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**Joint Research and Development
and Exchange of Technology
on Toxic Material Emergency Response
between LLNL and ENEA
1985 Progress Report**

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Abstract

For the past six years, the U.S. Department of Energy, LLNL, and the ENEA, Rome, Italy, have participated in cooperative studies for improving a systems approach to an emergency response following nuclear accidents. Technology exchange between LLNL and the ENEA was initially confined to the development, application, and evaluation of atmospheric transport and diffusion models. With the emergence of compatible hardware configurations between LLNL and ENEA, exchanges of technology and ideas for improving the development and implementation of systems are beginning to emerge. This report describes cooperative work that has occurred during the past three years, the present state of each system, and recommendations for future exchanges of technology.

Introduction

Since 1980, the U.S. Department of Energy (DOE), Lawrence Livermore National Laboratory (LLNL), and the Italian Comitato Nazionale per la Ricerca e lo Sviluppo dell'Energia Nucleare e delle Energie Alternative (Italian Commission for Nuclear and Alternative Energy Sources, also known as ENEA), Rome, Italy, have engaged in cooperative studies. These studies provide real-time guidance to emergency response managers for atmospheric releases of nuclear material.

During the past 13 years, LLNL has developed the Atmospheric Release Advisory Capability (ARAC) for the DOE to provide emergency planning, response, and assessment capabilities for atmospheric releases of nuclear material. An expansion phase that includes U.S. Department of Defense (DOD) facilities capable of handling nuclear material is presently nearing completion.¹ The ARAC service has responded to over 150 incidents and participated in major exercises during the past 11 years.

ENEA has developed a system similar to ARAC that is called the Accidental Release Im-

pact Evaluation System (ARIES). The ARIES system has been used extensively for exercise planning and participation over the past three years. ARIES has recently moved to a new facility and installed a new computer system.²

Both the ARAC and the ARIES systems use the LLNL-developed MATHEW/ADPIC (M A) models^{3,4} as their major emergency-response models. These models were transferred to the ARIES system in 1981 and have formed the basis for cooperative research and development and exchange of technology between LLNL and ENEA. A joint report,⁵ published in 1982, summarized the results of these exchanges for the first two years and described plans for the future.

The present report discusses the progress for both systems since 1982, the present status of model research and software development, and plans for future cooperative studies. A list of acronyms, symbols, and key words appears at the end of this report.

Progress During the Past 3 Years

Since 1982, the ARAC service has expanded its hardware, software, and number of staff members to meet new commitments for emergency planning, response, and assessment. A major, new commitment is being made to the DOD for its nuclear-capable facilities located in the U.S. Other new commitments include a closer tie to the U.S. Nuclear Regulatory Commission (NRC) for assistance in response to nuclear power plant accidents and to several states for possible nuclear accidents that might occur within their borders. At present, approximately 50 DOE and DOD facilities directly receive the ARAC service using a partially automated system. New capabilities have been developed by installing small computers to transfer data between nuclear facilities and the ARAC center. Expansion of the ARAC operational service by October, 1986 will provide continuing service to on-line sites and to U.S. agencies responsible for the health and safety of nearby populations.¹ Figure 1 shows the operations room of the new ARAC center. The computers and associated hardware are located in an adjacent area.

The ARIES project, started at the beginning of 1980 with cooperation from LLNL, quickly reached many of its goals.² From 1983 to 1985 the system moved from a develop-

mental to an operational phase. During this time, efforts were focused on ensuring that ARIES software and hardware were similar to that of the ARAC system to maximize cooperation between the two organizations. For example, when ARAC incorporated Digital Equipment Corporation (DEC) VAX computers to run the system, ENEA made the same decision. In particular, ENEA acquired a VAX 11/782 computer and transferred all software to this system. The complete VAX-compatible codes, MATHEW/ADPIC (M/A), were received from LLNL. Furthermore, an intermediate-level code, SPADE, was developed on the ARIES VAX system to describe wind-field and pollutant transport with a Lagrangian puff model.

ARIES currently services three nuclear power plants and several nuclear research facilities and will be able to service new power plants now under construction. The ARIES operations center is shown in Figure 2.

The Italian Emergency Coordination Center (ECC) recently issued a directive requiring an environmental impact statement, including accident and emergency preparedness analysis, for large Italian industrial installations that have a potential for toxic chemical releases. The Italian Civil Defense Ministry

Figure 1. ARAC operations center.

Figure 2. ARIES operations center.

asked the Directorate for Nuclear Safety and Health Protection (DISP) to supply technical support during accidents involving conventional toxic releases. DISP recently responded by starting an active program to make ARIES available in case of such accidents.

Exchange Visits

In 1983, four staff members from LLNL visited ENEA for 8 days to participate in an ENEA-sponsored international seminar and to plan for a continuation of the technology exchange program. The visit included observation of a field experiment conducted at a coastal nuclear reactor site at Montalto di Castro, located approximately 100 km northwest of Rome. The goal of this investigation was to release atmospheric tracers and to measure the downwind tracer concentrations and meteorological parameters under sea-breeze conditions. Meteorological and tracer data were collected for subsequent evaluations of models. The results of this work are now part of the total M/A evaluation data base.

The international seminar included presentations and discussions relating the role of real-time diffusion models in emergency response to accidental releases. Representatives from eight countries participated in the discussions, which focused on the use of transport and diffusion models and the associated support required for a real-time response. The systems presented at the seminar provided an opportunity to discuss the merits and shortcomings of a spectrum of capabilities involving both simple and complex models.

