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Selecting a Decision Support System Generator for the Air Force's Enlisted Force Management System

Robert G. Walker, Robert S. Barnhardt,
Warren E. Walker

December 1986

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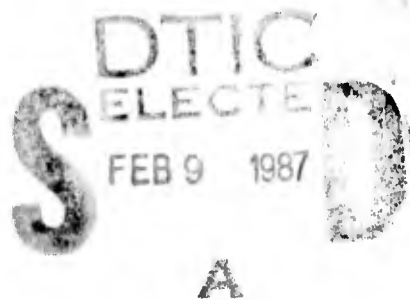
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A Project AIR FORCE report
prepared for the
United States Air Force



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PREFACE

In the process of building a decision support system (DSS) to help manage its enlisted force,¹ the Air Force decided that the only timely and cost-effective method of getting the programs for the system written was to acquire a single, general-purpose, off-the-shelf software package (called a DSS generator) within which the specific system models could be embedded. Early acquisition of a software package in this manner constitutes a reversal of the common practice of first acquiring hardware and then setting about to design suitable software support systems.

This report explains how the DSS generator was obtained. It presents the objectives defined for the generator and the specific requirements derived from these objectives. It then describes the structured evaluation process that led to the ultimate selection.

The report should be of most use to those who are, or may need to be, involved in developing a decision support system—whether from the perspective of a user, an analyst, an implementor, or an information systems manager. The topic of selecting a decision support system has received little attention in the literature. The report provides practical advice based on actual experience about how to select one. It should also be of interest to those who want to use computers to support decisionmaking in the public sector.

The work described here is part of the Enlisted Force Management Project (EFMP), a joint effort of the Air Force (through the Deputy Chief of Staff for Personnel) and The RAND Corporation to design, build, and implement an Enlisted Force Management System (EFMS). RAND's work falls within the Resource Management Program of Project AIR FORCE. The EFMP is part of a larger body of work in that program concerned with the effective utilization of human resources in the Air Force.

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¹See Grace M. Carter, Jan M. Chaiken, Michael P. Murray, and Warren E. Walker, *Conceptual Design of an Enlisted Force Management System for the Air Force*, The RAND Corporation, N-2005-AF, August 1983.

objectives, and user requirements of the system, and managing its development and implementation. Lieutenant Colonel Robert S. Barnhardt is Chief of the Force Management Branch of AFMPC/DPMDW. He is project officer for information systems support and applications development for the EFMS.

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SUMMARY

Traditionally, when computer systems are built to support some portion of an organization, hardware is chosen first. Software is then chosen that will operate on that hardware. In most cases, such a process will constrain the software choices available and may result in seriously compromising the performance of the system.

This report describes an alternative approach that was used to select a decision support system (DSS) generator for the Air Force's Enlisted Force Management System (EFMS). In this case, the software was selected first. This assured that the software capabilities would match the requirements of the application to be supported. The hardware for the system was chosen based on the availability of the software.

A structured four-step process was used to select the DSS generator:

1. Identify the overall objectives for the generator (what it should accomplish and why).
2. Infer the general capabilities that the generator must have to respond to the objectives (e.g., easy to use and powerful database management).
3. Infer a set of specific capabilities that will satisfy the general capabilities.
4. Identify and evaluate specific software products that have some or all of the specific capabilities.

In Step 2 of the selection process, the Air Force identified ten general capabilities that the DSS generator had to provide:

- Data management—the ability to build, maintain, and manipulate complex data structures
- External interfaces—ways to transfer data into and out of the system
- Data analysis—facilities for the statistical analysis of data
- Inquiry—an on-line interactive database inquiry facility
- Report generation
- Graphics
- Command language—an interactive English-like command language for application generation and system operation
- Multi-user support
- System management facilities
- Distributed data processing—the ability to function in a distributed data processing mode.

In Step 3, between one and six specific capabilities were identified for each of the general capabilities.

In Step 4, the selection team initially examined well over 20 software products in some detail. The specific DSS generator capabilities were used to eliminate products that clearly did not meet the Air Force requirement. This phase of the selection process consisted largely of the team's reading product documentation and having vendors demonstrate their products and answer questions about their capabilities. The team also used various reference services in the evaluation.

