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HMIMS: Hazardous Materials Incident Management System for Air Force Fire Departments†

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The Hazardous Materials Incident Management System (HMIMS), an integral part of the Air Force comprehensive hazardous material (HAZMAT) program, is a computerized chemical incident response system. It is intended primarily for use by Air Force fire departments to retrieve response information during chemical incidents and as an instrument to collect information on amount, location, and nature of chemicals on the base. Both graphic and nongraphic data are supported by the HMIMS. The graphics include a hierarchy of maps which supports both small-scale (as a regional map) and large-scale (building or room) display. The nongraphics databases incorporate the chemical inventories, Material Safety Data Sheets, Response Data Sheets, and standard operating procedures, and the site characterization and analysis information necessary to generate Superfund Amendments and Reauthorization Title III Tier I and Tier II reports. The HMIMS is installed on two personal computers, one at the fire house and another on a HAZMAT vehicle at the incident site. Communications software enables the two to act in conjunction. The HMIMS assists hazard assessment and response during HAZMAT emergencies, provides incident management guidelines, and functions as a training tool to simulate emergency response.

INTRODUCTION

The Hazardous Materials Incident Management System (HMIMS) is a software product designed to meet the on-scene hazardous material (HAZMAT) management requirements of the Air Force.[1] Emergency response personnel responding to HAZMAT incidents face complex and uncertain situations. In addition to familiar hazards, such as fire and structural instability, HAZMATs pose a threat which cannot be understood until the materials are identified and their characteristics are described. Despite incomplete information regarding the type of HAZMAT, protective clothing requirements, or potentially vulnerable areas, decisions must be made in response to emergency situations. To make a decision during such times, emergency managers need as much information as possible, as rapidly as possible.[2-4]

There is a great deal of environmental awareness and recognition of potential hazards associated with chemical exposures. Congress has proposed and the Environmental Protection Agency and other governmental agencies have promulgated a succession of environmental regulations to protect the public, workers, and environment. The Resource Conservation and Recovery Act, Clean Water Act, Clean Air Act, Occupational Safety and Health Act, and the Transportation Safety Act have generated numerous regulations and guidelines related to chemical spills, HAZMAT management, and worker safety. One highly visible public law, administered by the U.S. Environmental Protection Agency, is the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), better known as Superfund. In 1986, Superfund was amended through the Superfund Amendments and Reauthorization Act (SARA). One part of SARA, Title III[5] was a new and distinct law separate from CERCLA in intent, scope, and issue. It brought to federal, state, and local governments, as well as to private industries, numerous requirements in the areas of emergency planning, community right-to-know, hazardous emissions reporting, and emergency notification. The objectives of Title III are to improve local chemical emergency response capabilities and to provide citizens access to information about chemical hazards in their localities.

The Air Force has interpreted these laws and regulations for the Air Force community. Each Air Force base, depending on its size and mission, may have many different HAZMATs. Addressing their needs for emergency response can be a challenging task. The Air Force, through regulations and a letter from the Director of Engineering and Services at Headquarters, U.S. Air Force, dated Dec 16, 1985, has determined that the responsibility for initial response and coordination of HAZMAT incidents at each Air Force base resides with the base fire department.[6-8]

To assist fire departments in responding to HAZMAT spills and ongoing installation restoration programs, the Air Force

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initiated a project entitled Environmental Protection for Hazardous Materials Incidents. This project was sponsored by the Air Force Engineering and Services Center (AFESC), Research, Development, Construction, Fire (RDCF) (Interagency Agreement No. 1489-1489-A1). Under this project, Oak Ridge National Laboratory was given responsibility for (1) determining the extent of the HAZMAT problems; (2) characterizing and supplementing overall Air Force strategy directed toward HAZMAT management; and (3) developing a HMIMS.

During the earlier phases of the project, through visits to selected Air Force base sites, project members evaluated the available resources of the installation fire departments for HAZMAT control. The HAZMAT response infrastructure was also examined, and base-line procedures and ongoing programs within the Air Force related to HAZMAT incident management were identified. In addition, specific training and personal protective equipment needs of fire protection personnel were determined, and criteria for certification of response personnel were identified. The final phase of the project included identification and development of a prototype software package for HAZMAT incident management that satisfied the requirements and needs identified during the earlier phases.[1]

The HMIMS objectives were as follows:

