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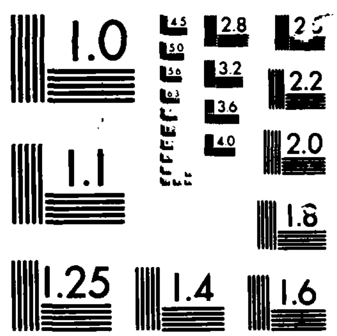

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

DESIGN OF A GENERIC DECISION SUPPORT
SYSTEM FOR USE WITH THE FAMIS SYSTEM

by

Renee Lefebvre Rodeck

March 1986

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This thesis will discuss the possible characteristics of a decision support system as a needed feature of the FAMIS system.

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Design of a Generic Decision Support System for Use with the FAMIS System

by

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ABSTRACT

In a national emergency, allocation of scarce communication resources to recovery agents will be vital to recovery efforts. To facilitate such allocation, the National Security Council is developing the Fly-Away Management Information System (FAMIS).

This thesis will discuss the possible characteristics of a decision support system as a needed feature of the FAMIS system.

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I. BACKGROUND

In any emergency, the right decisions must be made quickly. The more information a decision-maker (manager) has, the better his decision is apt to be. However, the more information a manager must assimilate, the less quickly he can reach a decision.

This problem of information assimilation for decision-making would become apparent if, during a national emergency, a manager was required to determine allocation of scarce communication resources to many competing users. The manager would be forced to answer questions quickly: What problems need to be solved? What users are out there? What resources remain? How can remaining resources be used by the remaining users most effectively to solve problems?

A Decision Support System (DSS) can aid a manager in answering these kinds of questions by assimilating, selecting and presenting needed information in form and volume the manager can understand and use quickly.

Such a DSS would allow an emergency decision-maker the option of considering the projected outcome of various possible choices through simulation models, selectively considering only needed information while screening out extraneous data and seeing, by using stored models, how changing circumstances alter the decisions reached.

An emergency-scenario DSS must possess certain characteristics to be useful to an emergency manager. The system must be portable to accompany the emergency manager to disaster sites. It must contain sufficient computer memory to house a database and sophisticated software programs used to interpret the database and provide simulation and optimization modelling. The user must have exclusive use of the DSS. In an emergency, the manager must use an instantly responsive system to enable him to receive information quickly.

Present day microcomputers are very appropriate to house such decision support systems. Unlike main-frame computers or minicomputers, microcomputers are fully portable, requiring only a power source. With the explosive refinements in hardware production, microcomputers now have sufficient available memory to house sophisticated databases to store and organize information, software modelling and optimization algorithms to interpret information and complex graphics packages to display the interpreted data in forms selected by the decision-maker.

Several examples of microcomputer use for emergency decision support systems exist. Three will be described briefly.

A. U.S. COAST GUARD SEARCH AND RESCUE PLANNING (SARP)

Part of the mission of the United States Coast Guard is to search for and rescue persons and craft lost at sea. To do this, the Coast Guard must identify the presumed position of the person or craft, called the "datum", and direct search and rescue (SAR) teams to that position. Fixing the datum's position on the ocean surface involves four steps [Ref. 1].

1. Determine drift forces. Three types of forces can act on a person or craft to move them over the water's surface. Sea current is the permanent, large scale flow of the ocean waters. Wind-driven current is the current generated by the wind acting upon the surface of the water for a period of time. Leeway is the movement of an object through the water caused by local winds blowing against the exposed surface of the object.

2. Determine vectors. These vectors are based on the three types of forces to determine datum position.

3. Determine error margin. Any possible error margin must be calculated for the vector determinations made in step three.

4. Determine the search radius. A search radius must be calculated around the datum position that will ensure, with a better than fifty percent probability, that the search target is within the search area.

Prior to the early 1970's, the Coast Guard performed manually the four steps described above. The current drift forces were determined by averaging wind and water speeds through weather forecasts. The vectors were determined through calculations. Error detection was not performed because such lengthy re-calculations consumed precious time. The search radius was determined through calculations and statistical formulas. The total time required to calculate the datum position and search radius manually was approximately forty-five minutes to one hour and required a search planner reasonably familiar with the system.

In the early 1970's, the Coast Guard automated the four steps on a time-shared main-frame computer. To use this system, the search planner drafted a message containing the time of the incident, the incident position, the desired datum time, two error calculation numbers obtained from the National SAR Manual and the type of leeway to be considered (obtained from a computer handbook). The message took approximately five minutes to draft and was sent by teletype to the main-frame computer. The SARP program reply, with the datum position and search radius, would be received by the search planner within twenty minutes, if no problems arose. If the search planner or the teletype operator typed errors into the message, the mainframe computer would send an error message back and the message would be retransmitted. This caused delays of up to several hours since the search planner would not know his message was unusable until he received the computer response. The computer program was inaccessible when the mainframe computer was not operating or when the teletype circuit was broken. In this case, the datum position and search radius were calculated manually.

In 1982, the SARP program was installed in a microcomputer. The current microcomputer version of the SARP program presents the search planner with a menu-driven display which prompts him for needed information. The program can calculate the datum position and search radius in approximately thirty minutes. The search planner works directly with the system, without a teletype interface and can verify immediately that his input is keyed in correctly. The system is reliable since the microcomputer is always accessible to the search planner.

B. AMERICAN RED CROSS EMERGENCY MANAGER DECISION AID

In a disaster, the Red Cross quickly and accurately assesses the physical severity of the disaster and the ability of people to cope with their losses [Ref. 2]. The Red Cross thus determines the level and monies which must be expended to alleviate the situation. To do this, the Red Cross performs four procedures.

1. Predisaster Surveys. The Red Cross maintains files of information gathered by periodic surveys conducted by local Red Cross chapters. These surveys estimate the value of property as well as facts about insurance coverage.
2. "Windshield surveys". Immediately after a disaster, Red Cross field teams assess and record the extent and nature of property damage.
3. Determination of disaster severity. The Red Cross emergency managers on site use the "windshield surveys", together with pre-disaster information, to determine the severity of the disaster and the appropriate resources that must be brought to the disaster site.
4. Case file preparation. At Red Cross emergency centers, emergency managers use the pre-disaster surveys, "windshield surveys" and claims of disaster victims to determine the extent of disaster victims' needs.

The Red Cross emergency managers must determine the severity of the disaster, the resources necessary and the fair resolution of victims' claims very quickly. They are required to compare data on pre-disaster conditions with disaster reports. They must ensure that disaster victims are fairly compensated, but that duplicate claims are not accepted.

When the emergency managers perform these procedures manually, many problems arise which can be attributed to a lack of two requirements, which are discussed below.

1. Timeliness. The managers cannot respond quickly to victims' claims if they must manually review and attempt to connect pre-disaster surveys, "windshield surveys" and victims' claims.

2. Accuracy. If expedition of claims processing becomes paramount, survey reviews and therefore prevention of duplicate claims becomes harder.

In 1979, the Red Cross tested a microcomputer-housed DSS in an actual field incident. The database within the DSS organized the information gathered by pre-disaster surveys. The information gathered by "windshield surveys" was entered into the database by simple menu-driven questionnaires. The emergency manager could then use DSS-driven programs to compare pre-disaster conditions with disaster information to determine disaster severity and the recovery resources required.

Case workers could enter files for victims by names, ensuring only one claim was filed per family, and then verify the victims' claims by comparison of their claim with pre-disaster survey information. All this information was reliable, available quickly and much more accurate than information gathered by manual methods.

C. REGIONAL EMERGENCY MEDICAL ORGANIZATION (REMO)

This organization, located in a six-county region around Albany, New York, is responsible for coordination of an emergency medical system which provides the region with effective medical services in the event of any emergency situation. Such service includes allocating ambulances in situations where the need for the ambulances exceeds the supply.