Eight products that could not be eliminated as a result of the initial evaluation were subjected to additional analysis. This phase of the selection process was similar to the previous phase but was conducted on a more formal and detailed basis. A systematic and consistent measure of product capabilities against the Air Force requirement called for a formal evaluation methodology. Each product was carefully measured against the specific DSS generator capabilities.

Products were rated as to whether they met the specific capability. Each was then given a summary rating on the ten major categories. Products were then compared for all ten categories. Only one product met all of the established requirements. The Air Force purchased it on a sole source basis.

The Air Force is satisfied that purchasing a DSS generator was the correct move and that it chose one in an appropriate way. Because of the generator's complexity, it would have been impossible to develop the EFMS in any other way. Since it was installed, we have been able to verify the hypothesis that a DSS generator can markedly improve productivity.

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I. INTRODUCTION

CHARACTERISTICS OF A DECISION SUPPORT SYSTEM

A Decision Support System (DSS) is a computer-based system whose objective is to support decisionmakers in unstructured or semi-structured decision situations. The term "support" implies that a DSS is an adjunct to the decisionmaker—extending his capabilities, but not replacing his judgment. In fact, a DSS is aimed at providing support for making decisions in cases where judgment is required—decisions that cannot be completely specified in terms of an algorithm and turned over to the computer.

To be most helpful in fulfilling its objective, a DSS should provide rapid response to user requests for information. Ideally, the response should be fast enough to keep pace with the deliberative process of the decisionmaker. In practice, this means that a DSS should be interactive, utilizing terminals for input and output.

Another important characteristic of a DSS is that it be flexible and easily modified. As conditions (or even decisionmakers) change, it should be easy to adapt the system to support decisionmaking in the new environment.

Structurally, a DSS embeds a set of interlinked decision models (or modules) in a management information system (MIS), and provides the decisionmaker with on-line access to both the information in the MIS and the outputs from the various models. The major elements of a DSS are illustrated in Fig. 1.

At the heart of a DSS is the policymaker and his staff. Through use of simple, forgiving menus and English-like commands, they interact with both an integrated database and an interlinked system of models.

This report examines the software that supports a DSS and enables it to be built, used, and maintained.

THE ENLISTED FORCE MANAGEMENT SYSTEM

The Headquarters United States Air Force Deputy Chief of Staff for Personnel is in the process of building a DSS to help manage its enlisted force.¹ Effective management of the enlisted force is of increasing importance to the Air Force as it tries to carry out its

¹All references to the Air Force with respect to the selection and use of a DSS generator should be taken to mean Headquarters USAF, DCS/Personnel.

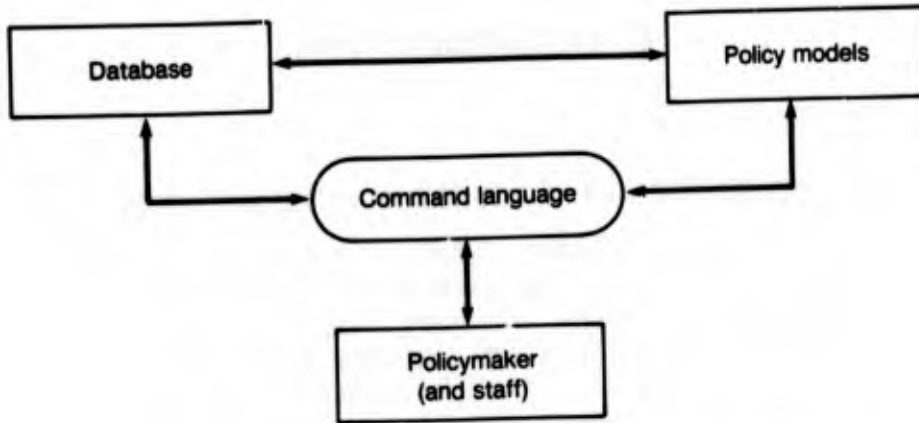


Fig. 1—Major elements of a decision support system

mission in the face of higher costs and constrained budgets. The enlisted component of approximately 500,000 airmen constitutes over 80 percent of the Air Force's active-duty manpower and absorbs over 20 percent of its total budget.

