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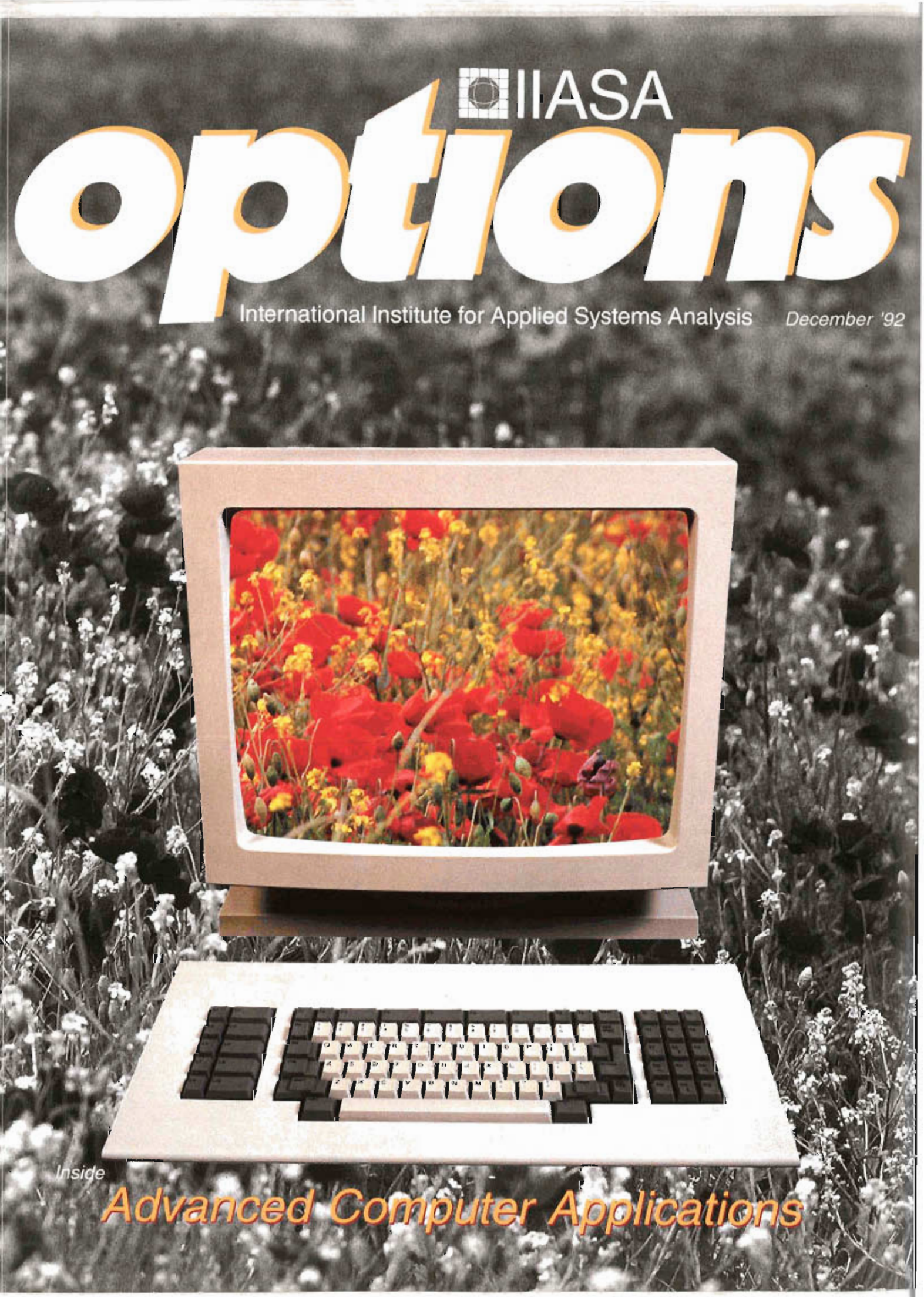
International Institute for Applied Systems Analysis

December '92



Inside

Advanced Computer Applications

IIASA BOOKS

Science and Sustainability: Selected Papers on IIASA's 20th Anniversary

A selection of 10 representative papers on a wide range of environmental issues presented at IIASA's 20th Anniversary Conference, which brought together practitioners of different disciplines to consider some of the contentious questions raised by the concept of sustainability.

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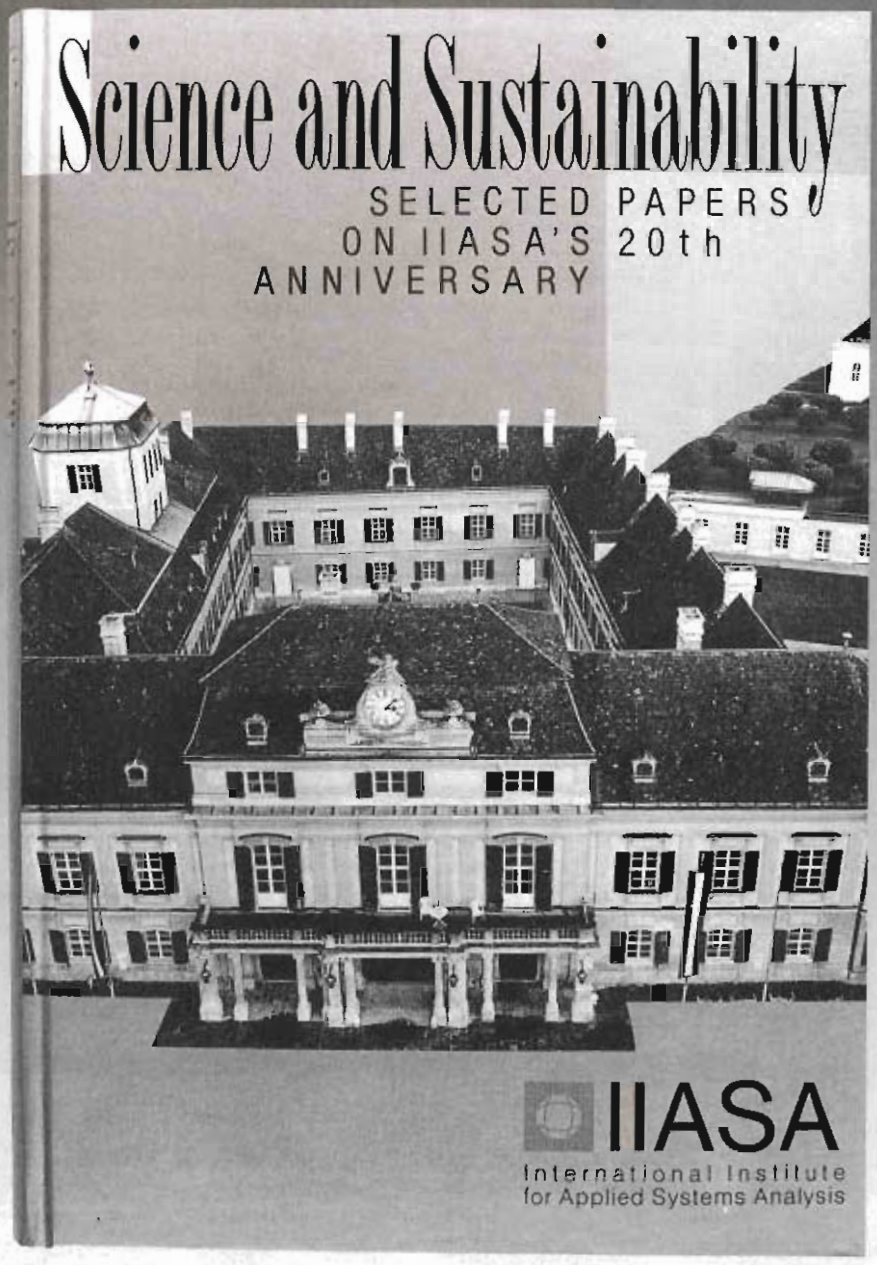

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IIASA is an international, interdisciplinary research institution which draws on the scientific and financial resources of member organizations to address problems of global significance.

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One of the challenges facing policy makers today in assessing complex issues is not the lack of information but the lack of effective organization of information. Even the simplest computer system can store vast collections of tables, graphs, and scientific data, but too often the users are left asking: What do they mean? This is the problem addressed by IIASA's Advanced Computer Applications group. ACA develops tools and techniques that help users to explore and understand complex issues, especially problems of environmental science, and to make more informed decisions.

In two ways the ACA team is unlike others at IIASA. First, it is driven by the needs of clients: the point is to produce software tools that clients can and will use in making decisions. Second, while ACA conducts its own research on generic tools for the analysis and display of information, it usually relies on outside sources for substantial blocks of scientific information specific for any given software package: outside specialists may have considerable knowledge of the client's problem, but they lack ACA's expertise in assembling data and models into useful, useable tools.

Also in this issue of *Options* are brief descriptions of three recent meetings that illustrate different facets of IIASA's evolving agenda. The meeting on trade and economic restructuring in Central and Eastern Europe is part of important ongoing work at the Institute. The conference on nuclear contamination of the biosphere, organized at the request of senior scientists and officials in Moscow and Kiev, was intended to lay the groundwork for a new research project. And the third meeting, concerning the effectiveness of international environmental accords, resulted in the Call for Proposals that was mailed out with this magazine.

This Call for Proposals, the second issued by IIASA, is part of a new and experimental process to develop new projects. The intention is to cast the net widely in order to attract researchers willing to organize scientifically sound, interdisciplinary, international projects at the Institute. In the future such Calls for Proposals will be become an important mechanism, although not the only one, in our program development strategy. I look forward to your responses.