To allocate the ambulances, the REMO dispatcher uses a DSS programmed on a microcomputer. The DSS attempts to minimize total time victims have to wait for an ambulance as well as minimize "bottlenecks" caused by over-allocation of any ambulance. The dispatcher users graphic map displays showing demand and resource locations. The DSS uses an optimization model algorithm to calculate the optimum ambulance use, given the resources and demand. The dispatcher can input different demand priorities to observe how different ambulance utilization and routes will change the optimal allocation.

The ability to determine optimal allocation under different circumstances before he dispatches the ambulances allows the dispatcher to assign ambulances more effectively and thereby reduces some of the job stress, and attendant mistakes, he might make by manual determination of ambulance allocation.

These three examples illustrate the value of a DSS to decision-makers in three areas critical to emergency decisions: speed, accuracy and data manipulation. The Coast Guard DSS provides information that leads to quick assignment of rescuers. Using their DSS, the Red Cross workers can approve damage claims for disaster victims with much greater faith in the accuracy of their data, than by manual methods. The REMO dispatchers can use their model algorithm to interpret the raw data of ambulance and passenger positions into optimal routes, thereby eliminating data inundation of the dispatchers.

As has been discussed, an emergency decision manager faces three basic requirements in any decision he makes. The decision must be made quickly to avert disaster or alleviate an emergency. The decision must be right, since emergencies do not allow for multiple attempts to solve a problem. The decision usually must be backed by analysis of data, which in an emergency comes to the decision-maker quickly and in an unorganized fashion. A computer-driven decision support system can help an emergency manager immensely in several ways. It can provide models of possible results of decisions, allowing the decision- maker to see the probable results of his decisions before he makes them. This modelling facility allows the decision-maker to improve the chances his decision will be accurate. The DSS can sort, interpret and present information to the decision-maker in a format he can understand. This data handling facility protects the decision-maker from inundation by all sorts of data, some of which he must know to reach a decision and some of which is superfluous to the decision process. Finally, the DSS performs these functions much faster than possible by a human staff.

The Decision Support Systems described in this chapter work because they provide decision-makers with the facilities described above. As will be seen in subsequent chapters, the FAMIS emergency manager will require the same types of services to perform his allocation decisions.

II. INTRODUCTION

Coping with the consequences of a nuclear attack and dealing with the aftermath of a natural disaster such as a hurricane or earthquake involve different problems, resources and solution methods. All such disasters, however, require reliable communications to allow people to assess impact, make decisions, put appropriate responses into play, allocate needed resources effectively and restore social stability. Given this country's dependence on telecommunications as a quick, reliable means of communication, the establishment and maintenance of a reliable telecommunications system in the advent of an emergency is vital for recovery from the disaster.

In recognition of this need, the Federal Government has empowered the National Security Council (NSC) to develop policy for emergency telecommunications management in conjunction with the Federal Communications Commission (FCC). The Nationwide Emergency Telecommunications System (NETS) that will eventually be developed will use existing resources of the Public Switched Network, to provide communications among many field recovery agents, who will oversee regional survival and recovery actions.

Since the break-up of AT&T, the Public Switched Network (PSN) has become controlled by many private and public companies. This thesis will not address the issues of policy, authority, and management which NCS must address to obtain cooperation of the various private companies and government agencies required to establish a viable NETS. Since this thesis is concerned with the automation of a certain decision aid tool for use in the operation and control of the NETS system, a working, valid NETS will be assumed to exist. The following discussion of emergency telecommunication requirements assumes the existence of NETS and requires cooperation among agencies.

The PSN refers to the combination of assets established by private, public and government agencies which are the telecommunications system for the United States. These assets include telephone lines, nodes to connect the lines, teletype/digital switching facilities to direct communication loads, satellite communications, microwave facilities and many other telecommunication devices [Ref. 3]. These assets allow a student in California to call his mother in Georgia, allow computers in New York to "talk" to computers in Hawaii and permit the Department of Defense to issue directives to military bases.

In an emergency, this telecommunications system would form the ideal media for emergency communications because:

1. it is already in place,
2. it can access the entire country, and
3. it is highly redundant, which means that many different communication routes exist between the same two points.

Given that NCS is empowered to manage this system in an emergency, questions regarding the policy and method of allocating the resources, i.e. the available telephone lines, of this system must be addressed. In an emergency, it can be anticipated that many more people will want to use available telecommunication facilities than are available. The telephone companies handle such an overload on Mother's Day and Christmas by queueing calls. That is, the caller gets a busy signal, or a "sorry, we're busy" message, until lines are available.

Such blind queueing will not be a workable solution to overload of emergency telecommunications lines because of possible:

1. low priority use. Such arbitrary queueing might prevent a caller with a more valuable function, such as delivery of hospital supplies, from making a call, while allowing the college student, who called first, to see if his mother is all right.

2. insufficient use. Unless controlled, lines might be in heavy demand for certain periods and in no demand during other periods. Callers who could have completed necessary calls at certain times would be unable to complete calls at other times.

The problem of blind queueing would be aggravated by loss of lines. Natural or nuclear disasters could destroy part of the telecommunications system, which is mostly comprised of lines stationed above ground.

An alternative to blind queueing is active allocation by NCS managers of resources (telecommunication lines) to recovery agants. As was shown in the REMO example in the previous chapter, such allocation decisions can be made more effectively by a manager with automated decision aids. In recognition of this fact, NCS is currently developing the Fly-Away Management Information System (FAMIS).

A. FLY-AWAY MANAGEMENT INFORMATION SYSTEM (FAMIS)

FAMIS currently exists in prototype form only. Installed on a microcomputer, it is a file-drawer system in that it is used solely for information retrieval. The following information is currently available to the FAMIS user.

1. A list of primary and secondary points of contact for various government and private agencies.
2. Instructions for activating emergency procedures.
3. Graphic map depictions of the NETS.
4. A damage model which will allow the user to superimpose simulated damage on the NETS, to determine projected remaining resources.
5. A word processor, currently Wordstar.

This thesis will discuss the possible characterization of a Decision Support System, which is a needed sixth feature of the FAMIS system. In determining the characteristics of the FAMIS DSS, questions and objectives which the emergency manager must address through the DSS will be examined in Chapter III. Information needed to answer these questions will be identified in Chapter IV. The necessary computer literacy of the emergency manager will be discussed in Chapter V. A possible adjudication algorithm will be analyzed in Chapter VI. Finally, the proposed DSS itself will be presented in Chapter VII.

III. DSS DESIGN REQUIREMENTS

This chapter will explore the objectives the FAMIS manager will achieve through utilization of a DSS. Since these objectives involve decisions made by the FAMIS manager, the decision process itself will be briefly discussed. Design requirements for a DSS will be described.

A. DECISIONS AND THE DECISION-MAKING PROCESS

Decisions can be defined as the end-products of information-processing. Any information-processing system that yields the finished product, i.e., the decision, can therefore be considered to be a decision-making system. For purposes of our example, the FAMIS manager will be considered a decision-making system.

A structured decision, also called a programmable decision, consists of three steps:

1. defining the problem,
2. designing choices, and
3. choosing the best choice.

If any of these steps cannot be described to a computer, the decision is considered unstructured. That is, human qualities of experience, association and intuition are necessary to reach a decision; the decision cannot be reached logically by a computer alone.

A DSS can aid a human manager in such decision-making in that it can answer structured questions posed by the manager that aid him in solving the unstructured problem. A simple example of such a decision aid is a pocket calculator. By itself, the calculator cannot suggest answers to engineering questions, but it can solve mathematical equations chosen by a construction engineer which allow the engineer to then decide where a new dam should be built.