Management of the enlisted force involves making decisions about force structure, promotion policies, and the procurement, assignment, training, compensation, separation, and retirement of personnel. The objective is to have enough of the right kinds of airmen in the right grades and occupations in the right places at the right time to carry out the Air Force's missions.

Currently these decisions are made by the Air Staff in the Pentagon and at the Air Force Military Personnel Center in San Antonio using tools that have both conceptual and operational shortcomings. A joint team of The RAND Corporation and the Air Force developed a conceptual design for a DSS—named the Enlisted Force Management System (EFMS)—that will overcome the deficiencies and enhance the capabilities of the present system.²

DSS GENERATORS

Many of the software requirements for a DSS are general, not specific to an application (e.g., database management, report generation, menu development). Developing the software to provide such capabilities would take much more time and effort than developing the

²The conceptual design of the EFMS is presented in Carter et al., 1983.

software for the specific application (e.g., the policy models). An early decision in the development of the EFMS was that the only timely and cost-effective method of getting the programs for the system written was to acquire a single, general-purpose, off-the-shelf software package in which the specific system models could be embedded. Sprague and Carlson (1982) refer to packages that provide a set of capabilities to build DSSs quickly and easily as *DSS generators*.

A software package was needed with an integrated set of capabilities, including report generation, inquiry capability, a modeling language, graphic display commands, database management, a set of statistical analysis subroutines, and the ability to call FORTRAN subroutines. Software packages for each capability are widely available; however, it was desired to be able to access all of these capabilities as part of an integrated system using a common set of command and control features. Figure 2 shows the relationship envisioned among the users, the command and control features, and the components of the software.

Such a software package would be desirable for a number of reasons. We discuss some of these below.

Timeliness and Cost Effectiveness

Flexible, integrated DSS software is quite expensive to develop from scratch and would take a long time to produce. The Air Force decided that the sophisticated nature of the requirements, high development costs, limited availability of technically qualified personnel, and long development time precluded the use of in-house or contract automated data processing (ADP) professionals for the major aspects of software design and programming.

Uniform Command and Control

Command and control common to all functions of the system would avoid the complexity and confusion of users having to learn many features for separate functions within the system. A standard command language would be complemented by menu and other screen display interfaces to the system.

Integrated Database

Data within the system would be common to all functions and available for use without the creation of separate data files, the conscious movement of data among functions, and the redefinition of data elements.

