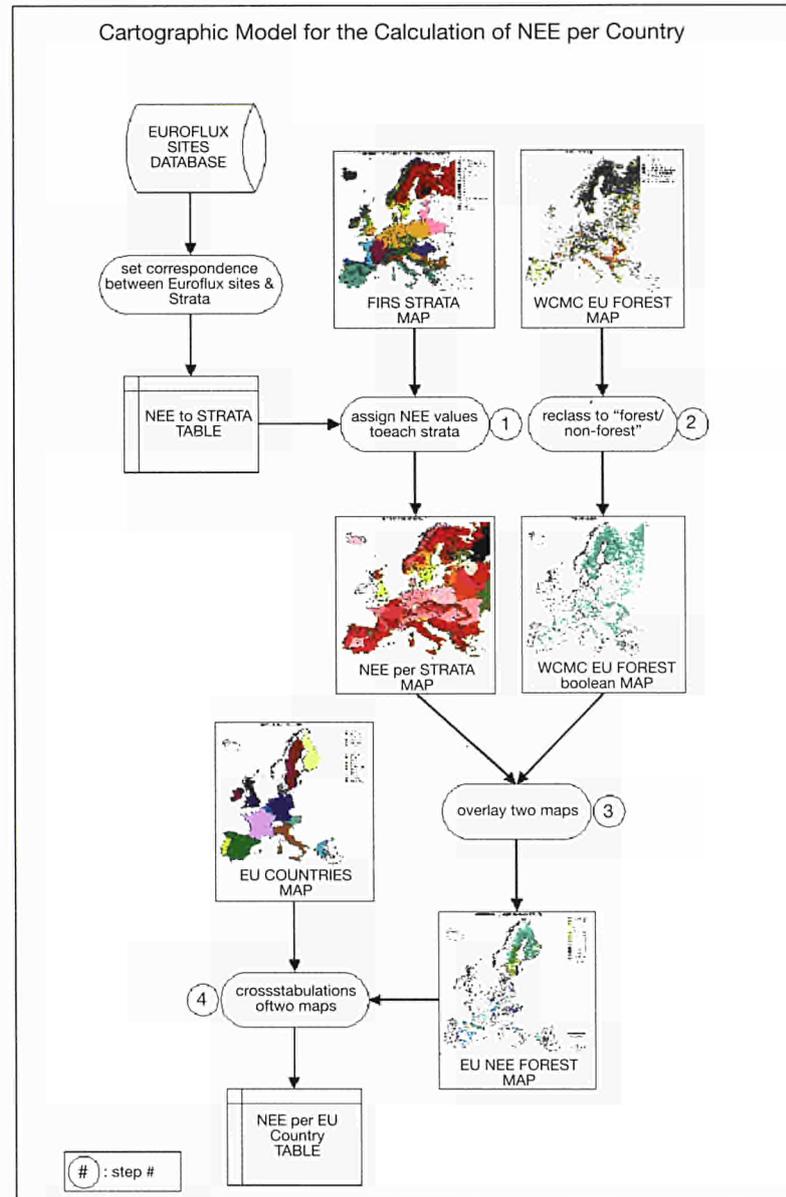
The VISIONS project "Integrated Visions for a Sustainable Europe" is being implemented for 3 different regions in Europe, ISIS being responsible for the Venice region. For this shared-cost action, a set of four images of the future of Venice in 2025 was prepared, providing insights about systemic interactions amongst different dimensions of sustainability. These scenarios were proposed through in-depth interviews to stakeholders in Venice organised according to 4 different categories: policy makers, business & engineering, citizens and entrepreneurs. There were various types of reactions to the four scenarios, including to the concept of scenario itself. A second phase of the social research component of this project will take into account these reactions, incorporating changes not only to the scenario contents, but also on the ways the scenarios are actually presented. A new multimedia tool is being implemented proposing different futures for Venice, showing in an interactive way the unfolding of the imagined visions of the future. This will be used in a participatory process for the discussion of the different contradictions of sustainability and the idea of Venice visions as metaphors of European future scenarios (http://alba.jrc.it/visions.html).