A more complex analogy can be drawn between a DSS and a human staff. When a manager with a staff faces a problem, he requires his staff to use available statistics, historical data or other information to produce answers to questions the manager then uses to help him decide. The answers such a manager seeks from his staff are not the direct answers to the problem. Rather, the manager's questions to his staff usually take the form of:

1. request for retrieval of information. Such information can involve statistical analysis of raw data or other such grouping, and/or
2. request for modelling information. Such requests usually take the form of ad hoc questions and involve projection of possible outcomes using historical data, optimization algorithms and data comparison.

The manager uses these answers to acquire some indication of consequences of various decisions. He can therefore make a decision with more authority. Such staff support differs from simple data retrieval because the staff is expected to interpret the raw data and present to the manager only that information, in a determined form, which will aid the manager in his decision process.

The staff therefore serves two functions for the manager:

1. providing the manager with information necessary for his decision, and
2. screening from the manager extraneous data, the digestion of which would interfere with his decision-making.

A truly effective staff can call upon enough varied analysis tools to provide answers to the manager's varied questions.

A computer-generated DSS should fill the same requirements as the staff for the manager. Using a DSS, a manager should be able to manipulate and selectively use information to determine answers which will enable him to make intelligent decisions for unstructured problems typical of the real world.

B. DSS DESIGN REQUIREMENTS

1. Design Criteria

Generally, decision support systems reflect four design criteria.

a. Representations

This means the use of CRT tubes in conjunction with software programs which will present reports, charts, geometric representations, etc. Such representations must be constructed in a form that is understandable to the decision-maker.

b. Support

Support of intelligence, design and choice activities. This includes operations like comparing current status with goals or standards, exception reporting and preliminary calculations.

c. Memory Aids

This includes English-like Data Base Management Systems (DBMS) which allow flexible, interactive access to data. The decision-maker requests information from the DBMS in English. The DBMS then constructs the software programs necessary to retrieve and organize the information.

d. Decision Maker Control

This means man-machine interaction, online and in real-time without the intermediary of programmers. Such immediate interaction between the DSS and the decision-maker is vital for three reasons. First, such interaction allows the decision-maker to see his input, assuring it is entered error-free. Second, an interactive DSS allows a decision-maker to ferret out specific information from a large amount of unassociated data quickly. Third, the decision-maker can observe answers to his questions immediately. Such immediate response is especially vital in an emergency, where the decision-maker must have projected result information quickly.

2. Requirements

To support these criteria, a DSS must fulfill the following requirements.

a. Data Management Capability

A data base management system (DBMS) must exist as a software interface between the decision-maker and his database. A database is a collection of data, also called information, which is organized logically into a system of some sort. The DBMS software programs accept requests from the decision-maker, in English, for information. The DBMS then retrieves the information, which may be stored logically in many disparate physical locations in computer memory. The DBMS then organizes, arranges and presents the information to the decision-maker, in a form specified by the decision-maker. For instance, a manager might request a list of all telephone users who require a dedicated phone line, and he may wish to see this information in a table, arranged in ascending order by last name. A good DBMS will take the English request and utilize the necessary software, internal to itself, to produce the table. At the manager's request, the DBMS can present the same information arranged by location of the user.

b. Analytical Capability

As mentioned previously, a DSS must be able to manipulate data, as well as present it. Many kinds of analysis tools are used by decision support systems and these tools vary in complexity, depending on the depth of analysis required and the breadth of data to be considered. A partial list of such analysis tools could include [Ref. 4],

(1) Data Analysis. In data analysis, historical data is subjected to statistical analysis and other projection formulae to determine trends, to project future outcomes and to determine present status. Many businesses use such analysis to predict sales trends, to

help compile five-year budget plans and other activities which require analysis of historical data. A FAMIS manager might use this tool to determine present capacity of lines or to compare priorities of competing users.

(2) Simulation. In simulation models, projection of outcome is based on algorithms which involve data. Such models are different from data analysis. In data analysis, the historical data and all factors which act on the data, i.e. interest rates, are known. In simulation modelling, some of the parameters which act on the data are unknown or assumed. A factor of uncertainty is thereby introduced. Representational models are particularly valuable when answering ad hoc kinds of questions, where some circumstances must be assumed to project an answer. The FAMIS manager could use a tool of this type to simulate reallocation of resources to accommodate a coast-to-coast line connection for two high-priority users.

(3) Optimization Models. These models describe situations mathematically as complicated puzzles whose solution is maximization or minimization of a particular goal. Optimal use of FAMIS resources, subject to certain constraints such as minimization of nodes involved, might be a potential problem which a DSS would employ an optimization model to solve.

(4) Suggestion Models. These models are more structured than optimization models and whose output is pretty much the answer to the decision-maker's problem. Such models are called expert systems and, while applicable to many areas, are inappropriate for application in the FAMIS system. Suggestion models are designed to suggest actions based on a pre-determined set of criteria or conditions. If these criteria change, such as changing the condition mode of the FAMIS system from survival to recovery, the suggestion model must be altered to produce

new suggestions based on the changed goal of recovery. It is considered more feasible in the FAMIS system to allow the manager to assume this role, supported by optimization, simulation and data analysis models as described above.

c. Transportability

It is unrealistic to presuppose that an emergency decision-maker will be able to remain at a particular location during an emergency. Available communications resources, facilities and other concerns might force such a manager to be mobile. A DSS used to support such a manager must be portable. The potential problems of interfacing with a stationary mainframe computer were illustrated in the Coast Guard SARP program example.

d. Reliability

DSS reliability will be of two types: reliability of the interface between the manager and the system, and reliability of the information passed between the manager and the DSS. Reliability of the interface, that is the percentage of time the manager can use the DSS, will be best served by having the decision-maker as the sole user of the DSS. Reliability of the information exchanged can be best assured by an interactive system, where the manager can instantly check that he enters the proper data and can instantly see the actual response from the DSS display.

e. Flexibility

It is impossible to determine in advance all questions a manager will be required to ask a DSS to accumulate enough pertinent information to make a decision. Therefore, a DSS must possess the flexibility in its software to accept new questions formulated by the manager. For instance, a menu-driven DSS which will only answer three pre-determined optimization questions will be of limited use if new circumstances arise. Such flexibility could possibly be built into a DSS by:

a) generalization of the model/analysis programs

b) incorporation of a model-building ability within the DSS. Such a model-building program would construct new algorithms for models as the manager requests new analysis approaches.

f. Maintainability

Maintainability, particularly of the database, is vital. A DSS used by the FAMIS system will be only as useful as its data is current and accurate. Optimization of user use of communication lines by priority will be impossible if some of the users no longer exist or if the lines specified have been changed prior to the emergency.

As discussed above, these requirements would be essential in a DSS associated with the FAMIS system. The requirements of portability and reliability would be best satisfied if the DSS resided in a microcomputer. The database on a microcomputer could be updated periodically by floppy disk or by connection through a modem, prior to emergency conditions, to ensure information is current. Most analytical tools, display packages and database management systems can operate in a modern microcomputer.

The actual components of a generic DSS, including design specification, program description, database types and hardware/software implementation will not be discussed in this thesis. The FAMIS system will serve as determinant of questions the manager and the DSS must address, as well as for description of data formats used for application of the DSS. These issues are considered in the following chapter.

IV. QUESTIONS ADDRESSED BY THE FAMIS MANAGER AND THE DSS

Within the FAMIS scenario, the manager must decide on the allocation of remaining scarce telecommunication resources to a competing set of qualified recovery agents who need those assets to solve specific problems associated with the emergency. As described in Chapter II, all available private and public telecommunications links would be combined to form an emergency communication network in the advent of a disaster. The Public Switched Network (PSN), which is the major telephone communications system in the country, is a vast complex of local offices, trunks and switching nodes. Given that it is feasible to reconstitute an emergency network from the surviving nodes and links, if the remaining available resources exceed the requirements of the users, the manager's allocation decision is uncomplicated and does not require the aid of a DSS.