- to use existing, commercially available databases and software to the maximum possible extent
- to provide easy access to the database by personnel in the alarm room and at the HAZMAT site and to facilitate modification and updating of data
- to provide a user-friendly command interface for use by personnel who are not trained as computer scientists or programmers
- to provide access to inventories, floor plans, Material Safety Data Sheets (MSDS), utility disconnects, plume models, and protocols
- to provide information for personal protective equipment, firefighting, and evacuation
- to provide a stand-alone system with capabilities for network linkages to the Wang mainframe (used by Air Force Civil Engineering)
- to provide a system that enhances training activities for HAZMAT incident response

Emergency management information systems are highly specialized computer application systems involving several different information technologies. Although 38 software systems were evaluated by the Oak Ridge National Laboratory team, at the microcomputer workstation level only two systems were found to offer a significant subset of the features required for HMIMS—the CAMEO (Computer-Aided Management of Emergency Operations) system developed by the National Oceanic and Atmospheric Administration[9,10] and the Emergency Information System/Chemical version (EIS/C) system by Research Alternatives, Inc.[11] They are similar because EIS/C is a commercial modification of CAMEO. CAMEO operates only on the Apple Macintosh family of microcomputers. The advantage of EIS/C to HMIMS is that EIS/C has been designed to run on IBM PC-compatible microcomputers and can therefore run on the Wang microcomputers already adopted and readily available in the Air Force. These microcomputers in turn can communicate with Wang mainframes. EIS/C was found to have the most comprehensive combination of HAZMAT data and map display functions. Maps are essential for displaying important geographic information, such as the location of incidents, HAZMATs, base facilities, transportation routes, projected air diffusion plumes, and emergency resources. Thus, EIS/C was selected as the basis for HMIMS development. Its primary shortcomings are in the area of geographic information processing and first responder level functionality, specific to Air Force fire departments. These areas were targeted for enhancement by Oak Ridge National Laboratory to meet HMIMS goals.

PROTOTYPE CAPABILITY

The Air Force HMIMS has been completed, and a prototype HMIMS system was tested for incident response during the system validation phase. HMIMS is fully operational at Scott Air Force Base. Several staff members in the fire department can operate the system and others are being trained to provide additional qualified staff. HMIMS is installed on two computers, one in the fire department alarm room and another on the base HAZMAT vehicle for on-site operations. Although each computer is capable of operating on a stand-alone basis, they can also exchange information to provide faster assessment of the incident for the first responder. HMIMS provides a simple and rapid means of accomplishing the following:

- locating and listing chemical inventories
- displaying maps and floor plans
- gaining access to MSDS and Response Data Sheets (RDS) which provide information on chemical hazards, fire and explosion hazards, health hazards, personal protective clothing, evacuation, and other response measures
- generating and plotting plumes for atmospheric releases
- entering floor plans into the graphics database
- creating and generating graphics for overlay on the maps and floor plans to reflect changes in the floor plans, indicate chemical locations, and display evacuation routes and output from the plume model
- retrieving lists of prefire plans, standard operating procedures, and other checklists
- printing SARA Title III Tier I and Tier II reports which provide information on the types and locations of HAZMATs within a facility
- tracking and archiving transient chemical stores data
- recording site characterization and analysis information
- automatically updating chemical inventory data
- accessing the Department of Defense Hazardous Materials Information System (DOD HMIS) CD-ROM[12]

HMIMS integrates these functions into a single, user-friendly package.[13] Access to most of the functions is a single-keystroke operation. It is possible for the user of the HMIMS to establish links, or relationships, between maps and the nongraphic database records that are created and viewed through the text screen panels. For instance, chemicals may be "tied" to icons (symbols) that are located on the map of the building in which chemicals are stored, so that the icons appear when the associated chemical records are referenced. A different type of linkage ties modules to one another. For example, the chemical name is a link between the chemical inventory and MSDS modules that allows the user to toggle back and forth between chemical inventory and MSDS panels for a given chemical. A separate module contains 50 000 synonyms cross-referenced to the RDS database via the Chemical Abstracts Service (CAS) Registry Number. In this way, chemicals can be defined by either their common or scientific designations.

The maps used in the HMIMS are organized in a hierarchy or treelike structure. This hierarchy permits progressively more

detailed maps to be examined as the user moves down the tree. The commands "zoom," "recede," and "scan" permit movement to more-detailed, less-detailed, and adjacent maps. A user may follow the paths that exist among the maps to move from one map to another. Alternatively, a user may access a given map directly by selecting it from a maps menu. The menu system permits a "point and click" means of going directly to any map in the system. These methods may be used in combination. For example, a user might move to a given map via the menu, then use the scan function to move to adjacent maps at the same level of detail.