A set of three global scenarios to develop a World Water Vision was designed by the Scenario Development Panel of the World Commission on Water on the 21st Century (see http://www.watervision.org/). A triple branch point for the World Water Scenarios around 2025 were developed as follows:

• The Business-as-Usual scenario (BAU).
• The Economics, Technology and the Private Sector scenario (TEC).
• The Values and Lifestyles scenario (VAL).

ISIS developed, on behalf of the Stockholm Environment Institute, a multi-media interactive tool that enables people to explore (via Internet) the world water scenarios and contribute with their feedback to the World Commission on Water, expressing comments, doubts, etc. Two different 'stories' were built. A first story features high interactivity, allowing the user to explore deeply all the information regarding the unfolding of the scenarios – in the future dynamic models may be coupled with this version. The second story features less interaction with the user, who simply assists to the unfolding of the scenarios' trajectories without interacting or querying - very much in the way one watches a movie. This tool is available as a stand-alone version to be distributed in CD-Rom, and at http://alba.jrc.it/wwwvisions/scenarios.htm.
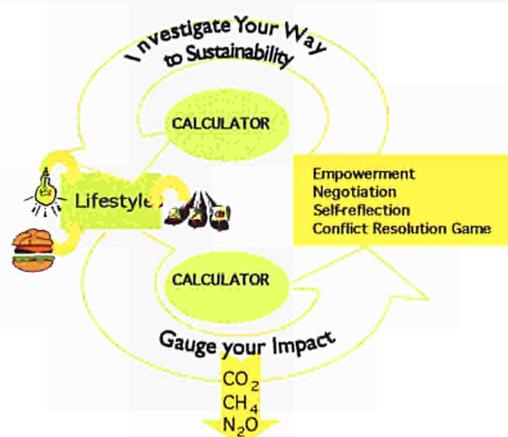
The GAS project (Greenhouse Gases Gauger and Scenario Explorer) applies Information and Communication Technology to participatory exercises. The software links climate change and lifestyles, showing how climate change is not a scientific abstraction, but a relevant issue related to human activities. GAS is mostly about social learning but can also be used in educational contexts, and decision-making processes. Thus the aim is to allow a 'personal visualisation' of the issues, and the potential impacts of chosen pathways.

GAS allows the user to explore routes to sustainability by playing with alternative lifestyles, e.g. "what are the trade-offs if I change from private to public transport?" or "what are the trade-offs if they (meaning policy/decision makers) change the fuel mix options for power production?" The scenario generator consists of a family of models that allow the exploration of scenarios for different perspectives of 'what is sustainable'. The C3ED of the University of Versailles is validating the present version of GAS. The validation considers the calculation core, as well as the appropriateness of the interface for non-specialised users. The final version of GAS will be available for 5 different countries in Europe: France, Italy, Portugal, Spain and United Kingdom.

Sustainable Energy Systems Analysis

authors: D. Sarigiannis, A. Brovelli, F. Ereno, W. Haslinger

Analysis of technological innovation and EU policies on renewable energy supports decision making with regard to fostering the penetration of renewables into the EU energy market whilst protecting the consumer and the environment from the respective technological risks. One of the major outputs of this work, an electronic Atlas of the bio-energy potential in the EU, helps decision-makers pinpoint the areas of major return to investment. Life cycle analysis of the the bio-energy cycle using fast pyrolysis of waste wood and energy crops helps identify best scenarios for cost-effective and environment-friendly energy generation in different geographic zones in the EU.

SHYLOC and Hydrology models for wetlands

authors: D.H.A. Al-Khudhairy, R. Calaon,
V. Hoffmann, I. Shepherd

Scientists and conservationists have long recognised the valuable functions wetland ecosystems perform within a social, cultural and economic network, which include refuge for wildlife, a filter for pollutants as well as a buffer against flooding. However, although wetlands are among the most important ecosystems on earth, they are still threatened by a wide variety of human activities (e.g. reduction in the quality and quantity of the water supply) both in developed and in developing parts of the world alike. Wetlands are driven by water. In other words, hydrology is the key factor behind the functioning and diversity of wetlands. Thus, an understanding of the hydrology of a wetland is a prerequisite for producing sustainable and integrated management plans for wetlands that can balance the present and future needs of all interested parties and that include wetlands as part of the water management system (see Figure 6.18). Frequently, however, little is known about historical hydrological conditions within wetlands, such as water levels and extent and frequency of inundation. This is a result of two main factors: First, wetlands were until relatively recently regarded as "wastelands" and thus were not monitored to the same extent as other types of ecosystems. Second, human interventions such as land use change, drainage and construction of hydraulic control structures (e.g. pumps, earth dams and sluices) have modified these historic conditions. Mathematical models offer the potential to reconstruct past hydrological conditions and to predict the effects of alternative management scenarios.