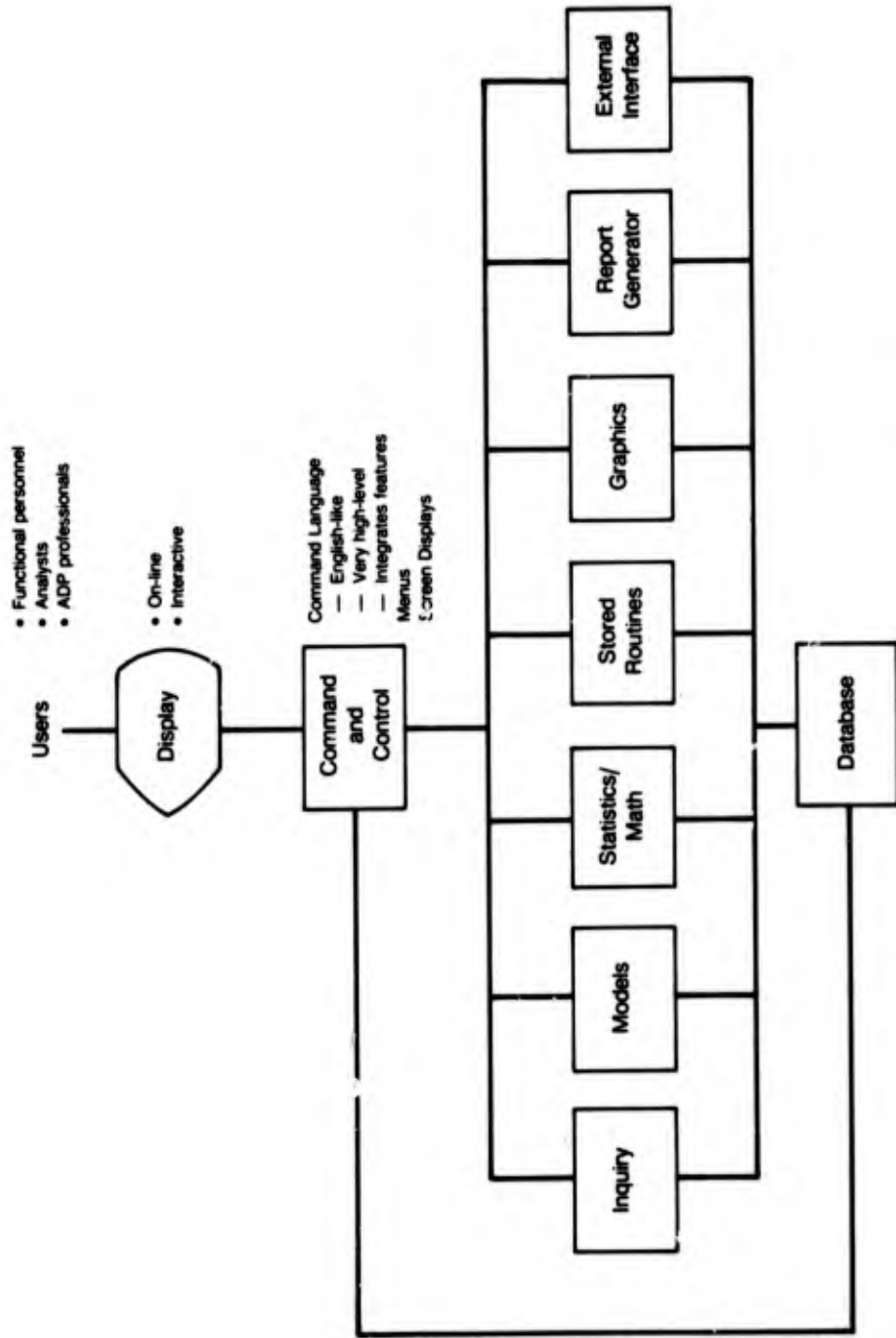


Fig. 2—Elements of the EFMS decision support system

No Interface Programming

Complex and inherently inefficient interfaces between system functions would not have to be developed and maintained by ADP personnel. These personnel would be available to work directly on applications.

OUTLINE

In May 1985 a software package called EXPRESS³ was installed on the Air Force's EFMS computer as the DSS generator. Section II explains how the requirements for the product were defined. After a set of objectives was spelled out, ten types of general capabilities were identified that would be required for the EFMS to operate as it was envisioned. Then specific capabilities were identified for each of the ten general capabilities.

Section III describes the process by which candidate DSS generators were identified and evaluated and by which EXPRESS was finally chosen. Section IV describes the lessons learned in this process. It contains advice for others planning to select a DSS generator and feedback on the Air Force's early experiences from using EXPRESS.

³EXPRESS is a trademark of Information Resources, Inc.

II. SPECIFYING REQUIREMENTS FOR A DSS GENERATOR

The Air Force developed a process for selecting a DSS generator closely paralleling the processes suggested by Sprague and Carlson (1982) and Meador and Mezger (1984):

1. Identify the overall objectives for the generator (what it should accomplish and why).
2. Infer general capabilities the generator must have to respond to the objectives (easy to use, database management, etc.).
3. Infer specific capabilities necessary to accomplish the general capabilities.
4. Identify and compare specific hardware and software products that could be used to implement the specific capabilities.

The Air Force then followed these steps in choosing the DSS generator for the EFMS.