During 1984, the ENEA sent Dr. Franco Desiato to LLNL for 2 months to work on a plume-rise module for the ADPIC code. Both organizations perceived the need for this capability. Dr. Desiato's visit provided an opportunity to develop this module and to share emergency response work that is ongoing at LLNL and ENEA. In addition, Dr. Desiato presented a seminar to the LLNL staff on the Montalto sea-breeze experiment.

In the spring of 1985, Dr. Desiato and Dr. Pasquale Armenise (ENEA) visited LLNL for 2 weeks. The ENEA ARIES system was

installed on the ARAC computers and demonstrated to the ARAC staff. The completed portion of the expanded ARAC system was also demonstrated to the ENEA staff. The demonstrations and resulting discussions led to further technology exchange through the sharing of application software. The model evaluation work by ENEA on the Montalto sea-breeze data set was also discussed for both the M/A and the ENEA sequential-puff model, SPADE. Several methodologies for comparing model calculations with tracer measurements were reviewed, and plans were made for additional work. A jointly outlined paper, discussing the results of this research, was presented at the 1985 international conference in Luxembourg.⁶ A draft of a paper, based on development of a plume-rise module for M/A, was completed.⁷

In the spring of 1985, Dr. Marvin Dickerson (LLNL) visited the ENEA for 1 week. Both an abstract and a paper discussing emergency response modeling from the user's point of view was jointly prepared for presentation at the Luxembourg conference,⁸ and the ENEA demonstrated their latest version of the ARIES system. Progress on cooperative efforts was summarized with emphasis on the modeling aspects, and each organization concluded that progress in system development efforts made future technology exchange in this area feasible. Finally, the outline for the present report was developed.

In the fall of 1985, Dr. Rolf Lange (LLNL) visited ENEA to compare the Montalto sea-breeze experimental results with the ARIES and ARAC nested-grid M/A model calculations. Investigations of decoupling vertical and horizontal diffusion coefficients using the sea-breeze data set showed improved comparisons between model and measured concentration values. The results were presented at the 1985 IAEA international symposium in Rome.⁹

Technology Exchange

The major area of technology exchange between ENEA and LLNL during the past three years is model improvement and evaluation. LLNL evaluated the M/A models against meteorological and tracer data measured in complex

terrain,¹⁰ rolling terrain,¹¹ and emissions from a tall stack in flat terrain.¹² These studies led to model improvements that, in turn, fed back to the operational models used by the ARAC and ARIES systems.

The ENEA used sea-breeze data obtained at the Montalto site to evaluate a simpler model, SPADE,⁶ as well as their version of the M/A models. Evaluation statistics produced by these studies were included in the overall statistical data base for these models. A summary of model evaluation studies performed for the M/A models was recently presented to an IAEA sponsored international symposium.¹³

Technology exchange in the system area has lagged behind that in the modeling area; however, efforts have been made to ensure that the two systems are nearly compatible so that future exchange of software and ideas can be readily accomplished. Once the basic expansions are completed, cooperative work in this area can proceed.

New Objectives

ARAC

The ARAC service is expected to complete its automated system by October 1986, when approximately 50 DOE and DOD sites will receive the service using the fully automated system. The service will continue to be available to the NRC for nuclear power plant incidents and to other government agencies responsible for managing emergency response activities associated with the transportation of nuclear materials. For example, ARAC provides guidance to the U.S. Federal Aviation Administration (FAA) in the event that a country tests nuclear weapons in the atmosphere. ARAC provides estimates of potential doses to passengers and crews of U.S. aircraft flying in or near the nuclear debris cloud. Should the estimated dose along the planned route exceed radiation guidelines, the flight path of the aircraft is modified.

ARAC will soon begin a feasibility analysis for response to toxic chemical releases. The fundamental principles of response to a nuclear accident are transferable to situations involving chemical accidents; however, response

for toxic chemicals can be much more complex than these for nuclear releases. Thousands of chemicals pose a risk: many have unknown health effects. Furthermore, the frequency and variety of accidents involving toxic chemicals are much higher than those involving nuclear material.

Development of a hydrodynamic model to produce wind fields for nuclear facilities located in areas of complex terrain and meteorology is a long-term ARAC research project. The initial objective is to model wind-field patterns under a given set of boundary conditions. Output from such a model will be used to assess the consequences of a potential accident. This first-generation model is not expected to provide assessments in real time, but implementation of an advanced, real-time hydrodynamic model is feasible in the future.

ARIES

The first objective for ARIES is to fully automate the system by completing the communication network. Site data are presently collected at the central facility by a standard commercial-grade voice line. Next, resources will be used to improve both the capability and the system manageability of both the central and site facilities. Expansion of the system to handle accidental releases of conventional toxic material will be initiated. The expansion is a substantial undertaking that will require a

gradual extension of present capabilities, concentrating initially on the most important response aspects and the most toxic chemicals. Finally, field experiments will be conducted to improve model parameters for sea-breeze and calm wind conditions.

Many of the activities planned for the near future will be conducted in cooperation with LLNL. The development of some modules of the system or the investigations and testing of the models will be performed separately. Information will be exchanged either through written reports or visits. The main cooperative studies will be in the areas of model development and evaluation and of system software development. In particular, the following subjects will be treated:

- Decoupling of vertical and horizontal source-particle diffusion parameters in ADPIC.
- Model evaluation using field data.
- Plume rise module.
- Description for vertical wind profile in the absence of upper-air data.
- Development of SPADE model.
- Diffusion in calm wind conditions.
- Diffusion of conventional toxic materials.
- Optimization of codes.
- Management of meteorological data.
- Management of radiological data.
- Graphical analysis.
- Telephone connection between ARAC and ARIES central facilities.
- System software architecture.