The two main objectives of the SHYLOC exploratory project (originally known as *Wetland Modelling during 1994-96*) were to first assess the appropriateness of the hydrological models available at that time for modelling wetland hydrology, and second to see how well information derived from remotely sensed images can compensate for the observed lack of ground-based data.

Figure 6.18: Wetlands are places where the land and water come together. Some people call them swamps or marshes whereas others refer to them as the "between-lands," because they are not really land and they are not really water. An example of low intensity sheep grazing in the Elmley Marshes, England and of a wetland co-existing with an agricultural landscape managed using traditional farming techniques sympathetic with the nature conservation status of the area.
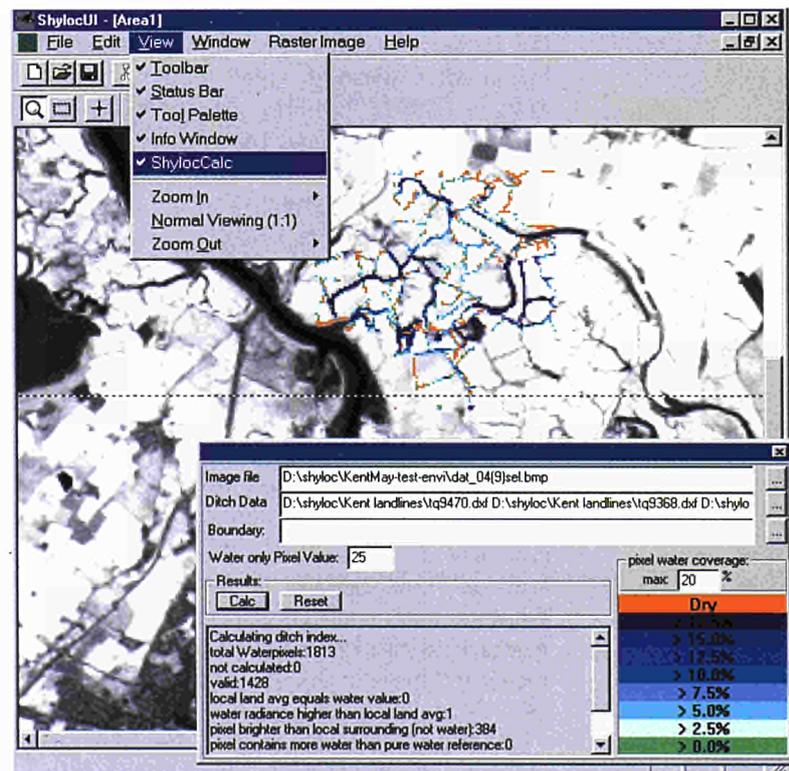

Figure 6.19: The SHYLOC user interface (main screen) and colour-coded view of percentage of the ditch network that is full of water (inset screen). The main screen shows the status of the stream network in the Elmley Marshes, N. Kent Marshes, England in February 1998.

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The major advantage of remote sensing is that an archive of Landsat TM images stretching back twenty years is available. The project was carried out in collaboration with University College London and the Greek Biotope Wetlands Centre. The project focused on two wetlands sites, the North Kent Marshes in Southeast England and the former lake Karla in Greece. Both sites are protected by national, European and/or international environmental legislation. The main findings of this project showed that although wetland hydrology could be modelled using advanced physically based hydrological models (e.g. MIKE SHE) in the presence of simple hydraulic structures, such models suffered from drawbacks in the presence of complicated hydraulic boundary conditions such as sluices, earth dams and water overspilling riverbanks [6.27, 6.28, 6.29]. The project also established that remotely sensed information can play an important role in calibrating and validating hydrological models [6.30].