However, if the recovery agents' requirements exceed available remaining communication resources, as is expected in the FAMIS system, then the manager must answer several questions associated with resource allocation.

These questions can be grouped into four broad categories:

1. What problems associated with the emergency need to be solved?
2. What recovery agents are out there to manage the required resources necessary to help solve the problems?
3. What communication resources remain?
4. What communication resources are needed to help which agents mobilize remaining resources to help solve emergency problems?

This chapter will discuss these four categories. The categories themselves will be discussed and questions addressed by the DSS will be identified within applicable categories. These questions will be examined and a necessary flow of information will be established which will be shown to culminate in resolution of allocation questions.

A. WHAT PROBLEMS NEED TO BE SOLVED?

In a national or regional disaster, the problems an emergency manager faces can be expressed in terms of mobilization. Mobilization is the process of marshalling resources to support a response to an emergency. [Ref. 5] Resources can include food, medical supplies, troops, building supplies and whatever else is needed to survive and recover from a disaster. Several categories of mobilization exist, dependent on the types of resources being mobilized and/or the application of these resources.

- Military mobilization - deployment of manpower, weapons and tactical information.
- Industrial mobilization - marshalling the manufacturers/producers to supply goods and services.
- Economic mobilization - marshalling money and credit to fund the mobilization effort.
- Human Resources mobilization - marshalling people to perform needed work toward survival and recovery.
- Infrastructure mobilization - marshalling such systems as transportation, energy, communications, construction and agriculture to support survival and recovery efforts.
- Civil Defense mobilization - marshalling forces to provide protection and recovery for people and industry from nuclear attack.
- Governmental mobilization - marshalling resources of local, state and federal governments to respond to and recover from the disaster/emergency.

In an emergency or disaster, regional recovery agents will manage these mobilization steps within their own geographic areas. The FAMIS system exists to allocate scarce remaining telecommunications resources to these recovery agents to enable the agents to direct mobilization.

Thus, the crucial first problem the FAMIS manager must address concerns identifying mobilization requirements. The category of mobilization needed will depend on the type of emergency/disaster. Logically, this information will come to the FAMIS manager from regional recovery agents or from other sources who have current information about the type and scope of the emergency or disaster. Since the FAMIS manager needs this information before he can allocate NETS resources, it is logical to assume that this information must reach the manager via a more dependable communication medium than the telephone. A high-frequency radio network is a viable possible communication medium for transmission of this initial information. Once the NETS is established, the FAMIS manager could also receive mobilization requirement updates from recovery agents via NETS calls.

Once the mobilization problems have been identified, the FAMIS manager can begin to solve these problems by determining answers to the questions in the remaining three categories listed in the introduction to this chapter and discussed below.

B. WHAT RECOVERY AGENTS ARE OUT THERE TO MANAGE THE REQUIRED RESOURCES?

To answer this question, the FAMIS manager will elicit information from the FAMIS DSS, as well as real-time information from his high-frequency radio network and/or NETS updates.

1. What is the current mode?

Allocation of communications resources will be dependent on the user's importance relative to the current mode or goal. If the emergency is in a survival mode, then recovery agents whose functions involve procurement and distribution of food, hospital provisions and other immediate needs might receive highest priority to use communication resources. If the emergency mode has changed to recovery, then recovery agents essential to re-establishment of non-essential services might receive higher allocation priority. The need to establish an emergency government might require priority use of resources by users who were unimportant for survival mode operations. The FAMIS manager will determine the current mode via high-frequency radio network and/or NETS updates from recovery agents or other field officials.

2. <u>What recovery agents are needed to mobilize resources for the current mode</u>?

The DSS will obtain the number and type of remaining recovery agents from updates from the FAMIS manager or through disaster modelling. The communication requirements of the recovery agents will have been determined before the disaster took place and will be part of the FAMIS database.

The following information has been collected for each recovery agent:

1. FACILITY TYPE/IDENTIFICATION. This includes the type of facility (e.g., C2 facility, field office, emergency operations center, warehouse) and any identifying name or number that be helpful in distinguishing it from other facilities. These facilities are those that are essential in the performance of the listed functions.

2. FUNCTION PERFORMED. This includes the number of function(s) that would take place at the facility.

3. LOCATION. The name of the nearest city or town and state.

4. LONGITUDE/LATITUDE. This information would fix the facility on a graphics map.

5. NUMBER OF PEOPLE REQUIRING COMMUNICATIONS AT THE FACILITY LOCATION. This would identify people who would perform essential functions.

6. TYPE OF VOICE COMMUNICATIONS NEEDED. Types include switched, which refers to standard switched telephone requirements including data needs that can be met using a dial-up line or a modem, and private point-to-point, which refers to private line voice systems between specified locations, used for security transmissions. For each communications requirement, the number of lines needed, the average number of hours per day the telephone would be in use to provide the essential function and security requirements would be listed.

7. DEDICATED DATA REQUIREMENTS. This refers to the number of dedicated, non dial-up data communications circuits needed, plus any security requirements for these lines.

8. OTHER SPECIAL NEEDS.

9. PRIORITY. This refers to the relative priority of the locations listed. Notice that different priorities

can apply to a user under different allocation goals. The DSS might be required to assign several priorities to each user, and select the priority appropriate to the allocation goal of survival, recovery or establishment of government.

The DSS would retrieve these facts, encoded in the database for each recovery agent, to determine their mobilization task, communication requirements and, under the current condition mode, priorities to use remaining communication resources.

3. <u>Of these qualified recovery agents, how many still exist?</u>

It can be assumed that, in any disaster, a subset of all recovery agents will be destroyed, incapacitated or otherwise rendered ineffective. To determine accurately how many recovery agents actually remain, the FAMIS manager will be required to augment and modify the historical recovery agent data he will receive from the FAMIS DSS. His high-frequency radio link or contacts he can make via the NETS are means of providing this information. An additional source for projection of recovery agent losses could be input from the FAMIS disaster model, which would indicate locations affected by disaster. Recovery agents in these locations could be assumed destroyed for communication allocation purposes, subject to confirmation by high-frequency radio or NETS link. The FAMIS manager must then input the corrected recovery agent information to the DSS database to maintain accuracy. Such accuracy regarding recovery agent information will become vital when the FAMIS DSS is asked to optimize allocation of communication resources.

At this point, the FAMIS manager will have identified the mobilization problems caused by the disaster and he will have identified, through DSS retrieval of information coupled with high-frequency radio updates, the qualified recovery agents who currently exist to solve the mobilization problems.

C. WHAT COMMUNICATION RESOURCES REMAIN?

The FAMIS manager must next determine the status of the existing communication network, over which he will allocate recovery agent communication use. To determine current network status, the FAMIS manager will retrieve answers to the following questions from the FAMIS DSS.

1. What is the normal network schema?

The DSS will use database files to determine the normal network of communication lines and nodes.

2. What resources (communication lines, nodes) remain?

Using a disaster model, plus casualty information fed in by the FAMIS manager, the DSS will then project the percentage and locality of lost communications to determine what resources remain.

3. Do these nodes connect locally/nationally?

The DSS must then use historical database information to determine if surviving nodes connect to form a local, regional or national network.

4. Is there connectivity?

Once this information is determined, the DSS can project the degree of connectivity, together with a graphic map display showing the route(s) of connectivity, to the FAMIS manager. The manager can alter this graphic display to reflect new connectivity information by asking the FAMIS DSS to compare original connectivity data with updates received via the high-frequency radio network or NETS. Also, as discussed in Chapter II, the presence and degree of connectivity must be updated as further damage is sustained by the network. The DSS could automatically check the status of the networks periodically or at the update request of the FAMIS manager.