Peter E. de Jánosi
Director

C O N T E N T S

FEATURE

Advanced Computer Applications

NO ONE CAN DOUBT THAT THE COMPUTER HAS REVOLUTIONIZED OUR ABILITY TO MANIPULATE INFORMATION; it is equally clear that more information does not necessarily mean better planning, policies, and decisions. Computer users, especially nontechnical users, are often frustrated by systems that make it hard to find critical information or present it in ways that are difficult to understand. Good

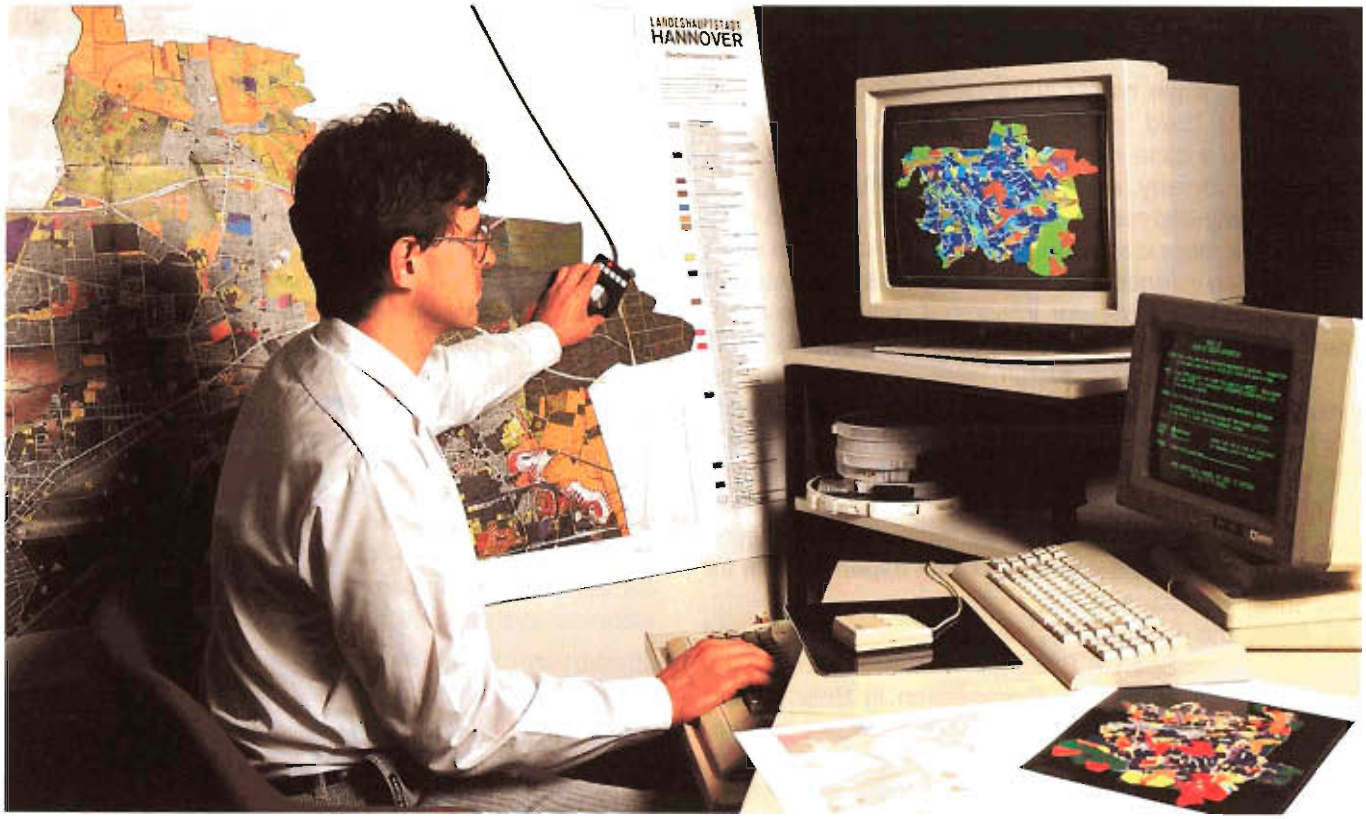
science is a necessary, but not a sufficient, condition for useful and useable information and decision support systems. This is the problem addressed by IIASA's Advanced Computer Applications group. ACA develops and implements easy-to-use, but scientifically sound, software tools and systems that bridge the gap between scientific research and real-world information needs. Since 1985 ACA has designed computer-based tools and developed software packages that combine models, geographical information systems, decision support and expert systems, and sophisticated graphic displays. Most of the applications are custom-made environmental information and decision support systems. Current projects include the development of systems to help clients manage air and water quality

and natural resources, to analyze problems of managing hazardous chemicals and toxic wastes, and to

assess the impacts of climate change. These problems are complex. Useful environmental information and decision support systems must combine a solid foundation in physical sciences with the ability to handle large amounts of complex data. Increasingly, they must also incorporate socioeconomic variables, social values and perceptions, and political factors. They require a multidisciplinary approach and the integration of advanced methods with specific domain know-how. Ongoing efforts to develop generic tools for analysis and communication of information and decision

support; seven years of experience in the practical, problem-oriented pursuit of applications; and a history of collaboration with people and institutions from China to California are ACA's distinguishing features.

The following series of articles on IIASA's Advanced Computer Applications group were written by Kurt Fedra, ACA Leader.



ACA started in 1985 as a spin-off of an exploratory project at IIASA dubbed "Dialoguing with Decision Makers." The problem addressed was, and still is, how to get scientifically sound information and methods of analysis into the policy- and decision-making process, how to communicate complex information to both scientific experts and nontechnical users. Modern information technology, and, in particular, interactive models for scenario analysis and computer graphics, emerged as a promising tool for this daunting task, building on IIASA's experience in modeling, decision support, and policy analysis.

The concept proved valid. Since 1985 ACA has developed custom software for application to a wide range of places and problems, from the Rhine River to the Mekong River, from local air pollution to global climate change, from toxic chemicals to regional development.

The first test of the concept was a project for the Commission of the European Communities Joint Research Centre at Ispra, Italy. The task was to compile computer-based tools that could support the implementation of the so-called Post-Seveso Directive of the EC, regulating industrial risk assessment.

The result was IRIMS, the Ispra Risk Management System. IRIMS integrated several data bases and simulation models with a fully menu-driven graphical user interface. Models of air, surface water and groundwater and of chemical production and transportation were linked to data bases on hazardous substances, industrial processes and waste streams, and major accidents. Throughout, the emphasis was on ease of use.

IRIMS quickly attracted attention. Demonstrations of the prototype led to follow-up projects in the USA, France, China, and the Netherlands. These applications of IRIMS included a geographic information system, or GIS — a tool that would become a central component of ACA's software — and the first integration by ACA of relational data bases together with a GIS and an interactive simulation and optimization model.

The step-by-step improvement of the ideas tested in IRIMS would become a hallmark of ACA. In the Netherlands, what began as a modest tool to analyze risks in transportation of chlorine has evolved into a fully integrated environmental information and decision support system (page 13).

When ACA needs to supplement in-house expertise, it turns to outside collaborators. One of the first examples was in 1987, when the US Bureau of Reclamation sponsored a development of the groundwater model of IRIMS. ACA teamed up with hydrological experts at the Institute for Mechanics of the German Academy of Sciences. Together they linked a finite element model with extensive graphical editing facilities and model output animation to produce a truly interactive groundwater model.

On behalf of the US Environmental Protection Agency, ACA also worked with the University of Colorado at Boulder on surface water quality models for the assessment of environmental risk of toxic substances. Again, ACA's role was to integrate dynamic simulation models, data bases, and GIS components into a homogeneous, user-friendly interface: to make a complex system easy to use and understand.

New projects steadily broadened ACA's range of

experience, while newer computer technology made it possible to build increasingly complex yet efficient systems. In a case study of heavy gas dispersion for a chemical company, several models of different degrees of complexity and resolution were coupled. In 1986 work began on a more elaborate project, a collaborative effort with Chinese scientists to integrate 16 major models and data bases into a tool for integrated regional development planning in the coal-rich province of Shanxi.

The focus of the system was coal: mining, the energy sector, transportation, and heavy industry were considered, but also agriculture, the environment, and natural resources, particularly water. Economic models in the system included both traditional input–output models and a new method of qualitative simulation based on cross-impact analysis or an expert system for site suitability assessment.

From the first stages, researchers, scholars, and officials from Shanxi Province and from the State Science and Technology Commission in Beijing were involved in the design of the system; end-user involvement and on-the-job training remain important parts of ACA's approach. In this international, intercultural setting, the use of computer graphics as a universal language took on a new importance.

A prototype urban environmental information system developed in 1989 for the city of Hanover, Germany, included a number of firsts for ACA. Project members integrated satellite imagery into the GIS. On the modeling side, they implemented a new groundwater model developed by the University of Hanover.

The Hanover project also allowed ACA to explore new interactive graphical user interfaces, made possible by the development of more powerful computer workstations and the transition from the original SIGGRAPH Core graphics standard, via the Graphical Kernel System, to the X11 Windows System. The new window-oriented graphics standards allowed more dynamic interaction and editing capabilities, while pseudo-3D visualization was added to the animated model output. Hypertext structures were developed and added to the model and to the data base interfaces, providing the user with more help and explanation.

Each of these tools has since been incorporated in other systems. Each ACA system is customized for a specific institutional framework, but all the systems share a basic set of generic software tools. Tools that work well in one setting can be reapplied to another. One example is a multi-criteria decision support tool first used in 1985 in a system to select paths for transportation of hazardous materials at minimum risk. The core algorithm, developed by IIASA's System and Decision Sciences Program, was subsequently used in systems dealing with other sorts of problems. In 1990 an improved version was implemented jointly with Tsinghua University, Beijing, in a project involving management of air quality and energy development in cities in China.

More recently, ACA has added rule-based expert systems and artificial intelligence components to its kit of generic tools. An opportunity to develop expert system technology emerged from a project for the Mekong Secretariat in Bangkok, Thailand. The task was to build tools to assess the environmental impact of water resources development projects; rule-based expert systems were seen as a way to operate effectively with

Methodology

ACA's focus is on the interface between user and computer. Efforts to develop systems to support decisions regarding complex environmental and socio-technical systems are guided by a few principles:

Integration — systems consolidate information and tools from different institutions and disciplines.

Interaction — they encourage users to define and explore problems incrementally and give quick answers.

Intelligence — software "knows" not only about possibilities and constraints, but also about the application and its context.

Visualization — sophisticated graphic displays allow users to see spatial and temporal relationships and to develop an intuitive understanding of problems and solutions.

Customization — systems are based on the end users' views of the problem, their language, experience, and needs; end users are directly involved in the design.

Current research topics include:

Hybrid information and decision support systems — in particular, the integration of data bases, numerical models, spatial information systems, and expert system technology. Wide-area networking and parallel processing are two relevant emerging technologies. The main objective is efficient management of very large and complex sets of data and information.