On the basis of these promising findings, the SHYLOC (System for HYdrology using Land Observation for model Calibration) pilot project started in November 1997. The three years project is partly funded by the European Commission, is led by ISIS and has partners in England, Denmark and Greece. The primary objective of the new SHYLOC is to further develop hydrological models and image interpretation software in order to improve the simulation of wetland environments.

A complete version of the SHYLOC software is now available for determining effective "wet" ditch widths in a network of drainage or irrigation channels over a certain area at a certain time, using a combination of Landsat TM images and digitised ditch positions (see Figure 6.19). The user-friendly SHYLOC software is mainly intended for hydrologists, and offers them a tool that serves as an operational link between "traditional research" based on field monitoring and the vast information obtainable using remote sensing techniques. Moreover, SHYLOC, through the provision of ditch water levels, is being used to provide calibration data for wetland hydrological models such as the integrated MIKE SHE/MIKE 11 modelling package developed by the Danish Hydraulic Institute as part of the remit of the SHYLOC project. The suite of SHYLOC software are currently being tested and applied in four wetland sites, protected by national, European and/or international environmental legislation, in England and Greece.

Urban models

authors: D. Sarigiannis, R. Guzzi

Modern cities are currently considered as dynamic and self-organising artefacts. They have become multifaceted economic, social, cultural and environmental systems making up an organic assembly of multiple interacting subsystems. With regard to their spatial dimensions, they are more appropriately considered as urban regions. During 1997-1998 ISIS, in collaboration with the group of Nobel laureate I. Prigogine at the Solvay Institutes for Chemistry and Physics (Belgium) developed COMPLEXCITY, a dynamic spatial-temporal economic model, which integrates population dynamics and migration patterns with social-economic drivers and environmental and transport dynamics.

During 1999, we have attempted to estimate the model with real data. This exercise requires a confrontation with very inhomogeneous datasets, including extreme conditions and "social depth" information, i.e. situations where aggregates do not behave like the sum of their parts, and where explicit hypotheses about their inter-relations may be tested. Thus we tested the collective dynamics assumptions of the urban dynamic model, and we made explicit the role of information. We focused on the study of impacts of the introduction of centralised information (such as the one stemming from Community policies) on fiscal policy (Figure 6.20), job markets, spatial occupation, traffic and pollution, revenue structures, or concerning emergent implicit co-operative behaviour [6.31].

Moreover, we reformulated a subset of the social-economic model on the basis of an explicit aggregation of microsocial dynamic interactions.
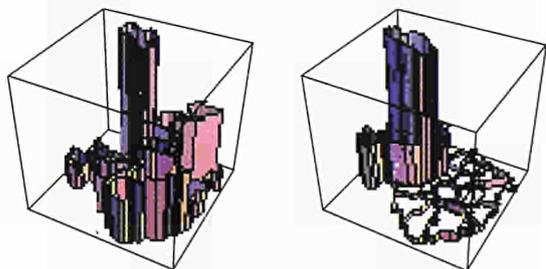
Figures 6.20: Time evolution of market services in the various zones of Milan due to a move of fiscal load from the tax-payer to the enterprise over a period of 50 years (1975-2025).