5. What is the capacity and throughput of remaining lines?

The capacity and throughput of communication lines are important when considering the lines' ability to accommodate a set of users. Once the existence of remaining communications lines has been established, the DSS can retrieve their capacity and throughput figures from the database. The FAMIS manager would update these figures if so indicated by recovery agent feedback.

6. <u>What degree of reliability of remaining paths exists</u>?

The reliability of remaining paths will be determined by the disaster model projection of damage, plus input to the manager from recovery agents who are utilizing the particular path.

7. <u>How survivable are the remaining paths</u>?

Survivability of the particular path will depend on projected future damage, plus historical data about the path. For instance, if the path is established via satellite, then the type of damage, i.e. earthquake, will determine if the satellite, and therefore the communication path, will survive.

By using the DSS capabilities of data retrieval and comparative analysis, the FAMIS manager will now know the current status of the emergency communication network. Using that information, plus identification of the mobilization problems and available recovery agents to solve those problems, the FAMIS manager can now address the fourth category of questions.

D. ALLOCATION DETERMINATION

What communication resources are needed to help which agents use emergency resources to help solve problems?

Applying an adjudication algorithm to the information discussed in the three previous sections, a DSS can determine optimum allocation of existing communication resources in a number of ways. This section will explore some of the possible ways in which allocation configurations can be made.

1. Is there alternate routing? (Do remaing lines connect in more than one way?)

Given that any node will connect more than two lines, the possibility exists that connections between any two points (recovery agents) can be accomplished via more than one route. The DSS must establish the existence of alternate routing because such alternatives may affect the manner of allocation, as well as establish the potential scope of the network. The DSS could use an optimization algorithm applied to existing lines to identify all possible paths connecting all points (recovery agents).

2. How can number of users on the system be maximized?

Two allocation issues become apparent in the FAMIS example: user priority and utilization time. The DSS will retrieve the current allocation goal from the manager. This goal will determine which type of priority will be associated with NETS users.

3. How can percent of time paths are utilized be maximized?

The DSS must also consider time constraints. For example, a higher-priority user who requires ten hours use per day might represent less effective use of the system than four lower-priority users who all together require only four hours use time per day.

4. How can priority use on the system be maximized?

Given the dual allocation constraints of priority and time, the DSS will probably provide the manager with possible resource allocation based on priority and time. The DSS will retrieve time requirements and priority information for recovery agents from its database and project combinations of recovery agent use to optimize priority use or percent of time the NETS is used.

5. How can the most reliable network between long distances be established?

The manager could then invoke further ad hoc questions to observe the results of further tradeoffs. It is important that the manager, instead of the DSS, effect these tradeoff questions to arrive at a compromise allocation. The manager, not the DSS, is the decision-maker and he must be able to consider the projected results of many options before arriving at, in his judgement, the best decision.

6. Is congestion possible?

Congestion of traffic flow over the network is a consideration the DSS must address in allocating communication resources. Congestion can occur when communication lines into a node contain more "traffic" than the node can direct on to other lines. Such congestion could easily take place if the DSS concerns itself solely with maximization of the number of users of the FAMIS system, without considering even distribution of that user load over available nodes. Depending on the geographic concentration of users, some nodes of the system might be overloaded while others are hardly used, unless distribution of the user load is considered.

7. If possible, how can congestion be resolved?

The DSS must have an analysis tool that will examine projected allocations, compare recovery agent requirements with line throughput and determine the possibility of congestion. Should congestion pass a critical probability point, the DSS must notify the FAMIS manager and propose alternate allocations to ease the congestion. Given the establishment of all alternate routing described above, the DSS could reallocate communication line use using an optimization algorithm, subject to constraints against using congested routes.

Once the FAMIS manager has obtained answers to the questions described above, he can provide solutions to the mobilization problems identified. Circumstances can change quickly in an emergency, however, and the FAMIS manager must be able to obtain new answers to any and all these questions if conditions change. The following questions fall into one of the four categories of questions discussed above, but they are mentioned here becuase they will be prompted by changes in the emergency environment.

8. When do conditions change sufficiently to warrant reallocation?

Questions which might be addressed to determine condition changes include:

- Is the condition mode different? (survival, recovery, etc.)
- Have resources changed?
- Have users changed?

Allocation priorities might change as the allocation goals change, as further damage to the network results in fewer available communication resources or even as recovery agents complete their calls and no longer need the communications resource. The DSS would have to recognize a valid condition of change and then examine qualified recovery agents to determine if their level of use priority changes. If so, new optimization algorithms might be required.

Additionally, the manager might decide to ask for the outcome of different methods of allocation, for which the DSS has no programmed algorithm. In these cases, the DSS might be required to have the capability to build algorithms to suit such one-of-a-kind questions.

By answering the categories of questions discussed in this chapter, the FAMIS manager can meet his objective of effecting mobilization of resources by recovery agents through allocation of communication resources to these recovery agents. The questions discussed in this chapter are representative of the types of questions for which data must be amassed and for which modelling programs and other analysis programs must be prepared.

V. THE FAMIS DATABASES

The previous chapter presented questions the FAMIS manager and the DSS must address. This chapter will discuss possible database types and update methods.

Data can be defined as facts, which are combined to provide information about something. Much of the data the FAMIS system will use has already been defined. Recovery agent information required might include:

- location (latitude and longitude)
- telephone number
- type of user (his function)
- priority of user (may be several entries, based on different condition modes)
- type of resource required
- duration of resource requirement
- name or code of user

Resource Information might include:

- location (latitude and longitude)
- category of resource (telephone line, microwave, satellite relay)
- type of resource (full-duplex, private, switched, secure, etc.)

Other information might be needed, depending on the types of decisions the FAMIS manager has to make.

Data arranged in an organized form is called a database. A card file can be a database, as can a printed list of names or facts stored in the human brain. For purposes of this thesis, a database will be defined as data arranged in a logical form and stored in a computer memory. Two distinct databases for use with the FAMIS DSS can be discerned from the data required. One of these databases will contain recovery agent information and one will contain communication resource information. Other FAMIS database groups may be identifed later, but the following discussion of database types and update procedures will apply to those databases as well as to the two databases identified.

The type of database is determined by its data model, which can be defined as the philosophy of relations and attributes of relations between data in the database. Many types of databases exist and four types will be identified and compared to determine a suitable database type for FAMIS application.

A. HIERARCHICAL DATABASE

A hierarchical database can be described as one in which all the data is arranged by following one logical rule. In a computer, a hierarchical database is arranged so that each bit of data has a logical pointer which points to another piece of data. The telephone directory, which lists all information alphabetically by the last name of the individual or organization, is an example of a hierarchical database system. Such a database is useful only if the data requested, i.e., an address, can be tied to a last name. Using the telephone directory, it is impossible to ask for "John's address" or to ask "Who lives at 35 Fremont Street?". Such questions cannot be answered because the telephone directory is not designed to allow retrieval of information by any other means than by last name. The last name is the "key" which unlocks the information in this hierarchical database.

Clearly, such a rigid database arrangement will be insufficient to meet the information needs of the FAMIS system. For example, to answer the question of what resources remain, the DSS must identify resources using their location key. The location can then be compared with the disaster model results to determine which communication lines remain. To allocate these resources, the manager may wish to know how many lines of a certain type exist between two points, such as secure lines, which can handle the calls of a certain user. To obtain that information, the DSS must identify resources by their type key. By considering other questions the DSS must use resource information to handle, it can be seen that the DSS must be able to access the data in a database using many different keys, grouping the data in many different ways to obtain the information needed by the FAMIS manager. This requirement eliminates a simple hierarchical database as unsuitable for FAMIS application.