Qualitative analysis, symbolic simulation, and approximate reasoning — expert systems, their integration with numerical methods, hypertext structures, geographic information systems, and forms of knowledge representation. The objective is to develop formal methods for the use of qualitative, unstructured information.

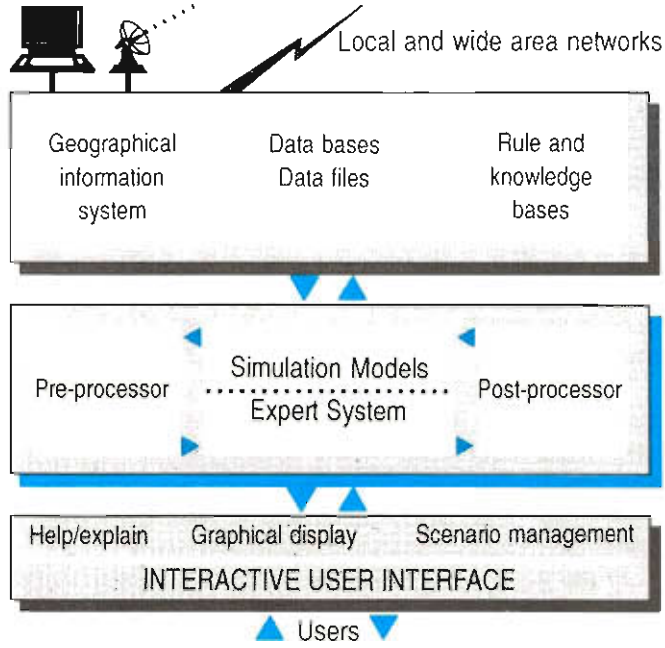
Scientific visualization, animation, interactive graphics, and user interface technology — problem representation languages for multi-media system, using a combination of numerical, textual, and graphical and sound elements that are intuitively understandable. The objective is the efficient communication of scientific information to a broad range of users.

severely limited data. Checklists of potential environmental impacts compiled by the Asian Development Bank were used as a starting point. Experts from the Mekong Secretariat provided many of the rules for the system's knowledge base.

Later the same expert system methodology was used in a pilot system for the Swedish Board of Agriculture involving agricultural water use and pollution. This case study, unlike the Mekong project, had vast amounts of agro-statistical data; the expert system helped users make sense of it.

These developments of expert systems tools led to a new concept: embedded artificial intelligence. Small expert system components could now be integrated with the simulation models and the user interface. Their task is to help the user compile complete and consistent input information, and to guide the system's operation. They act as built-in expert advisers — something of great value to users.

One application has been in ACA's Climate Impact Assessment Expert System (see *Options*, December '91). The system combines a global GIS and expert system with very large data bases of global coverage,



on topics such as basic geography, population, vegetation and soils, climate, and water resources, as well as the output of several general circulation models.

The system was also linked to the IMAGE model of climate change developed by the Dutch National Institute of Public Health and Environmental Protection (RIVM). An interface using embedded artificial intelligence helps the user to set consistent assumptions and policy variables in defining scenarios of global change and development. The interface includes a hypertext-based system to explain the model. The IMAGE model itself can be run interactively and its output viewed in graphs or as topical maps in the global GIS and mapping system.

Following ACA's work on applied artificial intelligence, the Austrian Research Foundation sponsored a study in machine learning. Monte Carlo simulation was combined with expert system tools in an attempt to "learn" a simplified and general description of a complex system from many examples of the system's behavior. To generate the learning examples, another new technology was adapted: distributed parallel processing. Like many other basic research elements of ACA, the parallel processing ideas evolved as part of IIASA's Young Scientists' Summer Program.

The following pages describe some of ACA's current work on environmental models and decision support systems in water, air, and risk. While the range of applications is wide, the projects have much in common: working with real users and clients worldwide; the integration of numerous sources of information and state-of-the-art tools; an interactive interface that is easy to use and allows the user to concentrate on the task at hand rather than on the technicalities of data management; sophisticated graphics that allow users to see and understand at a glance; and built-in intelligence that adds expert know-how to software.

Clients, Sponsors, and Collaborators

(A partial list)

Academy of Mining and Metallurgy, Cracow, Poland

Austrian Research Foundation (FWF), Vienna

Bureau of Reclamation, US Department of the Interior, Denver, Colorado

Center for Advanced Decision Support for Water and Environmental Systems, University of Colorado at Boulder, USA

City of Hanover, Environmental Protection Division, Germany

City of Vienna, Environmental Protection Division, Austria

ČSFR Federal Commission for the Environment, Prague

Delft Hydraulics, The Netherlands

Dutch Ministry for Housing, Physical Planning, and the Environment (VROM), The Hague

Environmental Research Laboratory, US Environmental Protection Agency, Athens, Georgia

Environmental Systems Research Institute, Redlands, California, USA

Joint Research Centre of the Commission of the European Communities, Ispra, Italy

Mekong Secretariat, Bangkok, Thailand

State Science and Technology Commission of the People's Republic of China, Beijing

Systems Research Institute, Polish Academy of Sciences, Warsaw

Thames Water International Services Limited, Reading, UK

Clean Air

Air Quality Modeling and Management

Air pollution is a problem common to many countries and regions, especially in metropolitan and industrial areas. Applied systems analysis can help design efficient, cost-effective control strategies.

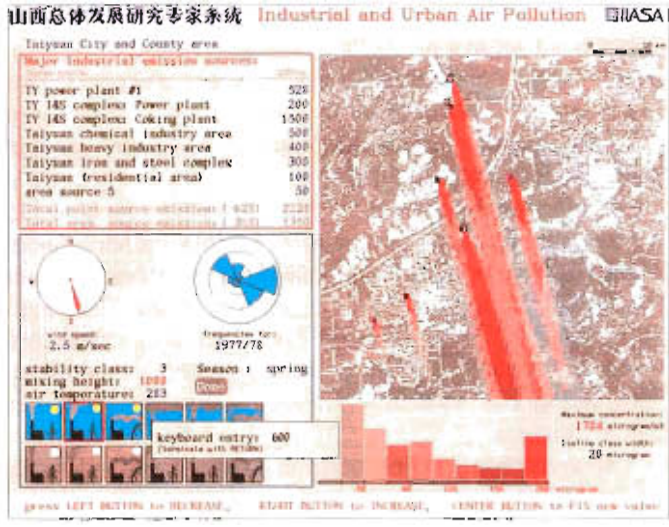
The ACA group has developed and implemented air quality models and information systems in projects worldwide. Following ACA's approach, all submodels and other components of the system are built into an interactive, graphical information system designed for users with little or no computer experience.

At the core of each system is an air quality model. Usually this is a modified version of a proven, readily available model, such as one of the UNAMAP series of models available from the US Environmental Protection Agency. ACA works with the end user to customize the model for the particular application. When off-the-shelf systems are not adequate, models are specifically developed in collaboration with other research institutions; in a current case study in Northern Bohemia, ACA is implementing a model developed at the Systems Research Institute of the Polish Academy of Sciences.

Each air quality information system includes a geographic information system and an emission inventory. The inventory can be easily edited using an expert system that helps users to estimate various parameters, primarily the emission of pollutants; this is particularly useful for unmeasured sources. Each system also includes several display options for visualizing and analyzing model results.

Other components can be added, depending on the needs of the user. Built-in optimization tools, for example, can help users to design minimum-cost solutions to meet given environmental standards, or to design the most effective investment strategy for a given budget. A discrete multi-criteria optimization module helps them to find compromise solutions to conflicting objectives under numerous constraints. The simulation and optimization components can be run interactively.

The first air quality model built by ACA was part of a regional industrial development planning system for Shanxi Province, China. The Shanxi decision support system includes a multi-criteria optimization model to balance production capacities and an expert system to identify feasible locations for industrial activities. Linked to this is a simple Gaussian air pollution model derived from the Industrial Source Complex model developed by the US Environmental Protection Agency. The modified ISC model is used to translate industrial technology and production scenarios into environmental impacts, providing planners and decision makers with additional criteria for evaluating alternative development strategies.



In 1989, the ISC model was adapted by ACA in collaboration with the Pollution Control Research Institute in Hardward, India, for Indian regulatory standards and subsequently used for environmental impact assessment studies.

More recently a version of the system was developed for the Environment Division of the City of Vienna. The ISC model has been combined with a geographic information system including imagery derived from Landsat TM and SPOT satellite data provided by Beckel GEOSPACE in Bad Ischl, Austria. The satellite-derived map has been combined with more traditional formats digitized from paper maps of the city of Vienna's land-use plan.

Integrated with the geographic information system is an inventory of area and major point sources of pollution. City authorities use the system to generate emission scenarios that simulate both short-term events and annual patterns, and compare the results with short-term and long-term air quality standards. They also use it to demonstrate the efficiency of installing pollution control equipment at major sources of emissions, such as power plants or waste incinerators.

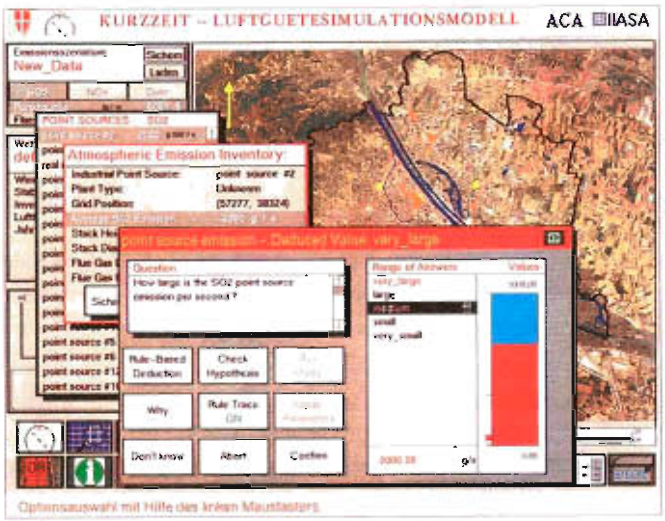
The same model is currently being adapted by ACA on behalf of the Dutch Ministry of Housing, Physical Planning, and the Environment for use in XENVIS, an environmental information system for the assessment and management of risks associated with hazardous chemicals (page 13). The air quality component of the model supplements classical tools for risk assessment, such as fault- and event-tree models analyzing accident scenarios, by also looking at the long-term, cumulative environmental impacts and hazards resulting from routine airborne emissions.