Several methods of data retrieval are provided. Retrieval may be based on the key field associated with each text screen panel, from other panel fields that are known as index fields, or by a process of pattern matching.

HMIMS can include one or more models for estimating the dispersion of airborne releases. The system has been designed to facilitate incorporation of meteorological data and data describing the characteristics of the release. The Simplified Atmospheric Release Assessment Model, developed at Scott Air Force Base, can be used to create sets of plume vectors, which may then be overlaid on the HMIMS maps.

Help screens, accessible from the map screens, provide information on how to access the various modules, enter and retrieve data, and move to the different fields within the text screen panels. Listed at the foot of each text panel are the commands that may be issued from that panel. This on-line guidance facilitates the ease with which the HMIMS can be learned.

The resulting HMIMS provides rapid access to map images and other spatial databases characterizing base facilities including buildings, utility lines, transportation networks, and emergency resources. The principle sources of such information are Air Force Base Comprehensive Plans (BCP), hard copy maps and engineering drawings, and computer-aided drawing (CAD) files.

The system design includes software and data structures for the processing and exchange of geographic and engineering data. This feature facilitates the processing of BCP digital databases into the HMIMS files. For Scott Air Force Base, Oak Ridge National Laboratory developed prototype digital databases characterizing the location of major facilities (buildings, selected utility lines, and emergency resources) and the interior floor plans of selected buildings. Scott Air Force Base has plans to obtain BCP maps in digital form, but digital BCP files are not yet available for the current HMIMS application. Chemical inventories were acquired by the Scott Air Force Base fire department.

The HMIMS menus, accessed via a mouse, provide a user-friendly interface. (On systems without a mouse, keystrokes corresponding to menu items are entered at the keyboard.) HMIMS provides for user access to chemical information through stock numbers, building numbers, room numbers, and spatial coordinates. Spatial coordinates are defined by cursor placement via the mouse and/or keyboard. Typical data sources include MSDS, HAZMAT databases, and Air Force base inventories. A CD-ROM reader is provided to access the DOD HMIS databases. The HMIS,[14] established at the Defense General Supply Center in 1979, is managed by the Defense Logistics Agency. The HMIS stores data from MSDS acquired during normal DOD procurement processes and contains information on more than 30000 chemicals. Data format includes microfiche, on-line, and CD-ROM versions which are updated by the DOD periodically.

Instructions can be entered into the HMIMS database for recall and display during hazardous chemical incidents and fires. Emergency management personnel may revise initially entered data at their discretion. HMIMS is designed to facilitate the preparation of reports in accordance with the SARA Title III requirements.

The user may indicate areas of interest on a given map by "pointing" with the cursor and drawing one or more polygons related to each location. These polygons may represent zones associated with emergency management, such as cordons, precaution areas, levels of risk, and plumes. They are defined as geometric shapes (circles, rectangles, and plume "sectors").

HMIMS is designed to facilitate access to lists of chemical stores by location (building and room or x,y coordinate) and by chemical name. Once a fire or other hazard has been located, it will be possible to identify chemicals stored in the room or in proximity to the room (same floor, other floors, same building, other buildings). Proximity may be defined in terms of a circle of specified radius or other use-specified polygon.

An integral part of the Air Force requirement is the information interface among emergency management operations and other Air Force base operations involved in the tracking of hazardous chemicals and the response to fires, spills, and atmospheric releases. HMIMS thus provides the capability for exchange of data files between the HMIMS system and the existing Air Force Work Information Management System (WIMS), with flat files from the Wang mainframe as the transfer medium.

The user may rapidly enter lists of chemicals in transit, such as explosives and other HAZMATs carried on aircraft, by location and chemical name. Once entered, the lists are accessible for rapid recall and display. All such lists can be archived automatically for future reference.