A hierarchical database could be built in a way that allows access of data by many different keys by producing separate lists of the same data grouped differently. To continue the telephone directory analogy, the directory would contain entries for each person listed by last name in one section, by first name in a second section, by address in a third section and so on. The obvious result of such redundancy would be a very large telephone directory. If FAMIS data is organized this way, much more computer memory storage will be necessary to contain all the redundant data. Retrieval of that data will be slow since most computers retrieve information using some form of a sequential search. To illustrate sequential search, we continue with our analogy. A person using sequential search would look first through the last name and first name sections and then the address section to determine who lives at 75 Rock Plaza, if the data is organized in that order. Such a search will waste a great deal of time looking through the two unneeded sections which preceed the address section.

B. RELATIONAL DATABASE

Such storage space and retrieval problems can be relieved considerably by use of a second type of database called relational database. A relational database can be described as one in which all data is stored physically only once, but can be accessed logically many different ways.

Such access can be accomplished because indexes are created within the relational DBMS which relate the bits of data in several ways. A relational database telephone directory would list each person only once, but would have indexes associated with each name which would logically re-categorize that person by last name, first name, address or by other characteristics. In FAMIS, a relational database would allow the DSS to retrieve information regarding remaining resources grouped in many different logical categories. This flexibility in data retrieval would allow the FAMIS DSS to answer ad hoc questions which had not been previously identified.

A disadvantage of a relational database system is the direct tradeoff between data access speed and the amount of memory storage necessary. A relational database increases access speed to data by creating more indexes to group the data in more numerous logical ways. The increased number of indexes take up more memory space. However, the decreasing costs for memory storage hardware and the increasing capacity of microcomputers to house thirty and even forty-megabyte hard disks render this disadvantage unimportant for purposes of FAMIS application.

C. NETWORK TYPE DATABASE

Unlike hierarchical or relational databases, which use one-to-one and one-to-many data relationships, a network database type uses many-to-many data relationships. A network database defines sets which contain rules for association of relationships between logical groups of data. Such a database type is effective for retrieving large amounts of data, but is inappropriate for answering ad hoc queries since this involves redefining data relationships. Such redefinition is more difficult when the relationships are defined by sets. A network database system, such as CODASYL, would be inappropriate for FAMIS due to this shortcoming.

D. FUNCTIONAL TYPE DATABASE (ENTITY RELATIONSHIP)

An entity relationship database describes data as entities and extracts information by assigning functions to these entities to establish relationships. Purported to most closely resemble human thought association methods, entity relationship type databases are still in pre-production phases and are therefore not suitable for consideration with FAMIS.

Once the decision of which type of database FAMIS will use has been made, user data, resource data and other data will be entered into the database to incorporate necessary keys into the data. At that time, the issue of data design must be addressed. Data design refers to the structure of the data. Use of the existing FAMIS data design would probably be preferable to use of a new data design because data already exists in the FAMIS format and because a new data design might not be useable with other FAMIS programs, such as the disaster model.

Updating the database will be critical to successful use of the FAMIS system. Any DSS is only as good as the data it uses. If the FAMIS manager allocates resources to users who no longer work in their designated functions, the system will not work effectively. However, data integrity must be maintained to ensure updates of information in the database do not remove or alter information which will be needed at a future time. To preserve data integrity, it is recommended that the FAMIS DSS maintain two sets of databases. One set, consisting of recovery agent and communication resource information, would reflect pre-disaster information and would not be updated. This database would be reserved as the starting point for initial FAMIS calculations and as a reference point. At the beginning of the FAMIS DSS exercise, a second set of databases would be duplicated from the master set. This second set could then be updated to reflect current information, while leaving the master database set unchanged.

An example will illustrate the wisdom of maintaining two database sets. Suppose a region is reported destroyed. The FAMIS manager would update the databases to reflect the destruction of recovery agents and/or communication resources. If subsequent reports refuted the original report of destruction, the FAMIS manager could recall the original data to correct the updated database if he had an original master database as a reference. Without the original database, the FAMIS manager would have no certain way to reconstruct the existing communication resources. Updating the database of the FAMIS DSS will be harder on a microcomputer than on a mainframe computer because the microcomputer is portable and therefore not always readily accessible. The Red Cross handles such an access problem by updating database information on a periodic basis before disaster strikes. Such a procedure is recommended for the FAMIS system for two reasons.

First, by knowing when updates will occur, the FAMIS manager will know how current his database information is and when he can expect the next update.

Second, these updates, which would originate with FAMIS geographic area field representatives, present an excellent method of maintaining contact between the field representatives and the FAMIS manager. Such contact ensures the viability of the data received by the FAMIS manager about the current status of resources and users. Such contact also ensures the FAMIS manager knows who and where his field representatives are, so he can pass policy and other decisions down to them.

The updates could be done via telephone modem hookup or by floppy disks mailed to updating locations. Each method has advantages. The modem method allows instantaneous update of the database, without the time lag of mail service. The floppy disk method does not require the FAMIS manager and field representatives to be connected to the same network at the same time.

The data included in the FAMIS DSS database will be determined by the types of questions the DSS must address. Most of this information has already been identified by FAMIS developers, although provision must be made for inclusion of other data which is determined to be germaine to FAMIS use.

A relational database, governed by a DBMS, will effectively accommodate the FAMIS data and associated indexes as well as provide methods to incorporate new data into the existing database.

Updates of the data will be imperative. To be effective, these updates must be frequent enough to ensure the FAMIS database reflects current information. The necessary frequency of such updates will depend on how often the data changes. The updates should be performed following a regular schedule. Such regularity promotes maintenance of current data, since the FAMIS manager will know when to expect an update and therefore will know if he has missed one.

This thesis will not attempt to specify all types of data needed by the FAMIS DSS. As the FAMIS project develops and its scope of responsibility is finalized, the amount and type of data will be identifiable. This chapter has attempted to provide possible arrangement of that data in a database and suggested manipulation of the data by a Data Base Management System.

VI. THE ADJUDICATION ALGORITHM

This chapter will present a possible adjudication algorithm to be used to resolve claims made by recovery agents for scarce communication resources. Switching facilities of the Public Switched Network will be briefly described to provide background for the algorithm. A possible claim problem will be isolated and discussed. The possible algorithm process will be presented and the DSS process involved will be discussed.

A. REDUNDANCY IN THE PUBLIC SWITCHED NETWORK

The current Public Switched Network (PSN) is comprised of switches, nodes, trunks and other telecommunications equipment which serve to connect the system. Many redundant paths between any two points exist in the PSN. This redundancy was built into the PSN to provide faster, more reliable telephone service. Calls can be rerouted along alternate routes if congestion exists on a primary path.

In an emergency or disaster, the built-in redundancy of the PSN will serve two purposes. Almost certainly, communication resources will be in heavy demand during an emergency and congestion will exist on certain paths. Additionally, the emergency or disaster might destroy some of the communication paths. Redundancy of paths will be used to relieve the congestion caused by the crisis, but such redundancy will also improve the probability that a working path still exists between two points where disaster has eliminated primary communication paths.

As will be seen in the claim problem examined in this chapter, the existence of PSN path redundancy will be mandatory to allow for allocation flexibility. The FAMIS DSS adjudication algorithms developed to solve the claim problem must therefore be able to take advantage of PSN path redundancy as discussed above.

B. THE CLAIM RESOLUTION PROBLEM

For illustrative purposes, one of the questions discussed in Chapter 4 will be used as our example problem, namely, How can the number of users on the system be maximized?