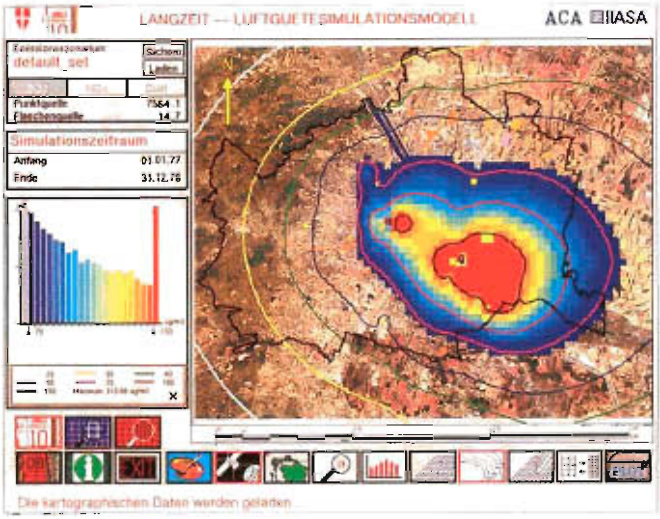
FEATURE

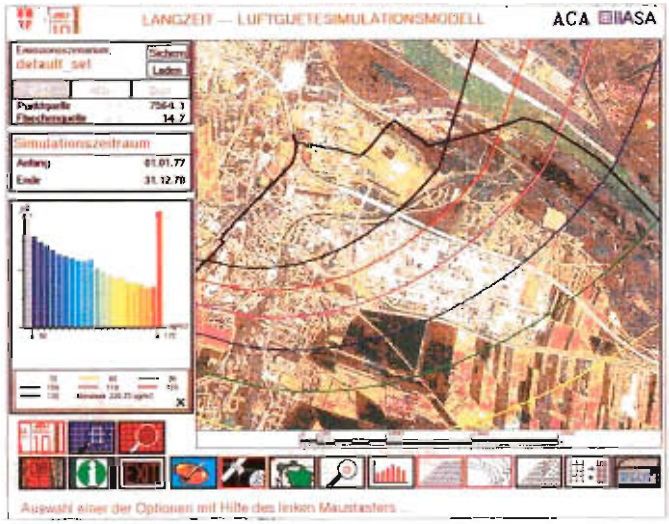
ACA has developed an expanded version of this air quality model which includes an expert system that helps users to estimate emission values from basic information on source type, fuel quality, production levels or power output, and emission control technology. The first application of the new, expanded system will be in the city of Ostrava, Moravia, in the Czech Republic. Discussions are under way with authorities in a number of other cities in Central Europe and in several developing countries (see below).

ACA is also developing a regional air quality information system for Northern Bohemia. The North Bohemian Basin, covering roughly 3000 square kilometers between Prague and Dresden, is a heavily industrialized and heavily polluted region in Central Europe. One of the main problems is coal: more than 30 million tons of low-quality coal (high sulfur and ash content) are burned annually in the region at more than 100 major point sources, leading to air pollution levels well above standards set by the World Health Organization.

Budget limitations in the region are severe. To help control emissions in a cost-effective way, ACA is developing a system of simulation and optimization models for





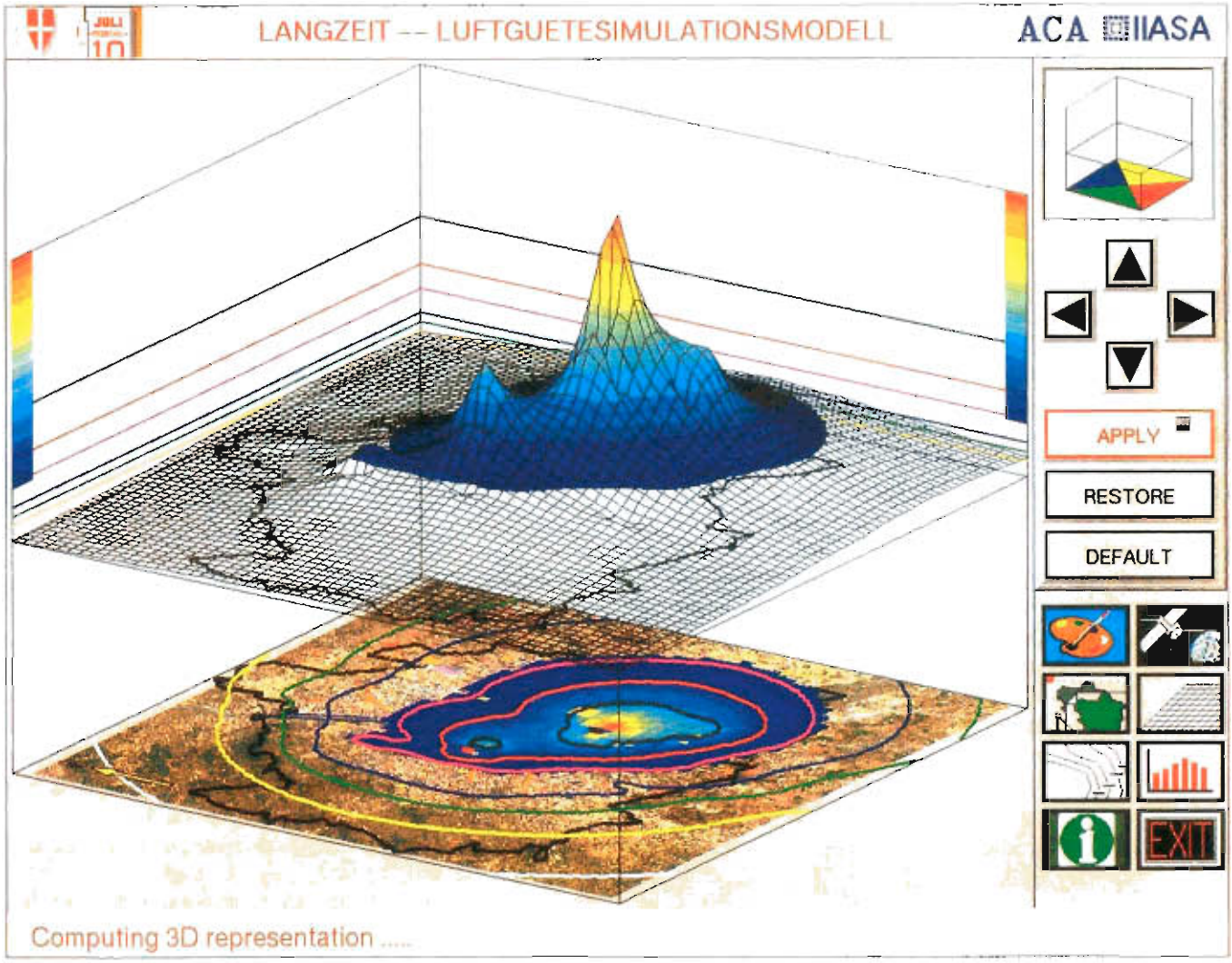


the region. The system combines a geographical information system and data bases on environmental features of the region, its vegetation, soils and patterns of land use, population distribution, meteorology, and air quality observations, with a source inventory for all major point and area sources. The system is designed to simulate short-term pollution episodes as well as long-term patterns, and to help authorities in the region design optimal pollution control strategies.

Given the complex topography and wind patterns of the region, the Gaussian model used in other case studies had to be replaced by a more sophisticated tool. In collaboration with researchers at the Polish Systems Research Institute, a model originally developed for the city of Warsaw was adapted for Northern Bohemia. Using a wind-field generator that considers topography, surface roughness, and surface temperature differences, the dynamic, multi-layer, finite element model can simulate the complex wind patterns of the region. The model has a regional version and a local version that are combined in a nested grid, meaning that the local model can be run within the regional one, using results of the regional simulation as boundary conditions and driving forces.

The model system can also optimize emission control. Computed unit-emission matrices relate target areas with emission sources for given weather patterns, such as the annual frequency of characteristic weather events; these matrices can in turn be scaled to reflect the effects of alternative emission scenarios based on the installation of pollution control equipment. This method, relatively simple but efficient, is the basis for the optimization. Given a set of technological alternatives for each source, the system can calculate a minimum-cost strategy to meet environmental standards. Alternatively, it will calculate a maximum of environmental benefits for a given investment budget.

The high-speed matrix-scaling approach also allows it to keep track of several cost components such as



investment, operational costs, or direct social costs, as in the case of plant closure. At the same time, it can estimate several criteria of environmental impact: for example, the total area in which certain air quality standards are exceeded, the frequency that standards are exceeded in the region, or the number of people exposed to a certain average level of pollution. The resulting, more comprehensive descriptions of a large number of alternatives can then be analyzed with a multi-criteria decision support tool based on DISCRETE, one of the software tools developed by IIASA's Methodology of Decision Analysis Project.

ACA is planning the continuing integration of various models and tools for urban and industrial air quality management. To find representative case studies for this project, covering a broad range of physiographic, meteorological, technological, and socioeconomic conditions, we invite potential research partners and institutional users such as city governments, environment ministries, and major industries to join the project.

ACA will make a basic implementation of the Industrial Source Complex model available to qualifying partners for a comparative study. Institutions participating in this project should:

- be end users of the software, such as a city council or ministry for the environment, with access to the environmental planning and decision-making process;
- be in a position to supply, directly or through research partners, necessary data such as maps (in digital form), satellite imagery, meteorological data, an emission inventory, pollution control cost functions, and air quality observation data;
- agree to share information related to the project freely with IIASA and among participants;
- be able to provide the necessary support, including a suitable UNIX workstation and local technical support for the equipment, support staff, etc.

For more information on how to obtain a version of the Air Quality Modeling System and how to collaborate with this project, contact:

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Clean Water

River Basin Management

Within the framework of the European Communities' EUREKA program (EUREKA ENVINET project EU487), ACA is participating in an international cooperative research project to design and develop an interactive software system for river basin management.

The project brings academic researchers together with industrial users. Academic partners include the University of Newcastle upon Tyne, UK, the University College York, Ireland, and the Centro IDEA at the University of Bologna, Italy. Two industrial partners, Thames Water International, UK, and Ansaldo Spa, Italy, also serve as prototypical users. Work on the project began in 1992, and the first prototypes were delivered to Thames Water in the same year.