DESIGN

The HMIMS development draws upon and enhances (1) existing public domain software developed and maintained by the Geographic Data Systems Section, Computing and Telecommunications Division at Oak Ridge National Laboratory and (2) the commercial software package EIS/C.[11] The design of the geoprocessing functions of HMIMS is based on Oak Ridge National Laboratory software, while the graphics and database functions of HMIMS are based on the design of EIS/C. All modifications and enhancements have been integrated so that *to the user* the resulting software retains the "look and feel" of EIS/C throughout. This was accomplished through direct modifications to the EIS/C source code acquired by license purchase from Research Alternatives, Inc.[11]

The EIS/C software provides the following functions and databases:

- MSDS, with information entered by the HMIMS user and RDS, which can be imported from an existing National Oceanic and Atmospheric Administration database of approximately 2700 chemicals
- chemical inventory database for identification of stock numbers, storage types, and amounts of individual chemical locations
- site characterization and analysis database for brief description of contacts, preplan status, and site description
- emergency notepad for preplans, standard operating procedures, and other instant-recall checklists
- locator system for on-screen digitizing of maps and floor plans using retrievable graphics of lines, areas, circles, and text
- map and floor plan drawing program to develop graphic images of base facilities upon which geographic representations of the nongraphic

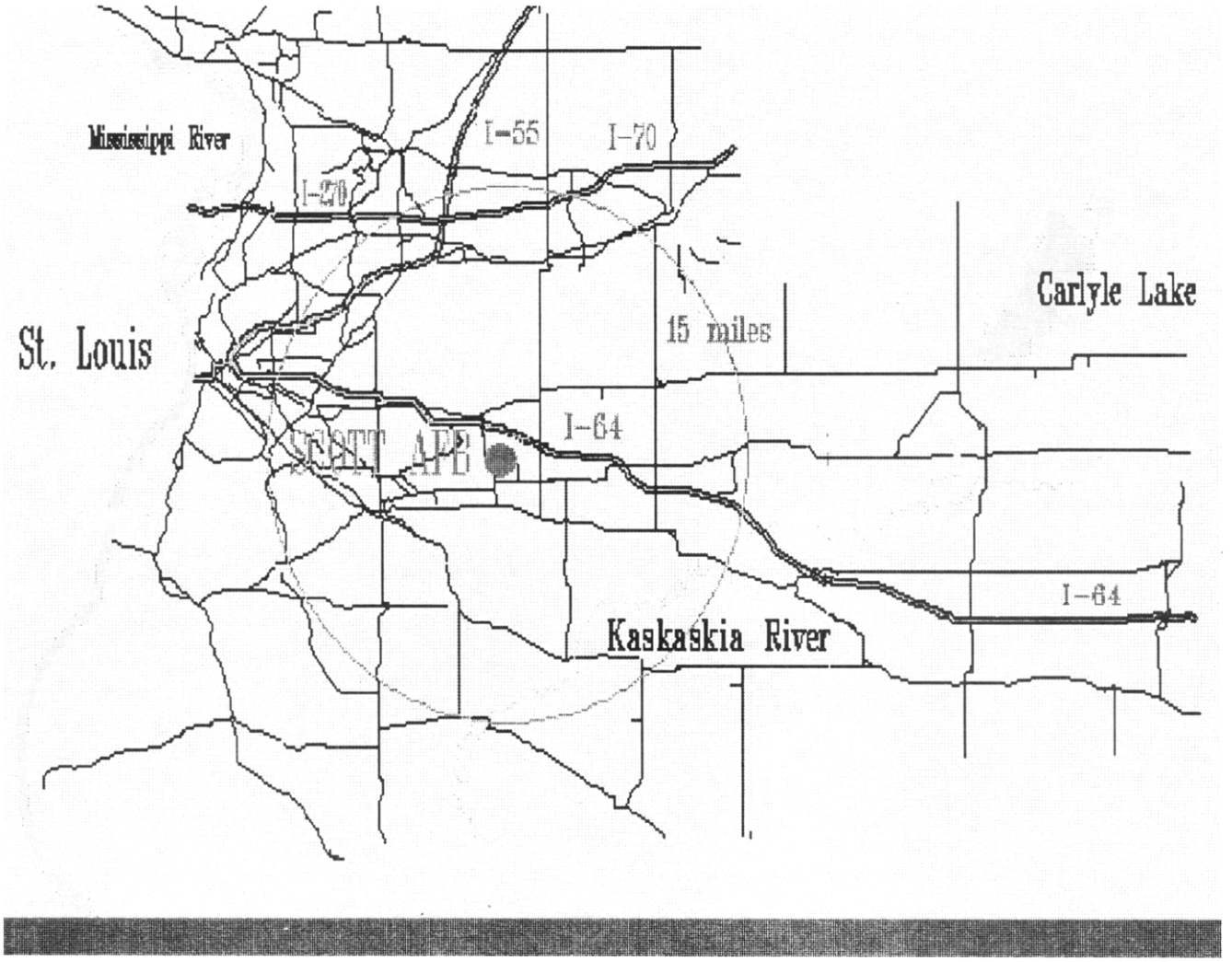

Figure 1. Regional map (Scott Air Force Base and vicinity).