Resolution of this question will involve several steps:

1. Determination of network status; what characterizes existing paths.
2. Determination of user status; what recovery agents exist and where are they on the NETS.
3. Determination of optimum allocation; how to connect the greatest number of recovery agents over the NETS simultaneously.

These steps are discussed at length below.

Certain characteristics of the NETS can be discerned by determination of network status as discussed in Chapter IV. For allocation purposes in our example problem, the characteristics of connectivity and capacity of the paths will be the relevant parameters of the NETS.

J. LaPatra and C. Pierson have developed a Coefficient of Connectivity (CC), which defines mathematically all possible paths between two nodes (recovery agents) within the PSN [Ref. 6]. Since the CC can be defined for every possible path within the PSN, it can also be defined for any remaining paths in NETS, since such remaining paths will be a subset of the original PSN.

Given this ability to express every NETS path mathematically, the FAMIS DSS could determine the capacity of these paths. Such determination would involve retrieving the capacity information for these paths from the DSS database and applying an update from the FAMIS manager to that information. Using a comparison program, the FAMIS DSS could then determine the lowest channel capacity link within this subset of system paths, since the capacity of any path can never exceed the capacity of its weakest link.

It should be emphasized that all paths in the PSN can be expressed individually in terms of the CC mentioned above. All PSN paths could therefore be defined in the FAMIS communication resource database by their CCs, rather than by numbered node connections or geographic positions. Such definition by CC would make it easier for the FAMIS DSS to express the NETS status mathematically in optimization models.

The determination of user status was discussed in Chapter IV. The user characteristics of interest in our example problem would be communication line capacity requirements and time requirements, since these requirements will determine which lines will meet the needs of certain recovery agents and the duration of their calls will determine how many users can be queued for calls.

The FAMIS DSS would retrieve these user characteristics from the recovery agent database. Note that user priority is not mentioned as a characteristic in our example. This omission is due to the emphasis on number of users, instead of priority use.

The FAMIS DSS could then employ an optimization model to maximize recovery agent use of the NETS, subject to the constraints of existing system connectivity, lowest path capacity, user capacity requirements and user time requirements. This optimization model could easily be adjusted to answer the other allocation questions listed in Chapter IV by altering the constraints.

The example problem discussed in this chapter is only one of several questions addressed in Chapter IV, which does not address all possible ad hoc questions the FAMIS manager might have to answer to resolve all possible contingencies of communication resource allocation. The characteristics of the NETS and the recovery agents can be combined in many ways and each combination might require a different allocation configuration. The example discussed in this chapter, however, is typical of the type of optimization problem which the FAMIS manager and his DSS will be required to resolve.

VII. THE FAMIS DSS

This chapter will describe the required attributes of a decision support system for use with FAMIS. The three parts of any DSS will be described briefly to define the interfaces between the manager and the DSS. Required and desired technical literacy of the manager will be discussed and coupled with necessary DSS functions. Finally, the information presented in this thesis will be summarized to identify required and desired characteristics of the FAMIS DSS.

A. COMPONENTS OF A DECISION SUPPORT SYSTEM

Decision Support Systems have been described in many different terms and categories. All decision support systems, however, are composed of the same three basic systems: Language System (LS), Knowledge System (KS), and Problem-Processing System (PPS). These three generic DSS systems are described briefly.

KS. A knowledge system in a DSS is the body of knowledge a decision support system uses to answer questions. Databases, files and other stores of information are common parts of a KS. Information contained in a KS must be arranged in a systematic, organized manner. The KS portion of the FAMIS DSS would include recovery manager information, resource information, any standard arithmetic rules inherent in computer calculations and any other information which the DSS would retrieve and use to answer a question.

LS. A DSS language system serves as the interface between the manager and the DSS. The LS can be defined as the total of all linguistic facilities made available to the manager by a DSS. As will be discussed later in this chapter, this interface can be designed to be as complex or as simple as required to be understandable to the manager.

PPS. The problem-processing system of a DSS takes the problems conveyed by the LS and, retrieving data from the KS, solves equations, compares data and otherwise analyzes and interprets data to provide information requested by the manager.

The terms language system, knowledge system and program-processing system represent logical entities rather than strict physical components and there can be blurring of the lines of responsibility between these three sections. Different decision support systems will allocate certain functions, such as standard arithmetic functions, to the PPS instead of the KS. The DBMS might also reside in the PPS instead of the KS. It is important to realize that these sections are defined broadly because each DSS will be arranged to suit its specific purpose.

The KS, arranged logically, interfaces with the PPS through a Data Base Management System (DBMS). As discussed in Chapter IV, the DBMS is a software program and it can reside in either the KS or the PPS. The DBMS retrieves selected information in a specified format from the KS and delivers this information to either the PPS or the LS, depending on whether the data must be acted upon or simply passed to the manager.

If the data must be analyzed, calculated on or somehow transformed, the DBMS sends the data to the PPS. For example, in the FAMIS DSS the DBMS would retrieve data showing historical resource locations along with disaster model results and place the information into the PPS. The PPS would then compare the two data stores to determine the percentage and location of remaining resources. This information would be sent to the manager via the LS and would also be sent to the KS for retention for future use.

For simple data retrieval, such as when the FAMIS manager wishes to see a graphic display of the NETS, the

DBMS would take the location data from the KS and send it directly to the LS. The LS would produce the graphic software necessary to project the map onto the manager's screen.

B. THE FAMIS MANAGER

Of the three DSS systems described, the language system (LS), as the interface between the DSS and the manager, will reflect to the greatest degree the FAMIS manager's level of computer literacy. The manager must be able to request information from the DSS. He must also be able to understand the answers the DSS produces. If the manager has little computer experience, then the LS must allow the manager to ask his questions in simple terms, perhaps as simple as colloquial English phrases, and must present the requested information in equally understandable terms, perhaps as simple as annotated map displays for depiction of NETS.

An example of a data-retrieval type of DSS which allows the user to ask questions in colloquial English is the Language Access to Distributed Data with Error Recovery (LADDER) system used on the ARPANET system. LADDER is written in a complex computer language called INTERLISP. The designers of the LADDER program assumed the user would have no computer experience and they designed the program to accept questions and present answers in colloquial English. LADDER will accept questions that are not couched in complete sentences and will even try to figure out the possible meaning of misspelled words. This feature allows users who are not comfortable "talking" with a computer to convey their wishes to the system and receive usable information back.

The LADDER system is somewhat slow, however, because the LS interface is so complex. The LS of any DSS must convert the user's requests into high-level computer code the PPS can accept to perform its tasks. If the user's requests are couched in varied English phrases, the LS must have within itself the necessary software to convert the English phrases to syntactically correct code. An additional problem with LADDER is that its LS will attempt to discern meaning from whatever phrases it receives and it sometimes misinterprets the user's meaning.

These two problems, slow speed and possible inaccuracy, are intolerable in an emergency DSS. An LS which will accept input as unspecific as LADDER's does is therefore unsuitable for the FAMIS DSS. It follows that the FAMIS manager must be at least somewhat familiar with computer use and methods of inputting and retrieving information.

From the LADDER example described above, it can be inferred that the more computer knowledge the FAMIS manager has, the less complex the LS has to be and the faster the system will operate. It is not practical to assume, however, that the FAMIS manager should be able to couch his questions in high-level or pseudo code for several reasons.

First, the FAMIS manager will most probably be a high-level government official. This presumption is based on the fact that the FAMIS manager will be given full authority to allocate communication assets nationwide during an emergency. As such an official, the FAMIS manager can be assumed to have a sound managerial background but, because computer literacy is only now becoming a requisite managerial skill, it cannot be assumed that he will have worked with computers extensively before.

Second, during an emergency the FAMIS manager may not have time to convert his questions from English into pseudo code or high-level code before entering them into the DSS.