The central theme is environmentally sound management of water resources, including groundwater, lakes, reservoirs, rivers, estuaries, and nearby coastal areas. The system — or, more correctly, each variant of the system, as each user will have a customized version — will allow users to address a wide range of problems and planning issues associated with water quantity and quality. Among other things, it will help them to simulate contamination of drinking water and develop cleanup strategies; to forecast and plan for future demands for water by agriculture, industry, and domestic users; to evaluate management policies and design better regulations; and to assess the environmental impact of proposed projects such as new reservoirs, irrigation systems, parklands, or industrial and urban development.

ACA's principal contribution is in the design and implementation of the system's framework and interfaces and the prototype development. ACA is also developing selected components, such as the groundwater model and an expert system for environmental impact assessment. The goals are ease of use, a high degree of integration, and intelligent display and analysis of information.

The complexity of river systems and water management problems means that no single software system could suit all river basins. Rather, the approach is to create flexible, modular software based on a tool kit that will allow users to select models and tools that give them the information they need to manage their water system.

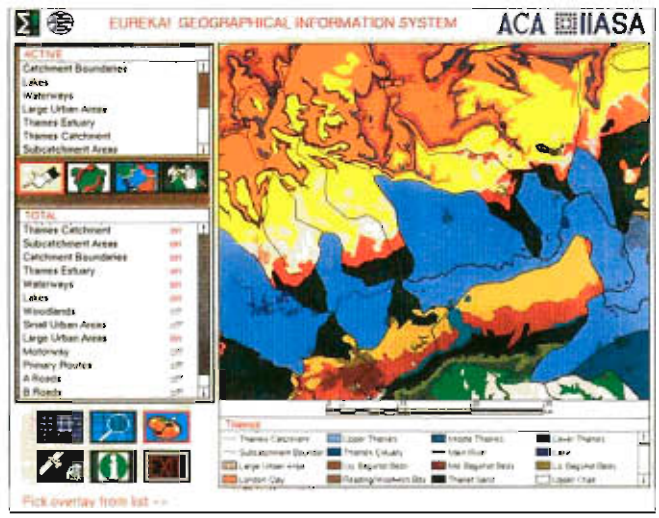
The system is designed to integrate geographic information systems (GIS), large data bases, simulation models, expert systems, and tools for visualization and sophisticated graphic displays — all elements common to ACA systems. The key is a framework for information management, communication, and model integration that will allow users to exchange models or add new ones without any major modifications to the system, as long as the new components comply with generic interface definitions.

For example, the current prototype's two-dimensional groundwater simulation model, developed by ACA, will be augmented by a three-dimensional model, developed at the University of Newcastle upon Tyne, able to simulate several contaminants and their interactions.

At the core of the EUREKA system is a GIS implemented with ACA's tool kit, with links to the various data bases and models. Satellite imagery such as Landsat TM provides up-to-date, synoptic data to the GIS. Integral digital elevation models define the basin itself. The integration of these data with information from soil maps and hydro-meteorological stations provides a rich information basis for modeling of surface runoff and routing, non-point source pollution, and erosion.

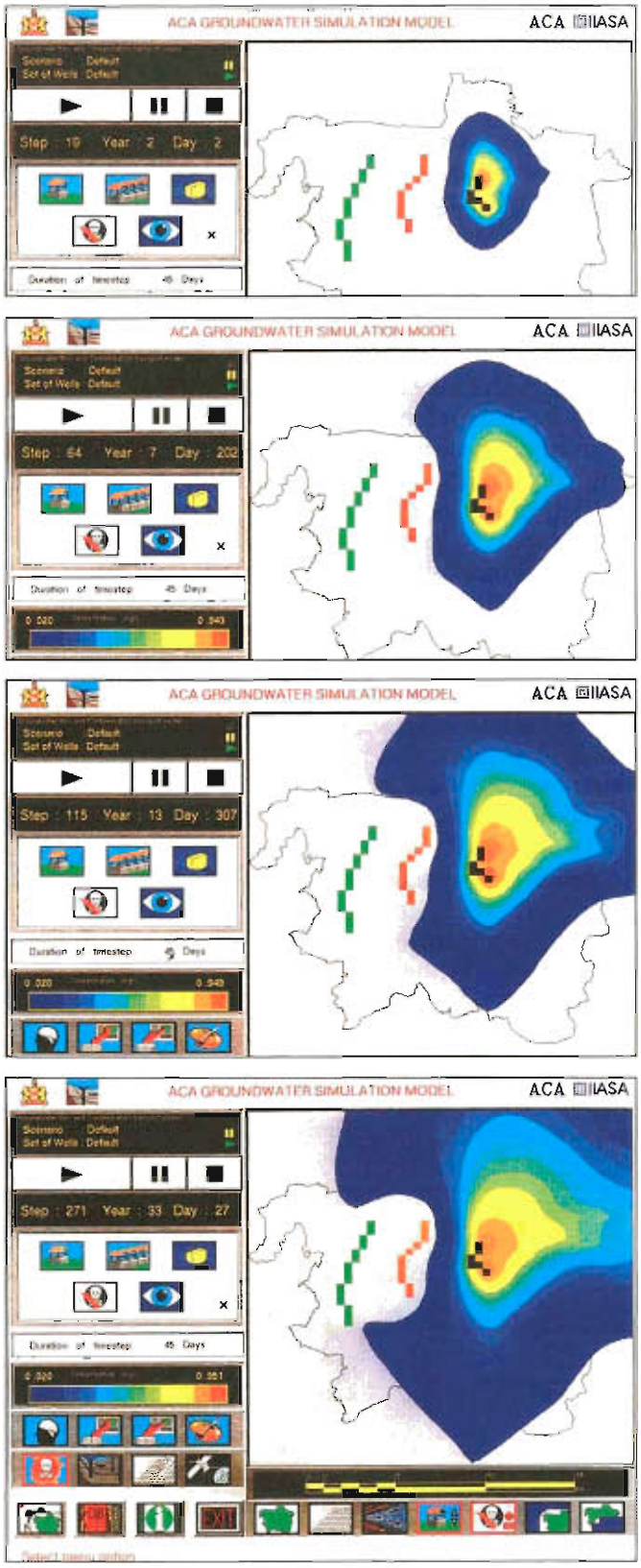
The goal is to couple various dynamic simulation models for scenario analysis to this framework of data bases and GIS. Eventually the system will include both natural-science tools, such as submodels describing rivers and reservoirs, the groundwater system, estuaries, and adjacent coastal marine areas, and tools to consider less easily quantified sociopolitical elements. The goal in combining "hard" and "soft" science is to give users a more realistic view of problems and options and to encourage a comprehensive approach to river basin management.

Social elements and some environmental considerations will be introduced using expert systems technology, rule-based inference, and qualitative reasoning. Other tools coupled to the simulation models will allow users to estimate the direct economic costs and benefits of alternative engineering proposals.



FEATURE

The first model implemented in the prototype was a groundwater model to simulate contamination due to localized leaching from landfills or to more widespread application of agricultural chemicals or sludge from sewage treatment plants. It is a two-dimensional horizontal finite difference model that allows the user to simulate time-variable boundary conditions such as pumping rates, groundwater recharge, or surface water interaction.



Its primary purpose is to address problems of contamination of drinking water. Alternative protection and cleanup strategies can be designed interactively and then simulated to evaluate their efficiency. A rule-based expert system can assist users in finding effective design alternatives, and the economic analysis keeps track of costs and benefits of each alternative. Technical options simulated by the system include hydraulic or physical barriers, interception pumping, or the relocation of wells and changes in the pumping regime.

An important feature of the model is its ability to use the system's GIS maps to graphically display the spread of water underground – a dynamic process that is often slow and difficult for managers to visualize. Users can edit the initial and boundary conditions of the model or modify a scenario during a run. The expert system in the user interface helps users to create scenarios that are complete, consistent, and plausible; for example, it can suggest reasonable pumping rates for wells.

The TOMCAT surface water quality model developed by Thames Water is currently being adapted for integration into the system. The QUAL2 model from the US Environmental Protection Agency, which has a different process representation and a different set of constituents simulated, is being considered as an additional option. The models will predict water quality for different flow conditions and environmental parameters, such as temperature, as a function of pollution, primarily from point sources such as waste-water treatment plants.

Another component currently under development is a tool for environmental impact assessment. This tool is derived from an expert system that ACA originally developed for the Mekong Secretariat in Bangkok, Thailand, for environmental impact assessment of water resources development projects. The system guides users through a series of checklists of potential environmental and socioeconomic problems, and helps them evaluate and classify potential problems on a scale of increasing severity.

Using rules for qualitative assessment and expertise rather than laws of nature, the system can also represent and include concepts such as perceptions, expectations, or public awareness which are difficult to quantify, but nonetheless important to decision making.

In combination with the numerical models representing physical, ecological, and economic aspects of a river basin, the rule-based approach extends the system's repertoire of tools for planning, assessment, and analysis, making it more powerful, more flexible, and at the same time easier to use and therefore more likely to be used.

A Safe Environment

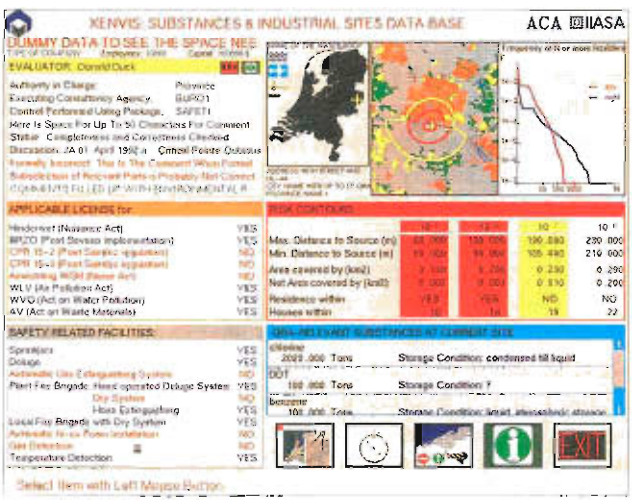
Technological Risk and Human Health

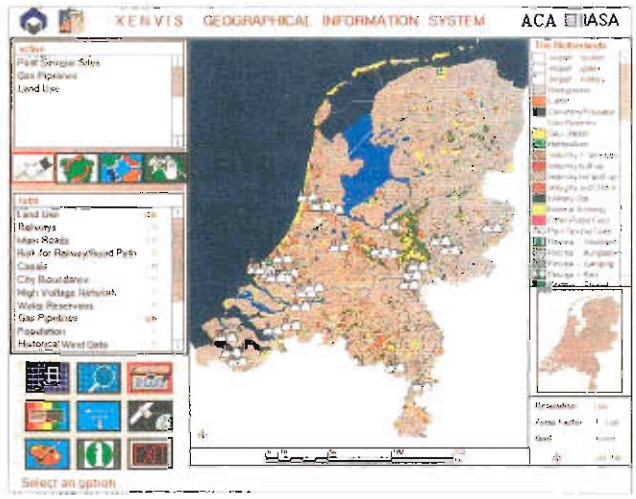
Technological hazards to environmental systems and human health are a growing problem for industrialized societies. People responsible for planning, managing, and regulating hazardous operations and substances need tools that bring to bear the best available science.