Present Status of Technology Exchange

Model Research

Extensive model research by LLNL and ENEA has been an ongoing and cooperative effort for the past five years. The following paragraphs summarize the major research conducted during the past three years, since the last progress report⁵ was issued.

Plume Rise

A prescription of plume-rise trajectory as a function of time was developed for ADPIC. This research covers momentum and buoyancy

for vertical and bent-over plumes in a stable, neutral, or convective atmospheric boundary layer. A draft report describing this work has been completed.⁷

SPADE

A sequential puff model of intermediate complexity has been developed during the last two years and introduced into the ARIES system. Sequential Puff for Atmospheric Diffusion Evaluation (SPADE) provides a real-time, fast-response assessment for accidental

release of nuclear material from a nuclear power plant into the atmosphere. SPADE is a 3-dimensional, Lagrangian, short-range puff model: effects of topography are not included, and it requires only simple meteorological and geographical data. SPADE has been recently evaluated with the meteorological and tracer data collected during the diffusion experiments in June 1983 and 1984 at Montalto di Castro.

SPADE was developed on the original ARIES computer system. In 1985, a new version of the model was implemented on the ENEA VAX computer. New techniques for determining puff trajectories and a time- and space-interpolated wind-speed calculation were installed.

ADPIC

A time-smoothed, particle-generation process was introduced into the LLNL and ENEA ADPIC models to improve the near-source distribution of the plume. Improved resolution of the concentration pattern was obtained with the introduction of a nested grid close to the source and an interpolation algorithm in the outer regions. This nested grid process, involving four successively smaller grids nested within the ADPIC grid, improves the accuracy of concentration resolution near the source by a factor of 16.

Input variables with averaging times different from those of the mean wind field (e.g., source term, rain rate, atmospheric stability, mixing-layer height) were separated in the ARIES version of M/A and listed in a new ADPIC input file (PICIN1) that can be read at time intervals different from the wind fields (WINDY). Improvements were also made in ARIES output graphics. During the execution of ADPIC, the plume shape and direction, updated at each time step, are displayed over site geography on a video terminal.

At LLNL, versions of the ADPIC and plotting codes were programmed for both the CDC 7600 and VAX computers. Such programming was the first step in generating a single master version of the ARAC models, thereby simplifying development and evaluation of codes.

Other improvements for the LLNL M/A codes since 1982 include a multiple vertical wind-profile input for MATHEW, improved curves for the vertical diffusion coefficient K_z that are based on similarity theory and validation tests, improved surface-air concentration boundary condition in ADPIC, and expansion of the friction velocity U_* calculation in ADPIC to a 2-dimensional array that represents the local winds and terrain. Some of these model improvements were shared by ENEA and LLNL.

Model Evaluation

The Montalto sea-breeze data sets collected by ENEA and Centro Comune di Ricerca (CCR) in 1983 and 1984 were used to evaluate M/A. Several continuous tracers released under sea-breeze conditions at the Montalto nuclear plant site were modeled by both ENEA and LLNL. Results of these studies were reported at the 1985 IAEA conference in Rome.^{9,13}

Extensive M/A validation studies were conducted by LLNL on the ASCOT-Geysters (drainage flows), MATS, and EPRI (tall stack) data sets. ASCOT refers to the DOE program on Atmospheric Studies in Complex Terrain; MATS refers to the Mesoscale Atmospheric Transport Studies; EPRI is the Electric Power Research Institute (U.S.). These studies were presented at the DOE/AMS Model Validation Workshop in October 1984 on Kiawah Island, South Carolina,¹⁰⁻¹² and at the American Meteorological Society (AMS) Conference on Mountain Meteorology in October 1984 in Portland, Oregon.¹⁴ These evaluation studies illustrated weaknesses in standard regression analysis when individual scenarios are modeled, and LLNL and ENEA developed optional statistical packages to judge the effectiveness of models. One of the procedures computes the percentage of cases in which measured and computed concentrations agree to within a factor R . Another technique compares agreement within some specified angular uncertainty. These methods will be tested in future studies.

Software Development

ARAC General Philosophy

The major goal for the new ARAC system was to improve response effectiveness by means of the following specifications:

- Transmission of preliminary calculations and graphics to a site within 15 minutes after initial notification.
- Completion of sophisticated calculations within 45 minutes and every hour thereafter until the release is terminated.
- Capability of handling up to three emergencies simultaneously.
- Twenty-four hour per day support by a staff of highly trained emergency-response personnel.
- Support of up to 100 remote site systems.
- Rapid response to accidents at arbitrary locations where no site computer system is available.

Support for remote sites was designed in the form of a small computer system. The computer enables sites to communicate with the ARAC central facility, to display products generated at the central facility, to manage local meteorological data, and to graphically display results from a simple atmospheric dispersion model continuously and automatically.

Backups in hardware, software, sources of meteorological data, and product delivery systems were designed to ensure that the new system could recover and respond despite hardware or software failures. In addition, the new system requires minimal interaction among operators and meteorologists at the central facility and personnel at the site facility. Modern programming practices were used to develop a modular system that has clearer interfaces to facilitate integration of enhancements and to reduce the cost of maintenance.