Third, since the LS interfaces with the PPS, it can act as a buffer to ensure the PPS receives information requests in the correct format. A simple LS allows the manager to interface more directly with the PPS and may result in inaccurate information being produced by the PPS.

It follows from this discussion that the FAMIS manager must possess at least some computer experience, but that he cannot be expected to know computer languages. The LS must require some structure of format in the requests it receives from the manager, but must still be sufficiently "user-friendly" to be understood by the manager.

A menu-driven LS is a possible compromise. Menus in a computer program can be described as lists of choices which are presented to the user. The current FAMIS prototype computer program uses a menu to present the types of information available to the manager. This list was presented in Chapter II. The benefit of an LS which uses menus is that it is readily understandable by almost any user. The disadvantage of a menu- driven LS is that the choices of information the manager can receive are limited to the choices presented by the menu. Such limitation of choices would be unacceptable where the FAMIS manager wanted to ask ad hoc types of questions, but could be used to initiate broader requests such as calling up a graphic map of the NETS or a list of all recovery managers.

Whatever language system is selected for FAMIS, it must satisfy the criteria that it be understandable to a manager with the projected computer experience level of the FAMIS manager. Since the FAMIS manager will most probably be a high-level government official and therefore hard to find or replace, it will be much more efficacious to tailor the LS to the manager than to require the manager to become a computer expert.

C. CONCLUSION

This thesis has strived to identify the requirements of a decision support system to be used to help adjudicate allocation of scarce communication resources in concert with the Fly-Away Management Information System.

As with any emergency DSS, the FAMIS DSS must support the three criteria mandatory for emergency decisions: accuracy, speed and interpretation of large amounts of uncorrelated data. This thesis maintains these criteria can be best supported by a computer-driven DSS, housed in a microcomputer. Three examples of such emergency, computer-driven support aids were given. Although only one of the examples involved allocation of scarce resources (ambulances), the nature of the decisions faced by managers in all three examples supports the necessity of a DSS which can support the three criteria mentioned above.

The FAMIS DSS, like a human staff, must be able to provide the FAMIS manager with information upon request and must, at the same time, screen the information to ensure the manager does not have to deal with data unnecessary to reach his decision. Various software programs exist to perform these two categories of functions and most of those will work easily in a microcomputer.

The questions associated with the allocation decisions the FAMIS manager must address are at the core of the issues of DSS design and the way in which the FAMIS DSS fits in with the rest of FAMIS. These questions can be grouped into the four main categories described in Chapter IV. It will be the FAMIS manager's ability to address these questions, using the DSS, which will make the DSS such a vital part of the Fly-Away Management Information System.

The type of database and Data Base Management System (DBMS) to access the data will be important considerations for the FAMIS DSS. A relational database is recommended because it offers the data flexibility necessary to enable the FAMIS manager to ask ad hoc questions of the DSS. Regular updates of the data will be vital. Without current information, the DSS and therefore the decisions of the FAMIS manager will be inaccurate.

An example of a possible adjudication algorithm for allocation of scarce resources was discussed in Chapter VI. Many other algorithms will be needed to provide the analysis necessary to resolve all allocation questions.

Possibly the most important part of the FAMIS manager/DSS system will be the computer literacy of the FAMIS manager. The DSS language system interface must be tuned to the manager's computer sophistication, since the DSS will be useless if the manager cannot input information or understand the DSS output.

Figure 7.1 depicts the flow of information into and out of the FAMIS DSS
as discussed in this thesis. From Figure 7.1, it can be seen that the DSS will need information from the recovery agents and communication resource databases, the FAMIS damage model program, and the FAMIS manager himself, along with the real-time resource claims of recovery agents to determine resource allocation recommendations. These recommendations must be sent to the FAMIS manager, not directly to the NETS, because the FAMIS manager must be the final arbeiter of allocation demands.

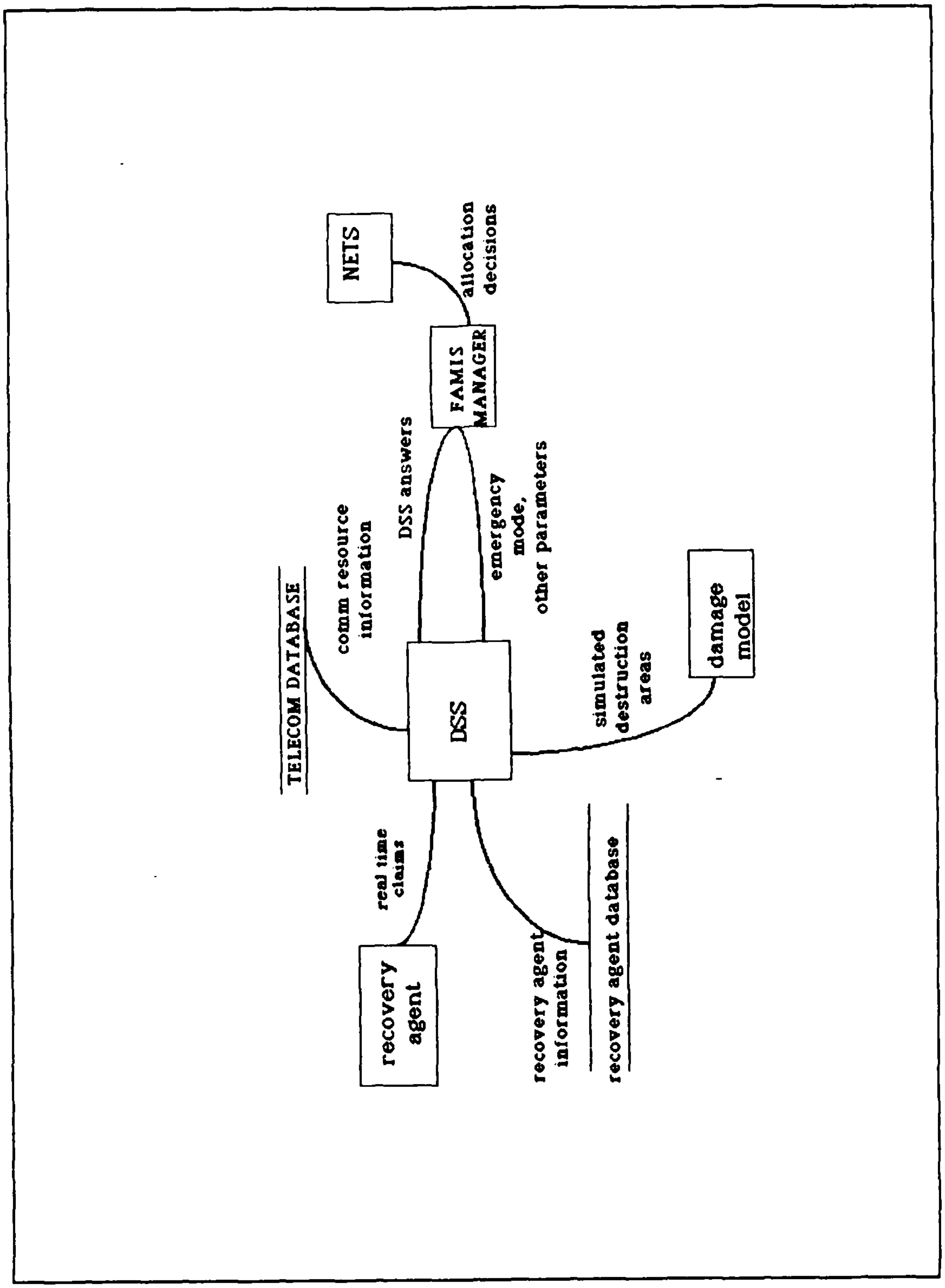

Figure 7.1 Interaction of the FAMIS DSS.

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