Since 1985 ACA has developed several software systems dealing with technological risk assessment. The first system, developed under contract to the Commission of the European Communities' Joint Research Centre in Ispra, Italy, was a prototype for use within the regulatory framework of the EC's Seveso Directive and related legislation. This system was the starting point for many other projects, including a prototype system for transportation risk assessment for the Haute Normandie region of France, developed in collaboration with the *Institut National de Recherche sur les Transports et leur Sécurité* of the *Département d'Evaluation et de Recherche en Accidentologie*. It also served as the basis for XENVIS, developed under contract to the Dutch Ministry of Housing, Physical Planning, and the Environment.

XENVIS began in 1986 as a study of interactive risk assessment of transportation of chlorine in the Netherlands. Since then it has been extended repeatedly, evolving into an interactive environmental information and decision support system that can be applied to a wide range of problems in the Netherlands associated with industrial risk and the management of hazardous operations and substances.

The continuing development of XENVIS has been made easier by ACA's modular design philosophy, which allows the incremental integration of individual building blocks. Submodels and data bases are linked into a coherent, easy-to-use system.





XENVIS is designed to support the Ministry's risk management tasks, within the framework of national and European legislation. It integrates, within one common interactive and graphical user interface, a geographic information system, several data bases and simulation models, a transportation risk and railway noise module, and an interface to a commercial fault- and event-tree risk analysis package, SAFETI, developed by Technica Inc., London.

An important part of XENVIS is the geographic information system. The GIS facilitates access to many of the system's functions: if, for example, users want information about long-term weather patterns in a particular area, they can use a mouse to point to a weather station in that area, and the system will call up the information. XENVIS presents the results of most of the system's analysis in familiar topical maps.

Users of XENVIS can create maps by selecting any combination of available topics, zoom in for local detail, highlight features, or plot analytical results. Available topics for display include administrative boundaries and land use, population distribution, the transportation network and infrastructure including roads, railways, and canals, pipelines and high-tension lines, and meteorological data. Maps can display the output of various analyses, such as risk contours or low-risk transportation corridors.

One of the main elements added to XENVIS was an industrial sites data base. To provide continuity in risk assessment, the XENVIS data base was built on a number of data bases already in use at the Ministry. For each site it typically includes a general description as well as specific safety-related and regulatory information,

FEATURE

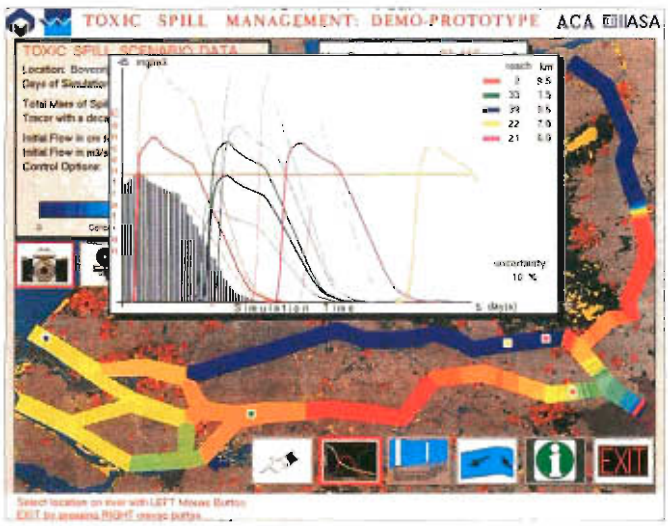
including the name, type, and location of the plant, a description of it, background information about recent risk assessments, and a summary of the risk information generated by the SAFETI module. Each entry also lists applicable licenses, safety-related facilities, and hazardous substances stored at the site, including the amount and condition of storage, and summarizes the status of safety audits and licensing.

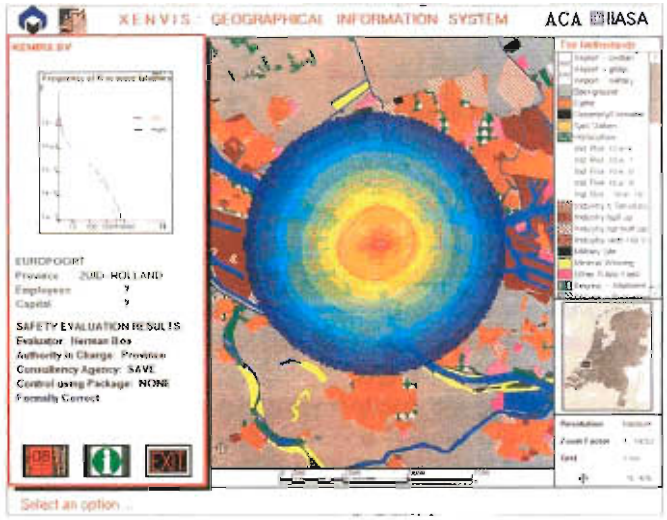
A second data base contains information on several hundred hazardous substances. The information page for each substance lists its name and synonyms, the chemical abstract, the chemical formula, related legislation and applicable directives, and the EC number. It includes general information, such as odor, appearance, and possible impacts, and shows a graphic display of the hazard sign and hazardous chemical code used for transportation labeling. It also provides a table with information on industrial processes and waste streams related to the substance, as well as tables on physical and chemical properties and on various aspects of toxicity.

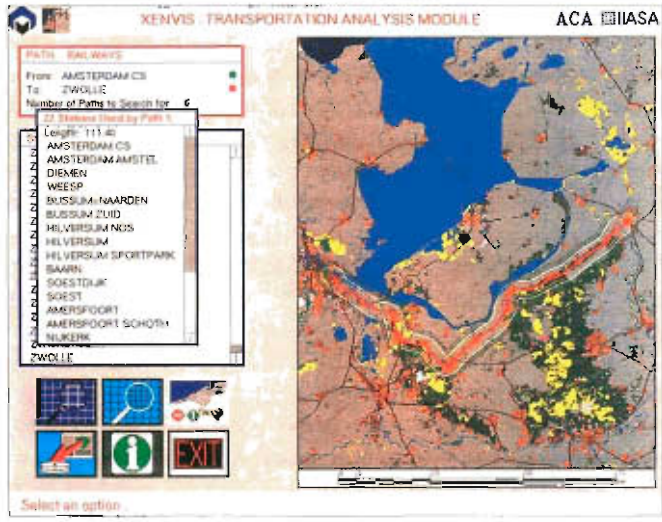
Use of the data bases in XENVIS is made easy by a hypertext style point-and-click interface. If, for example, users checking a site want more information on a particular chemical stored there, they can use the mouse to point to the chemical in the on-site list, then click a button: the system will call up the relevant entry from the hazardous chemicals data base. Similarly, each entry on a hazardous chemical lists all industrial plants known to store it: this in turn can be used to enter the industrial sites data base.

In keeping with ACA's design philosophy, the data bases are open. Users can check the sources of information and easily add, update, or delete information through an interface to a commercial relational data base management system.

Both the industrial sites and hazardous chemicals data bases are linked to a series of models. XENVIS currently has a river model and a transportation model;







an air pollution model is being added (see page 8).

The river water quality module, implemented in collaboration with Delft Hydraulics, simulates accidental spills of toxic materials into the Rhine River. The user defines an accident scenario by picking the location of the spill – for example, an industrial site along the river – the amount and release pattern of the pollutant, and the flow in the river. The model automatically downloads relevant information, such as the chemical's decay rate, from the hazardous substances data base.

The model can provide an animated display of the spill moving down the river, using a map from the GIS. It can also display various results of the analysis, including a plot of the pollutant's concentration over time at selected locations.

Each model complements the SAFETI risk assessment package. The transportation model, for example, can be used to determine "safe" pathways connecting industrial installations by road or rail, minimizing travel distance or the exposure of population along roads or tracks. The path can then be submitted to SAFETI for detailed risk analysis, and, coming full circle, the results can again be displayed as a topical map in the GIS. ■

Verifying Compliance with International Environmental Accords

29 – 31 October 1992

As the world's nations increasingly turn to international agreements of various types to address transboundary environmental concerns, they seek a better understanding of the means to ensure that agreements on paper produce changes in practice. Future agreements should incorporate lessons from current experience.

In October IIASA convened a meeting of international experts, listed below, to advise the Institute on a proposed **Project on Verifying Compliance with International Environmental Accords**. The goal was to help IIASA develop a Call for Proposals (included with this issue of *Options*) that would generate proposals from international, interdisciplinary teams of scholars for new, policy-oriented research. In addition, the workshop was to assess the current state of research into implementation of, compliance with, and effectiveness of international environmental agreements and related areas.

The participants were unanimous in suggesting that IIASA should be open to proposals for projects that would address any of the issues related to implementation, compliance, and effectiveness. They further suggested that the scope should allow for study of informal as well as formal international environmental commitments and should stress the need for greater participation from, and study of, countries with developing and transitional economies.

Discussions revealed a wide range of research already under way in the field. Several major projects take a political science approach to the problem; others are addressing it from legal and technological perspectives. The workshop participants recommended that IIASA's Director develop a *Compliance Research Coordination Strategy* to inventory and integrate existing research projects in this area and to identify gaps in these programs.