To save time and increase confidence in the calculations, human intervention focuses on quality assurance. All meteorological data are automatically validated, and both questionable and fatal input values are flagged. Historical plots of meteorological data at all stations are used so that a meteorologist or assessor can as-

sess the reasonableness of a given observation. A 3-dimensional graphics display for terrain is currently under development.^{15,16}

To notify the meteorologist of hardware and software problems, extensive error-detection routines are built into the system. Error messages generated by the site system are formatted into operator messages and sent to the central system. Interactive and automated processes inform the meteorologist of errors. In addition, all information (including messages) relating to a problem is archived to facilitate post-assessment studies.

Human engineering factors (ergonomics) were given careful consideration. Menus and forms for both site and central systems are tailored to a user's level of expertise. For example, certain forms are designed to guide the site user in data entry, while more flexible forms are designed for ARAC personnel.

ARIES General Philosophy

Recent structural modifications have been made in the ARIES hardware and software architecture. A DEC VAX 11/782 multiprocessor computer system has been dedicated to execute the system software. The increase in computational power and the need to improve system performance (especially when the ARIES staff is not immediately alerted to a problem) stimulated conversion of the software architecture from sequential to concurrent. At present the ARIES system is a virtually distributed system and consists of several different processes that share the two processors in the computer system. Furthermore, the main programs METEO, MEDIC, MATHEW, and ADPIC, as well as some other minor programs, are assembled into a pipeline architecture so that the output of one or more components is the input for another component.

All ARIES programs can be divided in two groups: either functional programs or programs for supervision and control. Those programs that directly relate to the system's final goals, e.g., codes describing wind fields and pollutant dispersion, are functional programs. Other programs that supervise and control the

whole system, such as MONITOR and SUPERVISOR, are in the second group. As a consequence of changes in hardware architecture, other structural modifications in the software architecture are made to improve system performance and to obtain greater reliability.

Operational Models and Support

Operational models are directly integrated into the ARAC and ARIES systems, whereas research models are used to develop improvements. In a carefully constructed set of procedures, improvements made in the research models are tested and may be periodically transferred to the operational models.

ARAC

Models. Several computer models are available to ARAC for simulation or estimation of the consequences of an atmospheric release of hazardous material on a local, regional, or global scale. Local assessments (within about 10 to 20 km from a source) and regional assessments (within about 100 km from a source) are performed with 3-dimensional M/A codes to estimate air concentrations, integrated doses, and ground contamination arising from continuous or instantaneous releases from point sources. Effects of stratified shear flows, calm conditions, topography, deposition, radioactive decay, and particulates can all be treated with the codes.

The KDFOC2 model¹⁷ can be used for assessment of radioactive fallout, and the 2BPUFF and PATRIC models can be used for long-range transport and diffusion from nuclear explosions.^{18,19} PATRIC is a coarse-resolution derivative of ADPIC, adapted to operate with hemispheric-scale wind fields to calculate the intercontinental transport and diffusion of material.

Model Parameters. Several aids are under development to help the meteorologist in selecting model parameters. These aids offer the meteorologist a choice of

- Algorithms for computing parameter values.

- Default values including those that are site-specific.
- Automatically computed values.
- On-line data bases.
- On-line help information.

Problem-specific information, such as location and time of the release, substances involved, and whether the release is in the form of a puff or a plume, is entered into an on-line questionnaire at the central facility or on a site system and then accessed by the computer models.

Site-specific geographical maps are displayed in the questionnaire for supported locations. To specify the release coordinates, the user positions a cursor at the reported location. Site maps are also used for interactive selection of the model grid. Parameter values are estimated automatically by software on the basis of available meteorological data and information contained in the questionnaire. The meteorologist can modify these values interactively by choosing algorithms, using default values, or entering values directly.

Information about potential accident/release sites, the half-life of various radionuclides, and dose-conversion factors for several exposure pathways is stored on-line for interactive use. On-line information to document procedures and to aid in decision-making is available throughout the system to help the meteorologist interact with the computer.

Meteorological Data Collection. The system has numerous automated capabilities that are initiated by the software when corresponding information is entered in the questionnaire. As soon as a release time is recorded on the questionnaire, automated station selection and meteorological data collection are initiated for stations within the default radius of the release. Meteorological data for the location and duration of a release are collected in real time for input to the models. Most meteorological data for these models come from the U.S. Air Force Global Weather Central (AFGWC), which provides a worldwide master station catalog of all stations that report meteorological data to the World Meteorological Organization (WMO). For hourly calculations, the system

typically collects the necessary meteorological data by 20 minutes after the hour.

Data Bases. The standard regional-terrain file for ARAC emergencies consists of a square that is 200 km on a side oriented on a Universal Transverse Mercator (UTM) grid with a resolution of 0.5 km. The data base created specifically for ARAC emergencies is composed of files that are also terrain grids at 0.5-km resolution that cover a 120-km square area oriented on a UTM grid.¹⁵ The system allows a file to cover any 1-deg quadrangle on the Earth. One terrain grid is available for each 1-deg quadrangle in the continental U.S. The southwest corner of each quadrangle is approximately 5 km north and 5 km east of the southwest corner of each terrain grid. The approach provides significant overlap with adjacent files. The system can access and create a terrain data file for any point in the U.S. in real time within about 2 minutes.