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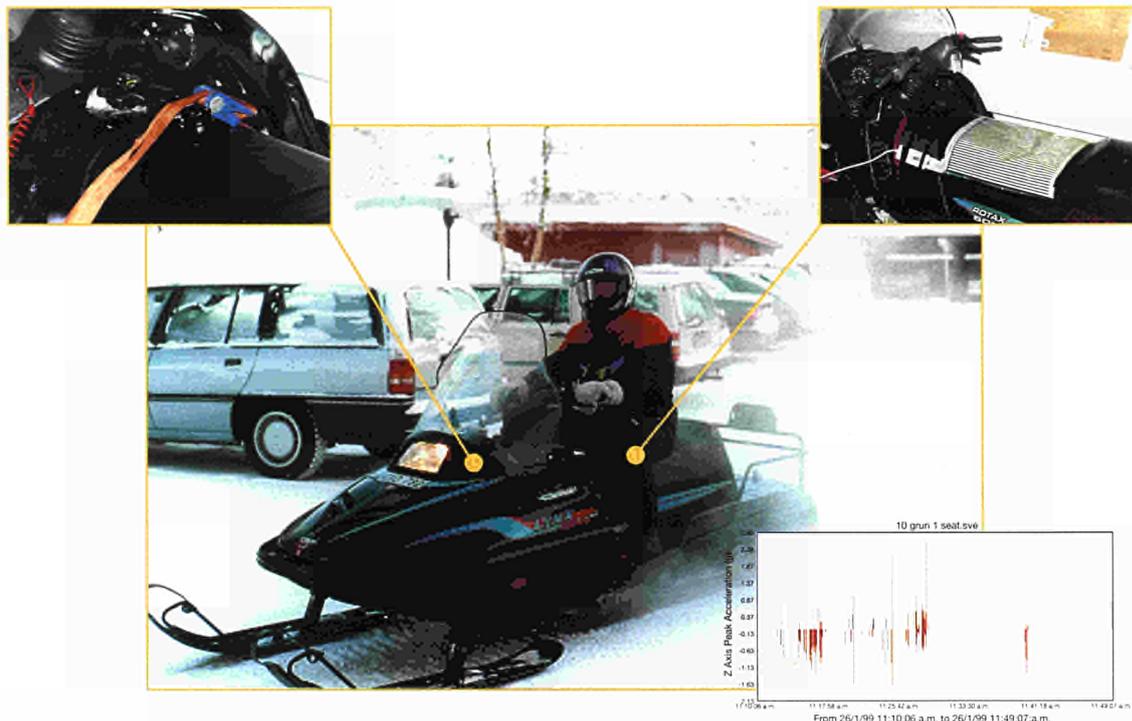
Figure 6.21: Cold Climate technology: Human-machine interface measurements reveal interesting results. The seat-pressure sensor (upper corner) gives information about the driver position. Accelerating measurements (lower corner) can exceed 2 G, a possible explanation for frequent bone-fatigue fractures observed with snow-mobile drivers.

Hence, it becomes possible to compare Monte Carlo simulations involving hazards linked to personal outcomes and rationales with the analytical predictions of the macro-equations. This should provide a very useful tool for the identification of specific boundary conditions for individual behaviours that favour the appearance of desired macroscopic stationary structures.