data (e.g., chemical inventories) may be displayed
hardcopy output

The selected software systems and databases have been integrated into a unified HMIMS framework with emphasis on ease of use, rapid response, and comprehensive coverage of emergency managers' needs. Oak Ridge National Laboratory enhancements include:

improved geographic coordinate structures
improved access to external databases, including the HMIS CD-ROM and CAD drawing exchange files
maps menu providing a direct means of moving to any map in the system
module to draw multiple cordons or other polygons and define these as windows for data retrieval
linkage to WIMS at Air Force Civil Engineering
access to and incorporation of data from the Air Force plume model, which was designed to provide maximum first-responder functionality
rapid inventory and archiving of transient chemical stores
automatic chemical inventory program

HMIMS software provides for combined application of both graphic and nongraphic databases. The graphics data (which is displayed in 6 colors) comprise both raster or bit map data (the maps and floor plans) and vector overlays, such as plumes and cordons. Bit maps are not composed of discrete geometric entities such as circles, lines, or other vector data, but are instead an array of values representing a regular grid of cells or pixels. Maps are arranged in HMIMS in a hierarchical order, with the map describing the largest area at the "top" of the hierarchy and maps of smaller areas "under" it (Figures 1 and 2). Graphic coordinates are defined for this top map. Maps on successive levels are registered to the preceding map(s) so that vector data overlay can be performed.

An HMIMS module allows the user to create floor plans and simple maps. More complex maps must be digitized and then converted into the HMIMS bit map format. The digitizing and conversion programs are not included in the HMIMS package; however, this service may be obtained commercially.

A file handling package called c-tree manages the nongraphic data. Calls to c-tree are made by the HMIMS software to permit the creation, modification, and retrieval of data records. Data display is accomplished in two ways. In the first, icons (graphic representations of nongraphic data) may be generated on the map screens. Icons are defined in terms of geographic coordinates which are maintained in the c-tree files and can be translated into screen locations. The second method of viewing the nongraphic data is through panels (text screens). Each panel or set of panels is tailored to a specific function. For example, the panel for the module that maintains data on transient chemical stores includes the following information: chemical name [according to nomenclature systems of the International Union of Pure and Applied Chemistry (IUPAC) or CAS or a common name that will clearly identify the chemical]; facility inventory number; health