OBJECTIVES

The objectives to be achieved with a DSS generator were spelled out in the conceptual design for the EFMS (see Carter et al., 1983). Most important, it had to permit quick and easy development of the system. It also had to facilitate meshing of the analytic power and technological capabilities of the computer with the judgments, needs, and problem-solving processes of the managers and analysts. And it had to make it easy to modify the system to meet changing needs, knowledge, and situations.

The EFMS has to be able to deal with unexpected problems, accept new policies, and adapt as circumstances change. This means that the programs must be written so that they are flexible (easy to change and revise), reshapable (permit the use of new variables), and dynamic (amenable to revision in response to changes in the data on which they are based). This means that the database also needs to be flexible, reshapable, and dynamic.

GENERAL CAPABILITIES

Soon after a conceptual design of the EFMS was developed, several Air Force analysts were assigned to work with intended users of the system, fleshing out the concept in terms of identifying the specifics of how the system would be used and the capabilities required to support the models identified in the design. This, along with associated work by expert Air Force system professionals, led to the identification of several required general capabilities for the DSS generator.

The project team determined that the DSS generator should provide command and control capabilities that were easy for users to learn and use. These features were envisioned to include an English-like syntax common to all aspects of the system, complemented by menus or other types of screen displays.¹ The user, without the help of a programmer, should be able to

- request information from the database,
- change data in the database,
- specify parameters and input data for an applications program,
- run a program, and
- tailor output reports (e.g., in terms of scope, level of aggregation, time period covered, and format).

To permit its most effective use in creative planning and analysis, the EFMS had to be capable of responding quickly to user requests. This, and the previously listed capabilities, suggested that the DSS generator had to be able to provide the following ten general capabilities.

1. Data management—the ability to build, maintain, and manipulate complex data structures
2. External interfaces—ways to transfer data into and out of the system
3. Data analysis—facilities for the statistical analysis of data
4. Inquiry—an on-line, interactive database inquiry facility

¹An important consideration in identifying the desirable characteristics of the DSS generator was that the Air Force wanted the end-use language to be a subset of a more comprehensive, sophisticated language with very high-level programming characteristics. When combined with the other application development and systems tools (a data dictionary, database manipulation features, report generators, etc.), the language would also serve the needs of the professionals responsible for EFMS development and maintenance. To use an analogy, children and nuclear physicists may use the same language, but they do not necessarily use the same vocabulary. Children are unlikely to be conversant in the realm of quantum mechanics, and physicists would not deal with these issues using a child's vocabulary.

5. Report generation
6. Graphics
7. Command language—an interactive English-like command language for application generation and system operation
8. Support of a multi-user environment
9. System management facilities
10. The ability to function in a distributed data processing mode

SPECIFIC CAPABILITIES

Within each of the ten categories of general capabilities, the Air Force defined specific attributes and features that the DSS generator should possess. Reasons for each of these needs were also formulated.

Data Management

- Build and maintain data in structures that allow the data to be managed so as to reflect the natural relationships among data elements—e.g., occupation, grade, years of service, and time. This includes capabilities to delete, add, and rearrange fields and records.
- Give system managers the capability to control and manage data and data structures as part of an integrated database system.
- Permit the user to operate on multiple structures, and perform transformations—combine, compare, consolidate, extract, and copy.
- Allow the user to determine the organization and content of the data.
- Permit the storage of other than numeric information in structures.
- Allow the use of data names that provide consistency with Air Force naming conventions and describe the data.

A major objective of EFMS is to provide access to information in a flexible and responsive manner and the ability to use and share it. It will be a multi-user, multi-function automated system. This will help to eliminate much of the fragmentation present in current enlisted force management processes. The data management capabilities of the decision support system must permit the data to be tailored to specific applications. Data must be able to be described, stored, and manipulated in ways that closely represent how Air Force managers look at

and understand the data. Features must be provided to describe, enter, and manage that data in an efficient manner consistent with Air Force standards; maintain it in ways that preserve meaningful relationships; aggregate or disaggregate it to an appropriate level of detail; and allow it to be manipulated into a wide range of combinations to accommodate the demands of a constantly changing environment. The presence of a data dictionary facilitates many of these functions.