Base Mapping. In addition to terrain data, ARAC also requires the fast generation of base map geography for any region. Such data are used as an overlay for the graphic products distributed to users of the ARAC service to orient the contours with respect to the region's geography. At present, this capability is limited. Information is digitized from various maps using the U.S. Geological Survey (USGS) 1:250 000 topographic maps as a base and supplementing them with detailed maps provided by each supported site. The process for preparing for an incident away from a supported site is time-consuming. A geographic data base using 1:2 000 000 mapping provided by the USGS will soon be installed.

Graphics. Quality control of terrain data is of the utmost importance. Corrupted data can appear at any point in the process of creating terrain data for the models. The key to quality assurance is graphical display of the terrain. Since the terrain system became operational, standard procedure has been to contour the regional terrain file as soon as it is produced. Interactive manipulation of small amounts of data permits recovery from certain types of problems. Future efforts will be directed to-

ward the development of additional techniques for recovering from losses of larger amounts of data.

A new graphics product now operational on ARAC VAX computers is an overhead view of a shaded-relief image of the terrain surface. This product uses color to provide an exceptionally clear rendering of the Earth's surface in which features are distinct and recognizable. It clearly highlights any problems in the data, even at the individual grid-cell level. A black-and-white example of terrain displayed by this system is shown in Figure 3.

Communications. A superior electronic communications system is of primary importance in a distributed application, such as ARAC, for which hardware components may be remotely located from the central system. Early in the project, it was apparent that the VAX hardware could not handle remote communications problems. DDCMP, a DEC standard protocol, was chosen to communicate with the remote site systems via LSI 11/23 communications front-end processors and the PC350 site system.

This communications system manages the transfer of messages and files among the ARAC central computers and the individual site computers. The DDCMP system will replace the present terminal line system that requests and receives worldwide meteorological data from the AFGWC. It will also obtain meteorological data from the site meteorological towers by means of the site-system computers.

Remote Site System. Site computer users can initiate a response at the central facility by entering source-term information into an on-line questionnaire. The site computers can also use the system to collect meteorological data from on-site towers, enter on-line supplementary meteorological observations obtained from local (sometimes portable) instruments, provide two-way communication with the central facility, prepare simple dispersion model calculations, and graphically display both these models and the ADPIC products prepared at the central facility. ARAC microprocessor-controlled meteorological towers are used to collect and archive observations continuously.

Figure 3. Computer generated terrain for a 40- x 40-km area surrounding the TMI-2 nuclear power plant site.

These towers are accessible to both the site and the ARAC central computer systems.

Hardware. The basic hardware configuration used by ARAC is shown in Figure 4. Hardware at the central facility consists of a cluster of two DEC VAX 11/782 computers that use three DEC LSI 11/23 computers, connected via Ethernet, as communications front-end processors. This system has ~2.7 Gigabytes of disk storage including 1.2 Gigabytes in a shared disk form. DEC PC350 computers and meteorological towers with Handar 540 microprocessors are used as the site system at ARAC-supported facilities. Connection to the ARAC central facility is via standard phone link used on an as-required basis. A Xerox 495 telecopier connected to the VAX computers permits direct transmission of text messages. Planned development of a graphics driver will allow the central facility to transmit VAX-produced graphics directly to remote telecopiers at both supported and nonsupported sites. A voice-synthesized, page-alarm system with micropro-

cessor is used to alert emergency-response personnel.

ARIES

Models. Two categories of operational models are presently being used by ARIES. The first are those models used to describe pollutant transport. At present ARIES uses the M/A complex models or the SPADE model. The second type of model is used to evaluate health effects, environmental contamination, and countermeasures in the event of inadvertent release of toxic material.

Meteorological Data Collection. The ARIES center receives meteorological data from the Italian Weather Service via a dedicated phone line. All meteorological messages for a 48-hour period are stored on disk files by an IBM/Series 1 computer. On the same computer, METEO software allows the user to select desired data, depending on the site and time of an accident. At present, the output

Figure 4. ARAC present hardware configuration.

of METEO is a printout of SYNOP decoded data and of METAR, TEMP, and PILOT undecoded data. Another program uses available SYNOP wind data to provide the streamlines in the region of interest and to calculate the best location of the M/A grid.

Data Bases. Data-base and management systems that allow for the rapid extraction of pertinent information needed during an emergency are an essential part of the ARIES sys-

tem. This component of the system was developed during construction of plant siting maps that were used to select the most suitable areas in Italy for nuclear power plants. Moreover, several integrations and improvements have been made regarding the quality, quantity, and spatial resolution of territorial parameters. Territorial variables that are presently available are:

- National, regional, provincial, and communal borders.

- Contours of cities, towns, and villages with 200 or more inhabitants.
- Demography (population of each center).
- Roads, highways, and railroads.
- Airports.
- Meteorological towers.
- Rivers, lakes, and watersheds.
- Seismic occurrences.
- Isolines of seismic activity and volcanoes.
- Topography (average heights of 250- x 250-m cells).

Graphics. Graphics software now in use to obtain color displays of output from the ARIES system is the Tektronix Interactive Graphics Library (IGL-TEX) and CALCOMP graphic packages. Output devices use Tektronix color graphic terminals and a Versatec electrostatic printer-plotter. The main components of the graphic software are:

- Interactive graphics to modify certain input parameters such as topography and wind profiles, when necessary.
- Graphics monitor to display the transport of the plume at each time step of the calculation.
- Standard graphics to display at 0.5- or 1-hour intervals the graphical representation of the analysis, e.g., wind field, concentration, and dose contours.
- Analysis of system events to display at selected times different sections and concentration contours.