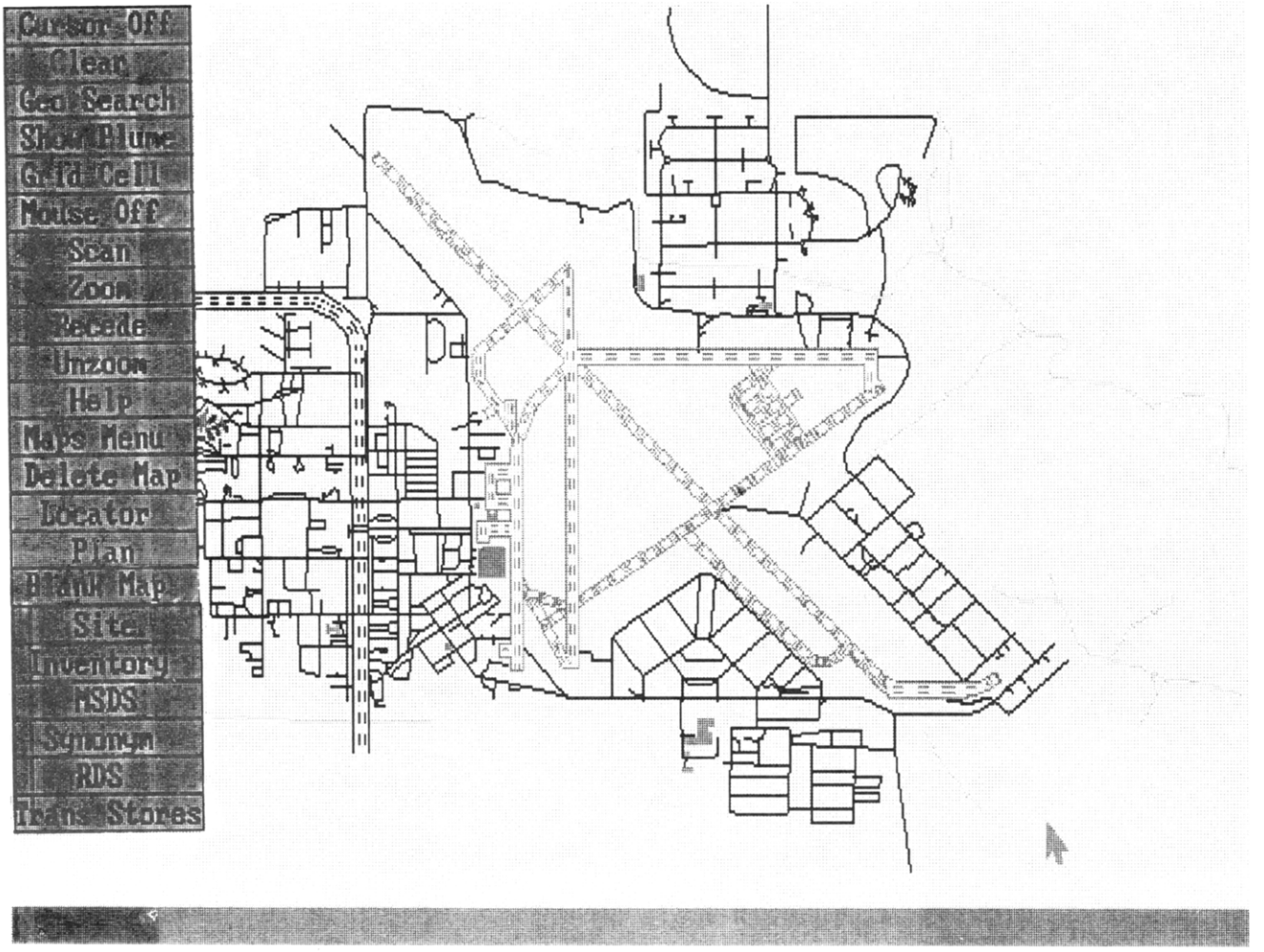

Figure 2. Main menu (Scott Air Force Base).

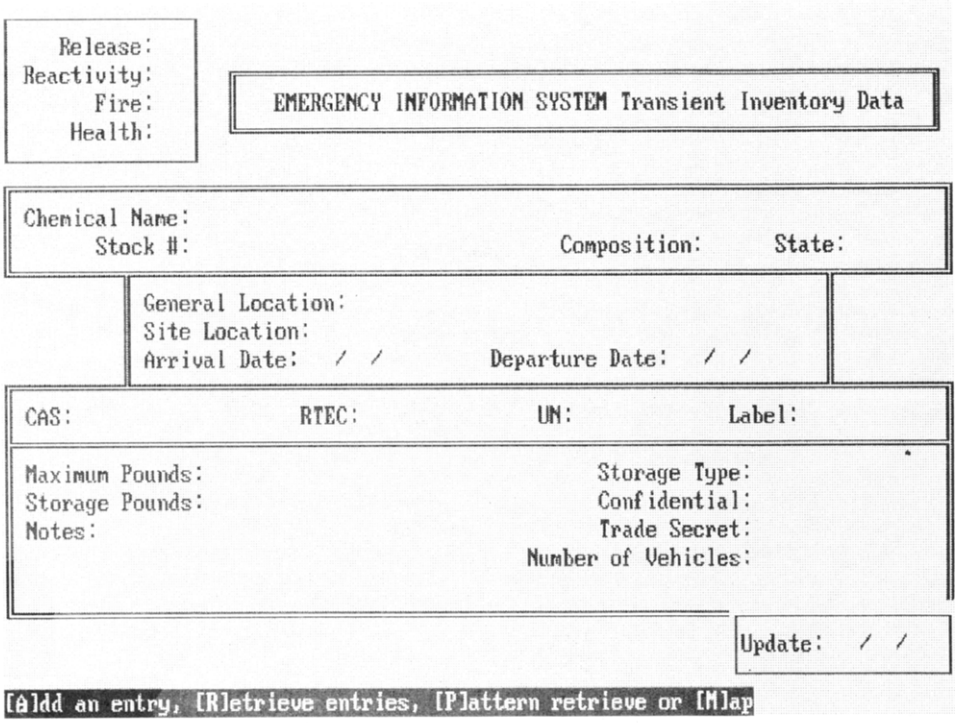

Figure 3. Transient stores panel.