Multi-User Support

- Provide for simultaneous access to data for inquiry purposes.
- Not constrain the total number of simultaneous users, subject to computer hardware capacity.
- Allow the users to create their own data structures.
- Provide safeguards for the security and protection of data at the record level and below.

One of the primary goals of the decision support system is to provide a set of general software tools to support a wide range of management applications. This is required for EFMS, which because of its scope and integration of related functions must serve many simultaneous users; it is also necessary if the system is to be more widely applied to other aspects of manpower and personnel management. Users must be able to inquire and extract common data while system managers protect and store data for secure applications. Security must therefore be provided at the record level and below for maximum access to common data where required and to protect data elements from unauthorized access or modification. The multi-user attributes of the decision support system will also enable system designers to solve fragmentation problems associated with the current methods of enlisted force management.

System Management

- Have facilities to control access to and use of selected features and data within the system.
- Integrate functions of the system (e.g., inquiry, graphics, and analysis) so as to make the transfer of data between functions transparent to the user.
- Give system managers the capability to describe, organize, control, and manage data and data structures as part of an integrated database system.

- Furnish facilities that aid the user in detecting, locating, and correcting errors of data and logic while using the DSS.

In addition to helping satisfy user needs, the DSS generator must support those who manage and maintain the system itself. It must contain facilities to control access to data and policy modules on a user-by-user basis. The DSS generator must also aid users and systems management personnel in describing and maintaining data and programs and in identifying and locating errors in the logic of application programs. It is especially important for the DSS generator to provide a means for determining where data elements are defined in the database and used in applications to make maintenance of the data flexible and easy. Finally, the DSS generator must provide integrated functions so that the user is not required to consciously transfer data between major functions of the system to complete a task.

Distributed Processing

- Provide capabilities for many users to be logged onto the system at one time.
- Allow the use of more than one mainframe host computer.
- Provide a means whereby data and programs can be transferred between the host computer and microcomputer workstations in an on-line interactive mode.

An explicit objective in the conceptual design of the EFMS was to explore new and emerging computer technologies that would correct the undesirable characteristics of traditional data processing. One important technological trend has been the use of microcomputers to distribute access and processing within a total system environment. The design of the EFMS envisioned multiple users at microcomputer workstations working in parallel. The need for large amounts of processing power and flexible solutions to processing growth, and the desire for redundancy to reduce the probability of total system failure suggested more than one host computer. Thus, the DSS generator needed to support an environment with multiple mainframe computers and large numbers of geographically dispersed microcomputer workstations.

External Interfaces

- Read data from an externally generated file.
- Write data to an external file.

- Exchange data between the DSS and external programs (e.g., a user-generated program written in FORTRAN) by means of a "calling" mechanism.

EFMS, as well as other potential Air Staff automated applications, is part of larger management processes, encompassing major elements of the manpower and personnel community. A great many of the data required by EFMS are resident in, or produced by, the Manpower and Personnel Systems. Data produced at the Air Staff level are also used by other organizations and functions. Numerous efficiencies would be realized if data could be transmitted through telecommunication between the decision support system and these users. There also may be some specialized tasks that the DSS generator's modeling language cannot accommodate, or accommodate efficiently—e.g., complicated optimization models that incorporate sophisticated mathematical functions. The benefits of the decision support system can still be realized to a great extent if it can integrate specialized models or routines written in scientific statistical languages, such as FORTRAN or SAS.

Data Analysis/Mathematical Functions

- Perform in-system statistical analysis and forecasting processes ranging from simple (e.g., totaling, averages, and standard deviations) to more complex functions (e.g., time series and seasonal analysis, simultaneous equations, regression, and curve fitting).
- Provide other common quantitative analysis functions, such as "what if," risk and sensitivity analysis, and goal seeking.
- Provide cross-tabulation features.