In addition, an exploratory study looked into the transfer of the urban modelling tools to the northernmost areas of Europe and the Arctic. A rigorous, structured approach to deal with the complex information load needed to analyze the dynamics of the interacting social, economic, and environmental systems would allow the development of a northern intelligence information system. Moreover, it should provide a methodology to assess the impact of regional development projects and policies locally. The data classes necessary for comprehensive regional sustainability assessment were identified and a regional development assessment system was designed. A Web-based interface to the Arctic Regional Intelligence System is currently under development.
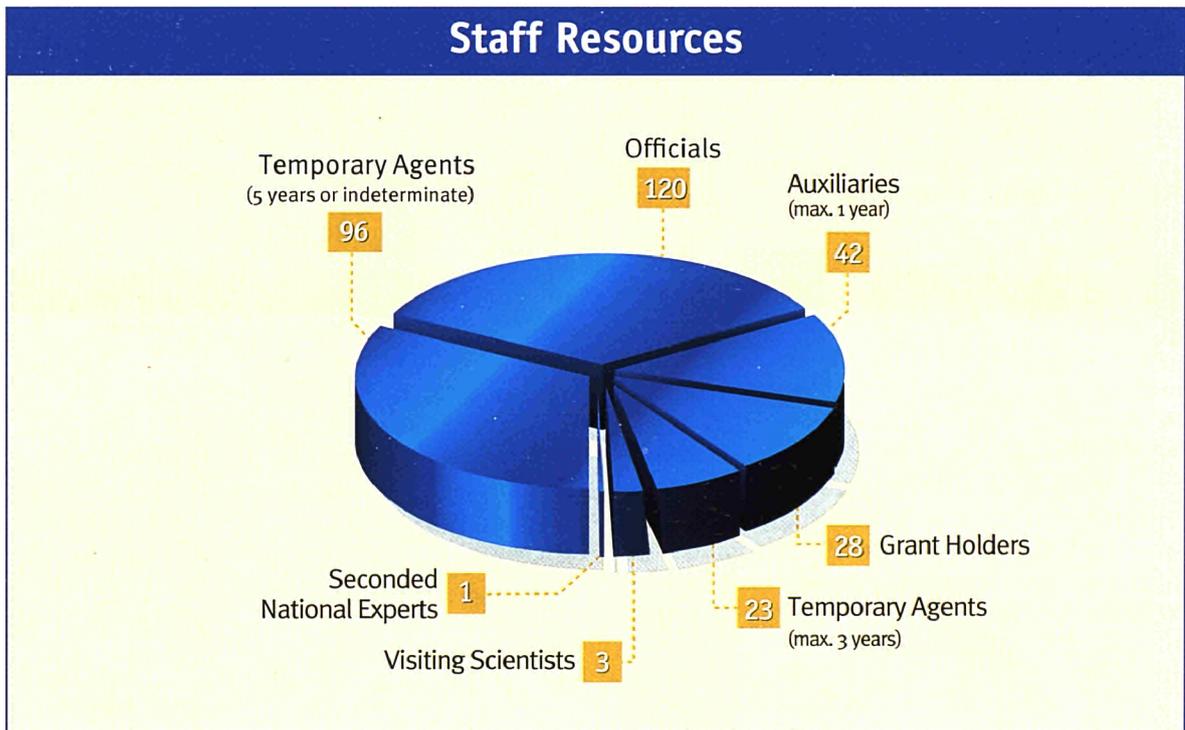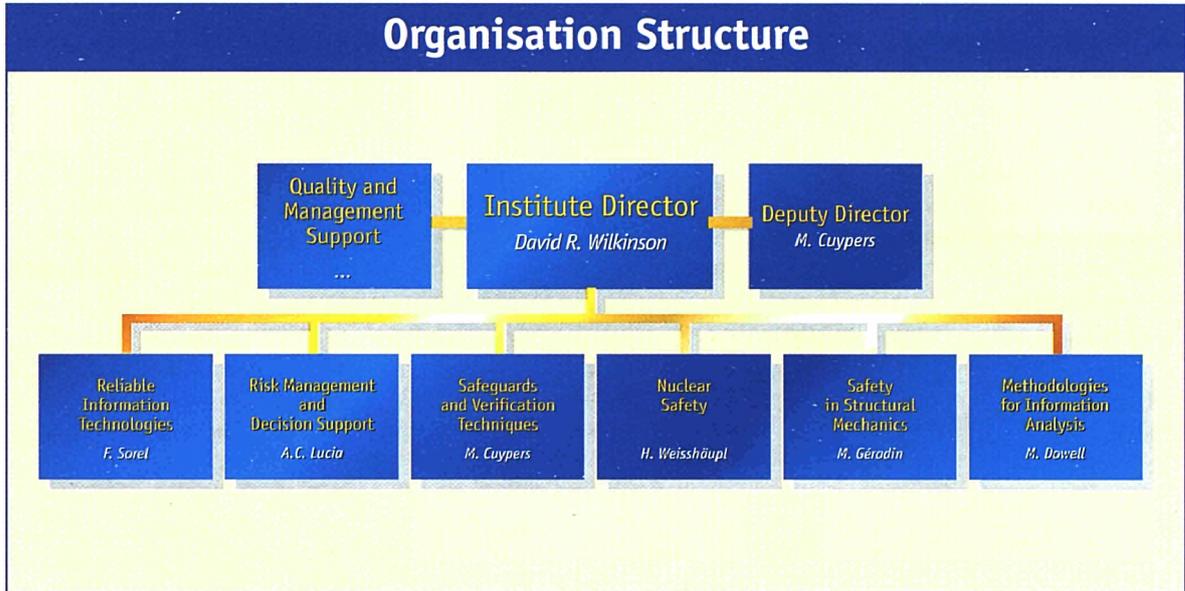
North Sweden-JRC Collaboration