hazards; identification numbers [CAS, Registration of Toxic Effects of Chemical Substances (RTECS), and Department of Transportation (DOT), United Nations (UN), or North American (NA)]; number of vehicles; and arrival and departure dates of the vehicles (Figure 3). The database used by the transient stores and most other HMIMS modules is user defined. The RDS function, on the other hand, is designed to take advantage of an existing National Oceanic and At-

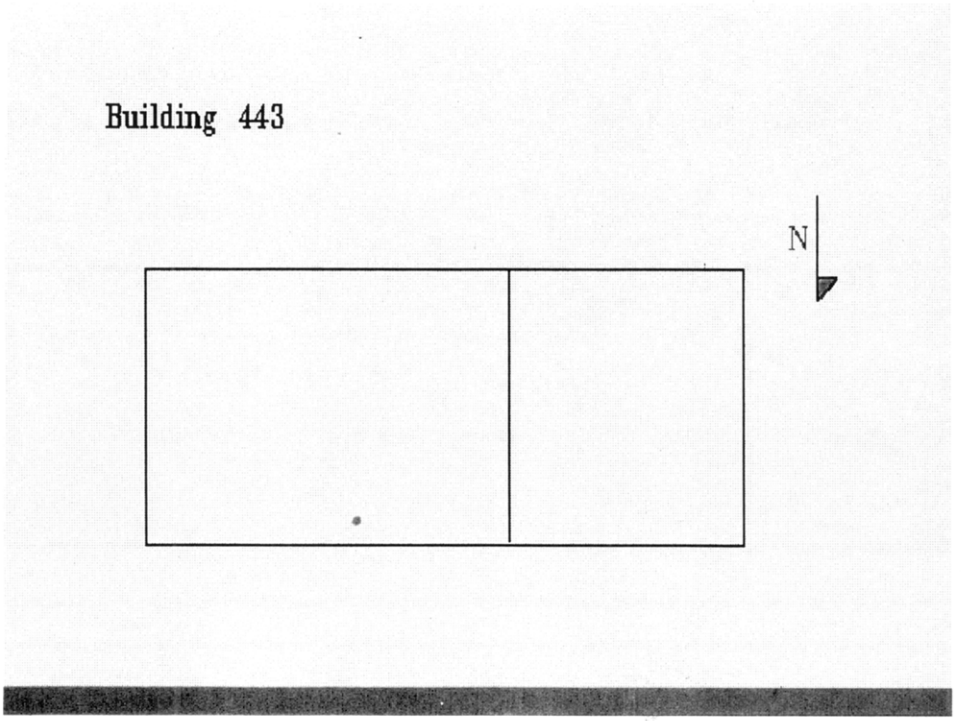

Figure 4. Digitized map (floor plan).

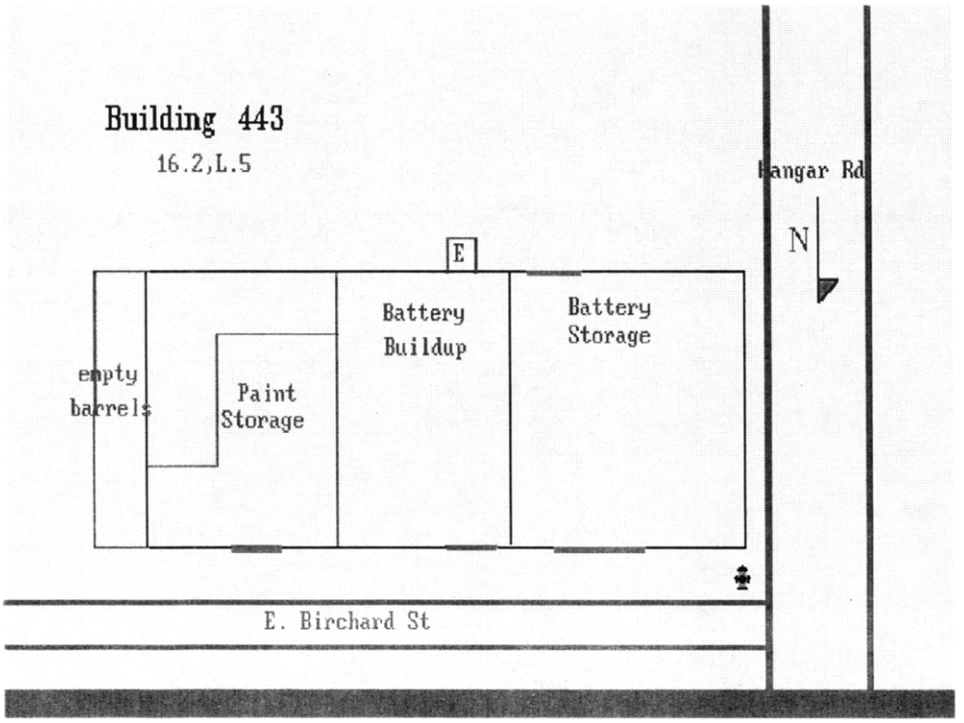

Figure 5. Locator data displayed on a digitized map (floor plan).

mospheric Administration database.