Quantitative analysis is a primary function of most Air Staff activities. This capability is implicit in the design and structure of the EFMS. Analyzing current activity, identifying trends, forecasting, and evaluating the effect of management alternatives are carried out in many forms on a continuing basis. Model building is also a frequent requirement. The structure of EFMS is designed to aid in these activities, but it will not be structured to handle all of the activities that require this support. In some cases it will produce data that require further analysis for ad hoc or specialized purposes. The models within EFMS will also require periodic revalidation using quantitative techniques. Incorporating data analysis and mathematical functions within the decision support system will greatly simplify these tasks. In many instances it will eliminate the need to transfer data between the

decision support system and a more specialized statistical system. All of the aspects of a given problem can be handled within the decision support system, using its common language and features.

Inquiry

- Allow interactive selection and retrieval of data by content—e.g., selecting and retrieving data items based on multiple criteria in a single inquiry.
- Permit multiple selection criteria within a single inquiry using relational operators, conditional logic, and logical operators.

Application of management by exception requires the type of inquiry capability specified. As mentioned above, EFMS and the decision support system environment in which it will be embedded will contain large amounts of data. Many applications in the system will take data from the DSS database rather than being entered by the user at a terminal. Users should also be able to selectively view only the data they need for a given task, without being forced to manually screen and select the data to be used. The DSS must therefore contain an inquiry capability.

Report Generation

- Allow designing and formatting of formal reports for presentation.
- Provide facilities to produce informal reports using default titles, headings, and labels.
- Permit line and column totaling and subtotaling.
- Support the on-line creation of cathode ray tube (CRT) screen formats.

Information from the DSS will be used for many purposes. Reports will be required for in-office use and will also go to senior Air Force management, the Office of the Secretary of Defense, and Congress. The system must provide a means of formatting reports to meet a specific need. In-office use will often require an informally formatted report, produced quickly to meet a short deadline. In those circumstances, the system should permit the user to easily construct a format. The system should be able to assume most of these tasks automatically by defaulting on spacing and taking headings from the data names used in producing the output. Formal reports should also

be able to be constructed within the system, eliminating the need for manual typing and reformatting to produce the quality required. The emphasis will be on on-line interactive usage. CRT displays, rather than written reports, will be the primary means of extracting information from the system. The capability to generate screen displays is an essential element in effectively using the system.

Graphics

- Contain an on-line capability to display data using bars, pies, lines, scatter plots, histograms, and text.
- Provide both monochrome and color graphics.
- Store a graph specification that can be recalled and combined with data in the system to produce a graphic representation without modifying the specification.

One of the major goals of EFMS is to improve decisionmaking. The ability to portray and analyze data in a graphic form will contribute greatly to achieving this objective. To make full use of the potential of graphic display, the DSS must provide many on-line interactive capabilities to users on several devices. Air Staff action officers require basic graphic capabilities to aid in the interpretation of raw data and to depict the output of various models and statistical analysis functions. The basic graphic forms include lines, bars, pies, scatter plots, histograms, and text charts. For these users the emphasis is on speed and simplicity in output generation. Most output would be monochrome with the option for hardcopy printing. Presentation quality graphics are also required for viewing by top decisionmakers—e.g., general officers, OSD, and Congressional staffs. This necessitates full-color high-resolution capabilities. The nature of Air Staff functions also requires the capability to produce print quality graphics for publication in official Air Force documents. The multiple capabilities required dictate that the DSS interface with a wide variety of graphic devices to provide the full range of needed capabilities.

Interactive Command Language

- Be English-syntax oriented and common to all major functions of the DSS (inquiry, data management, applications generation, reports generation, statistical and mathematical functions, and graphics).

- Be suitable for use by non-ADP personnel to accomplish basic tasks (simple modeling, inquiry, applications generation, reports generation, graphics, and data analysis).
- Be comprehensive enough for complex model building, in-depth data analysis, and applications generation associated with specialized data analysis and ADP programming.
- Allow sequences of commands and routines to be stored and later executed by user-named commands.

An objective of the Air Force is to place powerful computer-based tools in the hands of the end users. The DSS will be the primary tool to make this possible. It will form the core of the software system and serve as the main interface between the user and the computer. The command language will also be the programming language used by professional ADP personnel. To meet these needs, the DSS command language must have certain characteristics. It must be user friendly (English-based syntax and logical construction), common to all functions of the system to provide for ease in learning, have very high level data manipulation and analysis commands, and allow sophisticated application development tailored to specific user requirements.