authors: C. Korn, S. Morris, M. Cuypers, J. Sanders

When Sweden and Finland joined the European Union in 1995, one of the more obvious R&D areas to develop from the European perspective was the matter of cold climate and other arctic circumstances. Jointly with a group of research organisations from the Norrbotten region, the municipality of Kiruna and other North Swedish organisations, an extensive pre-study was performed to define collaborative projects for the development of the Kiruna/Norrbotten region [6.32, 6.33]. The study recommends the following projects: (1) the TEMPEST Cold Laboratory to provide testing and qualification services for technical equipment in cold environments, (2) an Euro-Arctic Methodological Training Centre which should become a centre of excellence on working and living in cold climates and (3) a Radar Imaging Service for estimating regional snow covers and for ice field measurements in front of ice breakers.

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Organisation Structure

Quality and Management Support
...

Institute Director
David R. Wilkinson

Deputy Director
M. Cuypers

Reliable Information Technologies	Risk Management and Decision Support	Safeguards and Verification Techniques	Nuclear Safety	Safety in Structural Mechanics	Methodologies for Information Analysis
F. Sorel	A.C. Lucia	M. Cuypers	H. Weisshäupl	M. Gérodin	M. Dowell

Staff Resources

Temporary Agents (5 years or indeterminate) 96

Officials 120

Auxiliaries (max. 1 year) 42

28 Grant Holders

23 Temporary Agents (max. 3 years)

Seconded National Experts 1

Visiting Scientists 3

ISIS customers include many sectors from European industry, regional governments and other Directorates from the European Commission. On average about 25% of ISIS staff work was dedicated to competitive activities. The institutional work covers the institutional support to Commission services and exploratory research under the various themes of the European Union's Fifth Framework Research Programme.

The three tables below show details of income and work executed during 1999.

Table I shows the new contracts which have been signed in 1998 and 1999.
Table II shows the competitive work executed in 1998 and 1999.
Table III shows the institutional work executed on each line of the Framework Programme.

From the tables it can be seen that:
- Previously set overall targets for contracts signed and work executed have been met and exceeded
- The competitive work has remained at the 25% level.
- The termination of the Competitive Support to the Commission line has been compensated by the other activities.
- The decline in signing shared-cost action projects was due to the start of the Fifth Framework Programme. Most new projects start in early 2000. New shared-cost action projects were signed for 1.3 M€ during January 2000.

Table I: New Contracts Signes 1998 and 1999.

Type of Activity	Value (M€) of Contracts Signed		
	Achieved 98	Target 99	Achieved 99
Competitive Support to Commission	8.48	1.00	1.04
Other Competitive Activities	2.56	2.00	0.67
Training and Mobility of Researchers	0.48	0.20	0.00
Shared-Cost Actions (50%)	4.03	0.80	0.47
Third Party Work	0.99	4.00	13.33
Total	**16.54**	**8.00**	**15.51**

Table II: ISIS Competitive Work Executed 1998 and 1999.

Type of Activity	Value (M€) of Work Executed		
	Achieved 98	Target 99	Achieved 99
Competitive Support to Commission	6.94	5.0	5.50
Other Competitive Activities	1.01	1.0	1.51
Training and Mobility of Researchers	0.40	0.5	0.62
Shared-Cost Actions (100%)	5.71	4.0	4.54
Third Party Work	2.11	2.0	1.79
Total	**16.17**	**12.5**	**14.01**

Table III: ISIS Institutional Work Executed 1999.

Type of Activity	Total FP5 (1999-2002) M€	Executed 1999 M€
Security and reliability in the information society	27.0	6.74
Safety of building structures and means of transport	27.6	9.69
Safeguarding against the proliferation of nuclear materials	75.0	16.60
Safety aspects of nuclear energy	16.5	6.20
Fight against fraud	17.8	3.98
Risk assessment and decision support	15.4	3.79
Total	**179.3**	**47.00**

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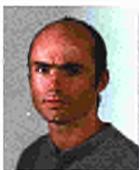Tel.: +39 0332 789237
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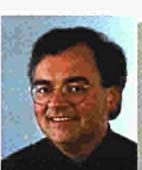Tel.: +39 0332 785932
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