Ronald B. Mitchell

Non-IIASA workshop participants:

Andronico Adede
Office of Legal Affairs, United Nations, New York

Edith Brown-Weiss
Georgetown University Law Center, Washington, DC

Francoise Burhenne-Guilmin
IUCN Environmental Law Center, Bonn, Germany

Anne-Marie Burley
University of Chicago Law School, Chicago, IL, USA

Abram Chayes
Harvard Law School, Harvard University, Cambridge, MA, USA

Juan Carlos di Primio
Forschungszentrum Jülich GmbH, Jülich, Germany

Abdul Fattah
International Atomic Energy Agency, Vienna

Franz-Nikolaus Flakus
International Atomic Energy Agency, Vienna

Peter F. Guerrero
US General Accounting Office, Washington, DC

Kenneth I. Hanf
Erasmus University, Rotterdam, The Netherlands

Toru Iwama
Fukuoka University, Fukuoka, Japan

Odette Jankowitsch
International Atomic Energy Agency, Vienna

Alexandre Charles Kiss
Université Robert Schuman, Strasbourg, France

Fumiaki Kubo
Johns Hopkins University, Baltimore, MD, USA

Winfried Lang
Permanent Mission of Austria to the United Nations in Geneva

Ronald B. Mitchell
Harvard University, Cambridge, MA, USA

Dinah Shelton
Santa Clara University, Santa Clara, CA, USA

Gunnar Sjöstedt
Swedish Institute of International Affairs, Stockholm

Detlef Sprinz
University of Michigan, Ann Arbor, MI, USA

Bernice Steinhardt
US General Accounting Office, Washington, DC

Paul C. Szasz
International Conference on the Former Yugoslavia, Geneva

Alberto Szekely
UN International Law Commission, Mexico, DF

Raphael Vartanov
Woods Hole Oceanographic Institute, Woods Hole, MA, USA

The following people provided written contributions:

Robert Keohane
Center for International Affairs, Cambridge, MA, USA

Peter Sand
World Bank, Washington, DC

Oran Young
Dartmouth College, Hanover, NH, USA

International Trade and Restructuring in Eastern Europe

19 – 21 November 1992

Eastern European enterprises sold to private owners were expected to adjust more rapidly to changes in demand and to export more effectively than their state-owned counterparts. But discussions at a recent IIASA conference suggest that success or failure depends less on ownership than on other economic factors.

This conclusion was one of several that challenged conventional wisdom about the economic changes now under way. The conference, cosponsored by the Austrian National Bank, brought representatives of key international organizations together with scholars and officials from the ČSFR, Hungary, Poland, Russia, and Slovenia, and many Western countries. Topics of discussion and interesting findings included:

Trade liberalization and privatization, and their impact on trade performance. An analysis of more than 60 privatized Polish firms indicates that private ownership had little bearing on export success. Firms that increased exports all had skilled employees, competent management, and well-established connections in Western markets *before* being privatized.

In most of these firms, foreign investors acquired substantial holdings. These investors usually injected significant capital and further broadened the firms' access to Western markets. Domestic buyers, in contrast, were seldom well acquainted with their new firms, had few clear ideas about their future, and seldom provided capital support or modern technology or improved access to new markets.

Foreign direct investment, while bringing significant capital injections and broader access to Western markets, has also had negative effects. A study presented at the conference indicated that experienced Western investors who set up businesses in ČSFR, Hungary, and Poland aggressively lobbied governments for new protectionist measures and concessions. Automobile makers, for example, have won special concessions in each of the three countries, including decade-long tax exemptions, higher import tariffs for passenger cars, and tariff exemptions that save them millions of dollars.

Changing trade patterns, geographical reorientation, industrial policy and growth. Since 1989 trade within Eastern Europe has virtually collapsed, while exports of industrial goods from Eastern Europe to the West, in particular to Western Europe, grew by more than 70 percent. But conference participants expressed concern about the nature of these exports.

An analysis of Polish trade shows that traditional and natural-resource-based industries such as the metallurgy, agriculture, forestry, textile, and food industries maintained their high share of Poland's exports into Western markets. In comparison, engineering industries that previously supplied Eastern European markets, such as the electrical engineering and computer industries, have not been able to divert their trade to the West.

This trend is not promising for the Polish economy, because demand for those goods that are most successful in Western markets – metal products, processed food, chemical, timber and wood products, clothing, and footwear – is increasing only slowly in industrialized countries.

In a discussion of trade policy measures, none of the conference participants supported the reintroduction of selective and strong protectionist barriers, but there was a consensus that Eastern European governments should adopt uniform, moderate levels of tariff protection and work to maintain competitive real exchange rates.

External financing of the restructuring process – constraints and opportunities. Most speakers expressed doubts whether Western assistance is as high as is often quoted in the press. Many of these funds are in the form of export credits which give only a nominal saving to the Eastern users. Other assistance plans have so many conditions attached to their use – for example, insistence on using the aid through joint ventures or on the importation of products from the donor country or region – that some participants expressed doubt whether the newly emerging market economies could absorb many more funds under such conditions.

The role of exchange rate policy and trade competitiveness. For the past three years the exchange rate policies of ČSFR, Hungary, and Poland were preoccupied with the need to keep inflation at a low level. This policy was recently abandoned in Poland, but continues in effect in the other two countries. One way to achieve this goal is to let the domestic currency appreciate in real terms in relation to Western currencies. Many conference participants suggested that it was time to end this practice, even if it means relaxing the fight against inflation. They argued that for Eastern European industries to compete, in both domestic and export markets, they need the cushion of a less-appreciated currency.

János Gács

Radioactive Contamination of the Biosphere

21 – 24 November 1992

Nuclear waste disposal and radioactive contamination are issues of concern around the world. The focus lately has been on the former USSR, where official disclosures reveal unprecedented levels of contamination. This legacy of the Cold War affects the environmental security of people in the successor states of the Soviet Union, and indeed around the world; the potential threat to the global biosphere remains unknown.

In November experts from nine countries came to IIASA to discuss problems of nuclear contamination and waste disposal, especially in the former USSR, and to consider whether IIASA should organize a project to address environmental aspects of the problem.

Workshop participants identified some problems common to all members of the nuclear club and others that are unique to the ex-Soviet republics. The main common problem cited is that no country has built or even begun to build a facility for the long-term storage of high-level radioactive wastes, mainly because of public opposition. In many countries the public's trust in the responsible institutions is waning or nonexistent. Participants agreed that no country has adequately addressed public concerns about nuclear risks.

Most of the discussions involved environmental contamination from various sources: Chernobyl, dumping of naval reactors and fuel, mill tailings at uranium mines. The problems are shared – indeed, the entire global biosphere is affected – but the scale of contamination appears to be far higher in ex-Soviet republics, particularly in Russia, Ukraine, Belarus, and Kazakhstan, than elsewhere.

Some of the worst problems are in the South Urals, near the huge Mayak atomic weapons complex. Past problems include the explosion of a nuclear waste tank at Kyshtyn and the routine dumping of wastes into rivers and lakes near Chelyabinsk. Several Russian participants described the waters of Lake Karachai as the most polluted and dangerous on Earth.

Members of one of the four working groups organized during the radiation workshop.

Ongoing practices at other military bases pose a continuing environmental threat. As one example, a Finnish participant cited a Russian military nuclear waste storage site close to the waters of the Gulf of Finland. There is also a risk of more widespread ocean contamination, including contamination of Arctic seas by nuclear submarines abandoned at Novaya Zemlya. One Russian official said that a state commission would investigate sea dumping, but he added that, for the foreseeable future, Russia will continue to dump low-level nuclear waste at sea.

All speakers stressed the need for better data. Senior Russian scientists and officials promised full access to data for a multinational research project based at IIASA. Serious efforts to assess the problem began in 1990. One official estimated that there are 6,000 tons of spent nuclear fuel in Soviet successor states and tens of thousands of fuel assemblies in Russian nuclear submarines.

The cost of cleanup will be enormous. In the USA alone, where the problems are much less severe, officials expect that it will take 30 years and cost $150–$250 billion to clean up or contain contamination at weapons plants. Similar amounts of money will not be available for Eastern Europe or Central Asia: there it may be less a matter of

cleanup than reducing the effects of contamination on people and the environment to "acceptable" levels.

This again raised the question of what the public will accept. All participants agreed that efforts to set priorities must involve the public, and that attention must be paid to two-way risk communication and the design of institutions to build public trust.

Several speakers noted the problems caused by political and institutional instability in formerly Communist countries. Legal, jurisdictional, and regulatory regimes are all in flux. Russian legislators have also passed a law forbidding the importation of irradiated wastes; in past years the Soviet Union took all of the spent fuel from Soviet-designed nuclear power plants in Eastern Europe and Finland, currently about 200 tons per year.

Workshop participants voiced strong support for an interdisciplinary project on nuclear contamination of the biosphere. They made the following recommendations and comments:

- The project should be based at IIASA, with much of the work done by an international network;
- The focus should be on problems in the USSR's successor republics;
- It should last three to five years;
- The first step should be to inventory current related work by other researchers and organizations;
- Considerable efforts will be needed to assemble and verify data;
- The data could support an overview study of comparative risks from nuclear contamination and priorities for remediation in Eurasia;
- Case studies could provide an interdisciplinary perspective on local issues and public concerns, institutions, and policy procedures;
- IIASA should work closely with the International Atomic Energy Agency and other relevant institutions.