Communications. The effective operation of the ARIES system is strongly dependent on rapid data exchange among the central facility, site facilities, local response centers, and other agencies involved in an emergency. The ARIES network is characterized by a "star" topology in which the ARIES Central Facility (ACF) is located in the central node. Peripheral nodes are, in general, connected to ACF by means of both voice (authorities rooms) and data phone lines. Other data are collected at the ACF by two radio receivers connected to the European Weather Centers and to Meteosat 2 (the ESA meteorological satellite). The three main nodes or groups of nodes linked by data phone lines are CNMCA (sometimes called SMA, which is

the Italian Weather Center), sites, and the Mobile Laboratory.

CNMCA transmits to the ACF meteorological observations from national and international surface and upper-air stations and forecasts for 6 to 96 hours. At present, the telephone line connects the CNMCA-IBM S/370 computer to the ARIES-IBM S/1 minicomputer. Soon meteorological data will be collected at the ACF directly onto the VAX by means of the DEC DUP11 synchronous communication interface and the DEC PE 3271 program emulator.

Remote Site System. In Italy, site facilities are generally located at some distance from nuclear installations. The utilities are responsible for collecting and transmitting source-term, meteorological, and radiological data to authorities engaged in the management of an emergency. Analysis of an accident is performed by a local committee, which includes ENEA-DISP personnel, and by the staff of the ENEA Emergency Center, including the ACF. This arrangement requires the ARIES network to have two links from the ACF: one to the local response center and another to the nuclear power plant to collect environmental data. Another link, not included in the ARIES network, connects the nuclear power plant to the local response center. Because of current difficulties in obtaining dedicated phone lines for data communications, these nodes (sites) are connected to the ACF by means of commercial lines. Fully automated data links are planned for the beginning of 1986.

As previously mentioned, ARIES has two different site systems at the nuclear power plants: one dedicated to data collection and another used for accident analysis. The second system is similar to the ARAC Site Facility and is located near the installation. This remote system: automatically collects data and has the capability of performing an analysis of the accident. It is equipped with a minicomputer for data management and for executing simple atmospheric dispersion codes. Recently, ARIES installed the SPADE model on a minicomputer similar to the one used as a remote system.

At research installations, many of which are ENEA research centers, the two functions of data collection and analysis are performed by one system, usually located at the plant emergency center.

Hardware. The ACF basic hardware configuration is shown in Figure 5. ARIES hardware consists of a DEC VAX 11/782 computer, an IBM Series/1 minicomputer used as a communications front-end processor, and several management components, e.g., system consoles, METEO facility, and graphics anal-

ysis. Each component consists of one or more input/output devices. The most complex device is the system console equipped with:

- A terminal for input of data (e.g., WINDY, TOPIN, MINVF, and PICIN).
- A terminal that monitors and displays the main parameters of the system.
- A graphics terminal that serves as particle-transport monitor.
- A graphics terminal for displaying intermediate graphics output.
- A printer for reporting on all phases of system performance.

Figure 5. ARIES present hardware configuration.

At present, all essential meteorological data acquired on the front-end system must be reentered by hand via the ACF input-terminal facility.

Cooperative Studies

Operational Models

At present, ARAC has two ADPIC versions on the VAX system. One is the traditional ARAC ADPIC, and the other is the new nested-grid version. ARAC is developing a "model parameters" interface to MEDIC. MATHEW, ADPIC, and PLCNT, which will aid the assessor in formulating the required model input data. This interface will incorporate default, first-guess, and assessor-defined entries in an interactive, graphically-oriented mode. This interface might be linked with the presaging processing of inputs in the ARIES approach.

System Design and Architecture

ARAC is currently configured on two multiprocessors (VAX 11/782) clustered with Ethernet/Decnet links to the communications front-end LSI 11/23s. The ARIES pipeline design provides an alternative approach. These two architectures provide the opportunity to conduct benchmark performance tests, which could be used to improve both ARIES and ARAC in future system configurations.

Data Retrieval and Decoding

At present, ARAC and ARIES have complementary meteorological data-processing codes. Exchanges of these codes in the future will benefit both organizations.

Graphical Display

In the spring of 1984, ARAC added a high-quality, pseudo-3-dimensional, color, overhead terrain-viewing capability coupled to the terrain data base. Because ARAC and ARIES have identical computer and graphic devices and ARIES can prepare the same input file of terrain data, this new software can be shared with ARIES.

Problem Monitor

As the ARAC and ARIES systems have evolved to more automated modes, each system has begun to develop problem-monitoring systems. Such systems keep the assessment staff updated on calculations, essential data, communications, and system resources (e.g., available disk space, memory, and CPUs.). ARIES has developed an informative, real-time, model status presentation that ARAC is evaluating for possible incorporation. The entire area of information processing and feedback is an appropriate candidate for mutual investigation and cooperation.

Future Cooperation

Model Research

Through both independent and cooperative research and development during the next several years, the ARAC and ARIES project staff members plan to continue to advance the state of the art of emergency response systems. Future joint ENEA/LLNL work in model research will address the following subjects:

- Decoupling the prescription of vertical and horizontal source-particle diffusion parameters in ADPIC. Based on the Montalto sea-breeze data and on general physical considera-

tions, decoupling of vertical and horizontal stability will lead to improved model estimates of concentration patterns and maximum concentration values.