Icons can be created to relate screen locations (and their corresponding geographic coordinates) to records in the nongraphic databases. For example, each building containing HAZMATs could be identified by a red star. In an emergency, these locations could be identified quickly by their flashing red symbols. Other graphic data, such as lines and text, can also be created and recalled as needed. In Figure 4, a digitized floor plan is shown. Figure 5 shows the same floor plan, with user-defined grahics overlaid to present more detail.

Polygons of several types, including plumes, can be defined to act as a window for data retrieval. If a window were in place at the time of retrieval for the above example, only the buildings associated with icons within the polygon's boundaries would be displayed.

Each of the main modules is tied to the others by key fields to permit "toggling" among them. For instance, a user can display (by retrieval based on a key field or a more general pattern search) a panel of data on chlorine stored in a given building. A single keystroke combination can extract the RDS information for chlorine; another can generate a display of the corresponding MSDS panels.

When running HMIMS, the user can temporarily suspend program execution in order to run the Air Force plume model. As the model executes, vectors defining the plume are written to a file that can then be accessed by the HMIMS software when HMIMS is restarted. These vectors can be overlaid on

the appropriate map(s) to show at a glance the projected area of impact. The polygon can also be used as a window for subsequent data retrieval, as described above.

Another module allows information that has been entered into the transient chemical stores database to be archived when the chemical is no longer on the base. In this way, a permanent record of such material can be maintained.

A pair of functions, which can be accessed from the main menu, were created to automate the updating of the chemical inventory. The first allows existing inventory data stored in the HMIMS database to be "dumped" to a computer file. Since this output file is external to the HMIMS system and in ASCII format, it can be edited at a separate location (for example, at the desk of the person in charge of base inventory). Once updated, it is read back into HMIMS by the second update function. Of course, inventory changes can be entered manually into HMIMS, but the primary advantages of the automated system are twofold: (1) it does not tie up the HMIMS system except for the brief amounts of time needed for the output/input operations and (2) it puts the editing operation into the hands of the person most familiar with the inventory.

Commercially available communications software and high-speed modems permit the exchange of information between the alarm room and incident site. This feature would be desirable for situations demanding a quick response. For example, while the HAZMAT vehicle is on its way to a chemical spill site, the HMIMS operator in the alarm room would run the plume model, display its output on a map of the Air Force base, and bring to the screen icons representing other data (e.g., chemical stores). When the HAZMAT vehicle arrived at its destination, the graphics generated at the station could be quickly transmitted (via the modems) to the computer at the site. (This process would save time for responders.) From this point on, each computer could access the databases as needed. For instance, the on-site system could be used to access MSDS, while that in the alarm room displayed evacuation routes of the area. It should be noted that computer communications between the alarm room and the HAZMAT truck is not a requirement of HMIMS. Each computer is fully functional and can operate as a stand-alone system. In addition, it may not be possible to establish this communications link, due to the poor quality of cellular transmission in some parts of the country.

CONCLUSION

The purpose of this work is to provide a tool to assist Air Force fire department personnel in their initial response to HAZMAT incidents. The system can also serve as a basis for maintaining a HAZMAT inventory that would provide information on location and usage/storage amount of HAZMATs. HMIMS can be updated periodically to maintain a state-of-the-art system.

Oak Ridge National Laboratory, in collaboration with AFESC/RDCF and Scott Air Force Base personnel, has developed a list of recommendations for future development. These recommendations include:

- an expert system, based on artificial intelligence, for identifying hazards and remedial actions, including information support for industrial warnings
- installation of map processing programs on the HMIMS work station
- an interface with robotic response systems
- software and data structures to process and exchange raster, as well as vector, data
- satellite data and aerial photographs
- telecommunications for mobile workstation access
- ruggedized equipment for mobile workstations
- enhanced modeling capability including other air diffusion and evacuation transport and routing models

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