Joanne Linnerooth-Bayer

NEW PROJECTS

Hazardous Wastes

The Austrian Ministry of Science and Research has given IIASA a contract to study national experience regarding the cleanup of hazardous wastes and the siting of facilities to handle such waste. The case study is part of an IIASA project to compare experiences with hazardous waste in Europe and North America. (Contact: *Joanne Linnerooth-Bayer*)

Economic Transitions

The Pew Charitable Trusts and the Ford Foundation have awarded IIASA funds to continue a series of seminars with officials of the Russian government on the behavior of enterprises during transition, unemployment, the tax system, and issues in the internationalization of the Russian economy. The seminar series is part of an agreement signed between IIASA and the Russian Federation. (Contact: *János Gács*)

Siberian Data

IIASA and SIBCONSULT have signed an agreement to collaborate in building a forestry data base for an IIASA study of forest resources, environment, and sustainable socioeconomic development in Siberia (see *Options* Sept. '92). (Contact: *Sten Nilsson*)

CONFERENCES

Future Population Growth in Less Developed Countries, Laxenburg, Austria, 1–2 October.
Selected authors came to IIASA to discuss the definitions of alternative scenarios on fertility, mortality, and international migration as part of a book project of the Population Project. The book, to be entitled *Alternative Paths of Future World Population Growth: What can we assume today?*, will be a follow-up to the recent Academic Press book *Future Demographic Trends in Europe and North America: What can we assume today?* (Contact: *Wolfgang Lutz*)

Intelligent Decision Support Systems, Kutzively, Ukraine, 1–8 October.
This workshop was jointly organized by IIASA, the V.M. Glushkov Institute of Cybernetics of the Ukrainian Academy of Sciences, Kiev, and the International Federation of Information Processing. The principal topics of discussion were methodological problems in creating decision support systems, data bases and knowledge bases, heuristic modeling and optimization, software tools, and applications of decision support systems. (Contact: *Marek Makowski*)

Second International Colloquium on Regional Development, Bardejov, ČSFR, 12–14 October.
Discussion focused on the potential for economic growth in the region, especially the possibility of transborder cooperation with neighboring countries. Papers pointed out several barriers to growth, especially the insufficient infrastructure. The meeting, organized with the advice of Tatsuhiko Kawashima of Gakushuin University in Tokyo, an IIASA alumnus, was attended by government officials, including the Chairman of the former Slovak Commission on Economic Strategy, Šimon Korbini, and more than 60 scientists from 12 countries. Proceedings will be published in 1993. (Contact: *Tibor Vaško*)

Integrated Assessment of the Consequences of Global Change at the Regional Level, Laxenburg, Austria, 28–29 October.
Comparison of the Environmental Status of the Rhine and Elbe/Oder Basins, Laxenburg, 10–11 December.
These meetings, supported in part by the Commission of the European Communities, were held to discuss a possible second phase of the study of industrial metabolism in the Rhine Basin, now nearing completion (*Options* Sept. '91). Participants agreed that a second phase should focus on the upper Elbe/Oder Basin, comparing it to the Rhine. The goals would be to: estimate accumulations of heavy metals in soils of the two regions since 1950; estimate the potential for the mobilization of these chemicals; identify soil management practices to minimize the risk of mobilization; develop scenarios for future inputs of heavy metals; and develop recommendations for reductions of major sources of chemical inputs. The study would also assess the societal, economic, and technological

CONFERENCES

factors in the Rhine Basin that led to the effective decoupling of pollution from production, and determine if this transition could serve as a model for other areas. (Contact: *William Stigliani*)

Verifying Compliance with International Environmental Accords, Laxenburg, Austria, 29–31 October.
See page 15. (Contact: *Peter E. de Jánosi*)

International Trade and Restructuring in Eastern Europe, Laxenburg, Austria, 19–21 November.
See page 16. (Contact: *János Gács*)

Nuclear Contamination and Waste Disposal, Laxenburg, Austria, 22–24 November.
See page 17. (Contact: *Yuri Ermoliev* or *Joanne Linnerooth-Bayer*)

Applications of Decision Support Systems, Tokyo, 26–27 November.
This conference, organized by the Japan Institute of Systems Research in cooperation with IIASA, attracted close to 100 participants, mostly from Japanese industry and research institutions. The conference focus was on applications of neural nets and fuzzy sets in decision support. (Contact: *Marek Makowski*)

Effects of Climate Change on Forest Productivity, Laxenburg, Austria, 28 November–4 December.
Fifteen experts in forest ecology, timber assessment, and climatology spent a week at IIASA testing ways to link detailed ecophysiological models of trees and forest stands in Europe with the climate-change component of the Dutch IMAGE model, developed at IIASA. Participants from Finland, Sweden, and Australia agreed to continue to work on an integrated package for climate change impact analysis, with IIASA as the coordinator, and to establish formal links with the IGBP and with an EC study of the effects of climate change on European forests. The system will also include a timber assessment model and tools to analyze socioeconomic impacts of climatic changes on forests. (Contact: *Sten Nilsson*)

International CHALLENGE Network, Laxenburg, Austria, 3–4 December.
Experts in the field of energy use and climate change from 18 countries met to exchange information on scenarios of greenhouse gas emissions and the possibilities of their reduction. The CHALLENGE network was established in 1991 as a forum for experts to analyze and compare national case studies on strategies to reduce greenhouse gas emissions. Future work will include the refinement of existing scenarios and the formulation of new reduction scenarios. The next CHALLENGE meeting will be held 22–24 June 1993, at IIASA, along with the International Energy Workshop. (Contact: *Leo Schrattenholzer*)

Forthcoming Meetings

IIASA will sponsor or cosponsor the following scientific meetings in 1993:

April 19–21: Acid Rain in Southeast Asia, Laxenburg, Austria. (Contact: *Markus Amann*)

June(dates to be determined): Risk and Fairness, Laxenburg, Austria. (Contact: *Joanne Linnerooth-Bayer*)

June 22–24: International Energy Workshop, Laxenburg, Austria. (Contact: *Leo Schrattenholzer*)

NEWS

IIASA Council

George S. Golitsyn, Director of the Institute of Atmospheric Physics of the Russian Academy of Sciences, Moscow, has been appointed Russian Representative to the IIASA Council and elected Council Chairman. **Yuri S. Osipov**, President of the Russian Academy of Sciences, who served on the Council from April until September, remains Chairman of the Russian National Member Organization for IIASA.

Marcello Benedini of the Water Research Institute of the National Research Council, Rome, has been appointed Italian Representative to the Council, replacing **Guido Torrigiani**, who held the post since 1978.

Peter E. de Jánosi was appointed by the IIASA Council to a second three-year term as Director.

Appointments

Gustav Feichtinger (Austria), from the Institute of Econometrics, Operations Research and Systems Theory of the Technical University of Vienna, has joined the Population Project.

Andrey Ganopolsky (Russia), from the Computing Center of the Russian Academy of Sciences and a participant in the 1992 Young Scientists' Summer Program (YSSP), has joined the Climate Change Strategies Project.

Ilia Masliev (Russia), from the Siberian Branch of the Russian Academy of Sciences and a participant in the 1992 YSSP, has joined the Water Resources Project.

Vladimir Petukhov (Russia), from the Institute of Atmospheric Physics of the Russian Academy of Sciences and a participant in the 1992 YSSP, has joined the Climate Change Strategies Project.

Anatoly Shvidenko (Ukraine), Director of the All-Russian Scientific Research Information Center for Forest Resources in Moscow, has joined the Forestry Resources Project.

In Memoriam

Myron B. Fiering (USA), a researcher with IIASA's Energy Program in 1973 and 1974, died on October 28, 1992, in Cambridge, Massachusetts, USA.

PUBLICATIONS

Coping with Crisis in Eastern Europe's Environment. J. Alcamo, editor. The Parthenon Publishing Group, Carnforth/Park Ridge. ISBN 1-85070-433-3.

Science and Sustainability: Selected Papers on IIASA's 20th Anniversary. IIASA. ISBN 3-7045-0118-2.

Vegetation Dynamics and Global Change. A.M. Solomon, H.H. Shugart, editors. Chapman and Hall, London, New York, Tokyo. ISBN 0-412-03671-1 (Cloth) 0-412-03681-0 (Paper).

◆ Capital Cities of NMO Countries

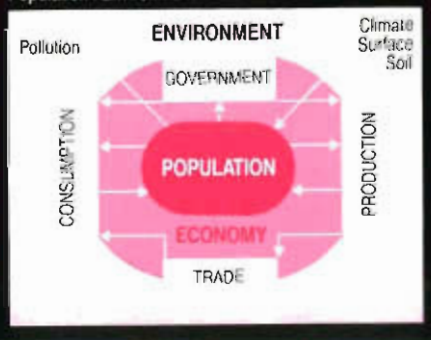
IIASA

International Institute
for Applied Systems Analysis

IIASA's ROLE

The International Institute for Applied Systems Analysis is an international, nongovernmental research institution sponsored by scientific organizations from 15 countries. IIASA's objective is to bring together scientists from various countries and disciplines to conduct research in a setting that is non-political and scientifically rigorous. It aims to provide policy-oriented research results that deal with issues transcending national boundaries. Resident scientists at IIASA coordinate research projects, working in collaboration with worldwide networks of researchers, policymakers, and research organizations.

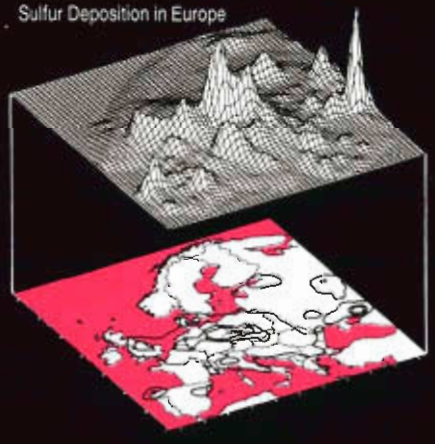
Population /Environment Interactions



RESEARCH

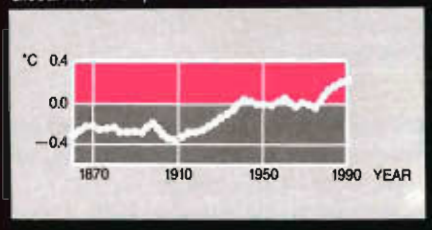
Recent projects include studies on global climate change, computer modelling of global vegetation, heavy metal pollution, acid rain, forest decline, economic transitions from central planning to open markets, the social and economic implications of population change,

Sulfur Deposition in Europe



processes of international negotiations, and the theory and methods of systems analysis. IIASA applies the tools and techniques of systems analysis to these and other issues of global importance.

Global Mean Temperature



MEMBERSHIP

IIASA was founded in 1972 on the initiative of the USA and the USSR, and now also includes eleven European countries, Canada, and Japan. IIASA has member organizations in the following countries: Austria, Bulgaria, Canada, the Czech and Slovak Federal Republic, Finland, France, Germany, Hungary, Italy, Japan, the Netherlands, Poland, the Russian Federation, Sweden, and the United States of America.

FURTHER INFORMATION

Further information about IIASA and its work is available from: The Office of Communications, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria, Telephone (0 22 36) 715 21-0.