- Continuing model evaluation studies, particularly for diffusion experiments in complex terrain. The next field data used for model validation will be ASCOT (LLNL) and Brasimone (ENEA) data. Brasimone is a site of complex terrain in the Appennine mountains where METEO-diffusive experiments were performed in September 1984 and June 1985. The ASCOT data base was established with field

studies in Brush Creek, an area of complex terrain in western Colorado.

- Installing the plume-rise module in the LLNL ADPIC code and testing the resulting calculations against diffusion experiments that include plume-rise effects.

- Improving the prescription of the MEDIC vertical wind profile when no upper-air data are available.

- Addressing several aspects of the SPADE model, such as improving interpolated wind fields from three meteorological stations to extend the spatial range of validity, improving time resolution of wind data with interpolated wind fields at each time step, decoupling of vertical and horizontal stability, and selecting different expressions for diffusion coefficient.

- Investigating diffusion in calm conditions. At present, diffusion in calm conditions is included in the models as a physical parameter obtained from wind conditions. This circumstance is mainly due to the lack of experimental tracer data in calm conditions.

- Performing feasibility studies for release of heavier-than-air toxic chemicals. In terms of model development, this study will address the possibility of combining a 2-dimensional, heavier-than-air model that would treat the first stage of the diffusion with ADPIC and would cover diffusion after the gas had mixed sufficiently with air.

System Software

Operational Models

Providing timely calculations requires streamlining and optimizing of the model's environment. For the MATHEW/ADPIC/PLCNT suite of models, graphics elements will be separated from calculational elements. Each element will then be code-optimized for improved throughput performance. At the same time, the primary calculational arrays will be placed in shared, global sections so that graphics processing can proceed on one VAX 11/782 CPU while calculational processing continues simultaneously in the second CPU.

System Architecture

At present, it is difficult to obtain full use of all CPUs in the LLNL dual-VAX 11/782

environment. ARAC will review the current architecture with respect to more loosely coupled, separate CPUs (11/780s or 785s) with some shared memory bank. The DEC VAX-cluster technology is proving to be a strong alternative to the 11/782 master/slave architecture; however, some impacts on the nonmodel portion of the new ARAC software will occur if a change is made in architecture. Alterations to the system architecture will be postponed until an impact assessment is completed.

Meteorological Data Decoders

ARAC presently uses one U.S. Airways decoder and one WMO upper-air decoder. We look forward to exchanging the latter with ARIES for their synoptic data decoder. The exchange will increase the capabilities of both organizations.

Graphical Display

ARIES and ARAC share similar graphics workstations (Tektronix 4115); hence, it is possible to share display software. The difficulties with graphics stem from differences in libraries, but these factors should not be limiting. ARAC will deliver a pseudo-3-dimensional terrain display package to interface with the ARIES terrain data system early in 1986.

Communications

ARAC presently has communications modems on the VAX that permit 300- and 1200-baud terminal connections and 4800-baud DECNET node definition. During 1986, ARAC will conduct feasibility studies to find the best connector node for the exchange of ARAC and ARIES system improvements. If a DECNET node is used, models can easily be jointly activated and tested. The potential for mutual assistance will then be greatly enhanced.

Hardware

In the near future, ARAC does not envision major hardware changes beyond those required for a shift to the loosely-coupled architecture. More disk storage, laser printer, and plotter devices will be purchased as support funds become available.

The main changes in the ARIES hardware configuration will be to the computational components. The DEC VAX 11/782 computer will be divided into two VAX 11/780s with an upgrading of one unit to an 11/785 for

improved performance. Furthermore, for the communications front-end functions, a Micro VAX-II will be acquired and connected to the two VAX computers by means of a local network (Ethernet), as shown in Figure 6. The

Figure 6. ARIES hardware configuration planned for the future.

Micro VAX-II will provide the communications interface to a number of remote sites and a mobile laboratory. The previous data links to the IBM Series 1 front-end computer will be connected directly into the Unibus of the VAX 780, thus solving the data-transfer problem of the existing configuration (e.g., CNMCA and

ENEA networks). The primary terminals and work stations will be moved from the VAX 782 to a shared configuration on Ethernet. Further improvements will be associated with central memory, mass storage, and peripheral and communications buses.

Recommendations

The following recommendations are those expected to provide the highest future pay-offs. Recommendations are based on five years of cooperative experience between LLNL and ENEA.

Input/Output Standardization

At the beginning of cooperation between LLNL and ENEA, a substantial difference existed in hardware configuration of the ARAC and ARIES systems. This discrepancy required several modifications in the input/output structure of the Italian version of the M/A codes. At present both organizations have similar hardware components. It is both possible and desirable (in view of future telephone connection of the two central facilities) to standardize the input/output component. The following items are recommended with respect to standardization:

- Test the M/A codes by means of experimental data collected during field experiments both in the United States and Italy.
- Test and validate with a sample case the upgrade and improvements of the system modules and the introduction of new modules developed by both organizations.
- Execute an exercise or problem from both the ARAC and ARIES systems simultaneously.

Model Development and Evaluation

Emergency-response systems, such as ARAC and ARIES, are dependent on improved models that are evaluated with field experimental data. This area of cooperative research between LLNL and ENEA should continue to

receive high-priority status. Field experiments (e.g., the tracer experiment during calm winds that has been proposed by ENEA) conducted by both organizations should continue to provide data to develop better parameterizations for the models and to add to the model evaluation data base. Efforts should continue toward development of a hydrodynamic assessment model; improvements to the SPADE and M/A models should also be pursued. By working jointly in the area of model development and evaluation, more objective and useful results can be expected for improving and evaluating the emergency-response models.

Criteria for Emergency-Response Models

Both ENEA and LLNL should pool their expertise and experience to develop a set of criteria that emergency-response models would be expected to meet. Many techniques are available for quantitatively describing how well models perform against measured air-concentration data obtained from field experiments; however, guidelines should be established for expected performance criteria (EPC) for emergency-response models. Once the EPC have been established, then techniques for evaluating models can be suggested. LLNL and ENEA should take the lead in establishing the EPC and then solicit input from other countries and organizations.

Emergency Response for Toxic Chemical Releases

Both organizations recognize the need for applying emergency-response techniques, learned through planning for nuclear accidents,

to the toxic chemical industry. The emergency-response framework represented by the ARAC and ARIES service can be used as an excellent starting point for expansion to other hazardous atmospheric releases. As with nuclear-accident

responses, ENEA and LLNL can combine their expertise and experience as a function of each country's needs to develop an improved emergency planning response for the toxic chemical industry.

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Glossary

Acronyms, Symbols, and Keywords

ADPIC	Atmospheric dispersion, particle-in-cell model. A 3-dimensional computer model for the dispersion of atmospheric pollutants (LLNL).
AFC	ARIES Central Facility.
AFGWC	Air Force Global Weather Central (U.S.).
AMS	American Meteorological Society.
ARAC	Atmospheric Release Advisory Capability (U.S.).
ARIES	Accidental Release Impact Evaluation System (Italy). The main computer programs used by ARIES are METEO, MEDIC, MATHEW, and ADPIC.
ASCOT	DOE Atmospheric Studies in Complex Terrain (U.S.).
CALCOMP	Graphics software package used to obtain color displays for ARIES.
CCR	Euratom (Ispra, Italy) Centro Comune di Ricerca.
CNMCA	Centro Nazionale di Meteorologica e Climatologica dell'Aeronautica. Italian Weather Center, also referred to as SMA.
DDCMP	DEC proprietary communications protocol incorporated in the ARAC communications system that transfers messages and files between the ARAC central computers and remote site computers.
DECNET	DEC communications networking software system.
DEC VAX	Digital Equipment Corporation multiprocessor computer system.
DOD	Department of Defense (U.S.).
DOE	Department of Energy (U.S.).
ECC	Emergency Coordination Center (Italy).
DISP	Direzione Sicurezza e Protezione Sanitaria (Italy). The Directorate for Nuclear Safety and Health Protection.
EPC	Expected performance criteria. Used as guidelines that emergency-response models should meet.
EPRI	Electric Power Research Institute (U.S.).
ESA	European Space Agency.
Ethernet	DEC proprietary product that serves as a local area network for ARAC.
FAA	Federal Aviation Administration (U.S.).
Handar	Microprocessor and data logger.
IAEA	International Atomic Energy Agency.
IGL-TEK	Interactive Graphics Library (Tektronix Corp.) software used to obtain color displays for ARIES.
KDFOC2	ARAC computer model for assessment of radioactive fallout.
K_z	Vertical diffusion coefficient.
LLNL	Lawrence Livermore National Laboratory, Livermore, California.
M/A	MATHEW/ADPIC emergency-response model developed at LLNL.
MATHEW	Mass-adjusted, three-dimensional, wind-field model (LLNL developed). One of the four main computer programs used by ARAC and ARIES.
MATS	Mesoscale Atmospheric Transport Studies.
MBA	DEC computer component—MASSBUS adapter.
MEDIC	Meteorological data-interpolation code that initializes MATHEW.
METAR	An international meteorological data code. This form is used for reporting surface weather conditions.
METEO	One of the four main computer software programs used by ARIES. METEO

	software enables the user to select site- and time-specific meteorological data required for an accident or emergency.
Meteosat 2	ESA meteorological satellite. ARIES receives Meteosat 2 cloud imagery via a special communications link.
MINVF	Input data file for MATHEW specifying the number of MEDIC wind fields to be processed.
NRC	Nuclear Regulatory Commission (U.S.).
PATRIC	Computer model derived from ADPIC and adapted to hemispheric-scale wind fields to calculate intercontinental transport and diffusion of material.
PJCIN	Input file for ADPIC model.
PJCIN1	Input file for ADPIC model that can be read at time intervals different from those of the wind fields.
PILOT	An international meteorological data code. This form is used for reporting upper-atmospheric wind speed and direction from balloon-borne measurement systems.
PLCNT	Plot contours. This plotting code is used for ADPIC input.
SMA	Servizio Meteorologico dell'Aeronautica. The Italian Air Force Weather Service, also referred to as CNMCA.
SPADE	Sequential Puff for Atmospheric Diffusion Evaluation. A three-dimensional, real-time, Lagrangian-puff model for evaluation of atmospheric diffusion.
SYNOP	An international meteorological data code. This form is used for reporting surface weather conditions.
TEMP	An international meteorological data code. This form is used for reporting upper-atmospheric temperature data from balloon-borne measurement systems.
TOPIN	Input data file for ADPIC specifying terrain data and grid relationships.
U_x	Friction velocity.
UBA	DEC computer component—UNIBUS adapter.
USGS	U.S. Geological Survey.
UTM	Universal Transverse Mercator coordinate system.
WINDY	Input file for MATHEW model that specifies observed wind data.
WMO	World Meteorological Organization.