In summary, a major goal is to provide appropriate capabilities to two categories of personnel. It should provide the benefits of a nonprocedural language to users who operate the models, generate reports, and make inquiries against databases. It should also insure that systems professionals have all of the facilities within the language to write complex applications programs without having to resort to traditional high-level programming languages, such as COBOL or FORTRAN, to a large degree. This demands a language that combines simplicity for one category of user with a powerful and varied syntax for another. Implicit in the command language of the DSS generator must be the potential for realizing increases of several hundred percent in productivity over using more traditional programming languages.

III. SEARCHING FOR AND SELECTING A DSS GENERATOR

Once a search was begun for a commercially available software system to provide the necessary capabilities, it took approximately two years (from January 1982) until the necessary approvals were received to purchase the generator (to February 1984). In this section we describe the search process and explain why it took as long as it did.

SEARCH PROCESS

The initial phases of the search for a DSS generator were, in fact, a continuation of the process used to define our requirements. To help us develop our ideas and insure that we were specifying a set of requirements that had a realistic chance of being satisfied, we read technical publications, examined system documentation and literature, interviewed system users, attended seminars, and had discussions with vendors. By the time we had developed our requirements to the point described in Sec. II, we believed that we had a good understanding of the marketplace, had generally ascertained the capabilities and limits of the technology, and knew the kinds of questions to ask. We could now direct our attention to the search process itself, using these requirements as a benchmark against which to measure individual DSS generators.

Our activities in the next phase consisted largely of reading system documentation and having vendors demonstrate their products and answer questions about specific capabilities and features. We also used various reference services to assist in the evaluation. We examined well over 20 products in some detail, eliminating those that clearly did not meet our requirements.

We subjected eight products that could not be eliminated as a result of the initial evaluation to additional analysis. This phase of the selection process was similar to the previous phase but was conducted on a more formal and detailed basis. To provide a systematic and consistent measure of product capabilities against the Air Force requirement, we developed a formal evaluation methodology around the specific DSS generator capabilities that had been used in the previous phase. Each product was carefully measured against several specific capabilities that were defined for each of the ten general categories of

capabilities. Products were rated yes or no as to whether they met the specific capability. Table 1 presents a portion of the matrix for data management capabilities. Only the successful DSS generator EXPRESS is identified. Appendix A presents complete evaluation matrixes for all ten specific capabilities.

The product was then given a summary rating on each of the ten major categories. Again the rating was on a yes or no basis. To receive a yes rating in a given category, a product had to be rated yes on all capabilities within that category. We then compared products for all ten categories of the requirement.

Table 2 presents the summary evaluation matrix. EXPRESS was the only product that met all of the requirements that had been established for a DSS generator for the EFMS.

In addition to this methodology, several other actions were taken to provide input to this phase of the selection process. For example, the programming language features of each product were extensively examined and compared. Vendors provided customer references. We

Table 1

ANALYSIS OF DATA MANAGEMENT CAPABILITIES

Capability	EXPRESS	DSS A	DSS B
Build and maintain data in structures that allow the data to be managed so as to reflect the natural relationships among data elements—e.g., AFSC, grade, years of service, and time. This includes capabilities to delete, add, and rearrange fields and records.	Yes	No	Yes
Give system managers the capability to control and manage data and data structures as part of an integrated database.	Yes	No	No
Permit the user to operate on multiple structures, and perform transformations—i.e., combine, compare, consolidate, extract, and copy.	Yes	No	Yes
Allow the user to determine the organization and content of the data.	Yes	Yes	Yes
Permit the storage of other than numeric information in structures.	Yes	Yes	Yes
Allow the use of data names that provide consistency with Air Force naming conventions and are descriptive of the data.	Yes	No	No

Table 2

SUMMARY EVALUATION FOR DSS GENERATORS

Capability	EXPRESS	DSS A	DSS B	DSS C	DSS E	DSS F	DSS G	DSS H
Data Management	Yes	No	No	No	No	No	No	No
External Interfaces	Yes	Yes	Yes	No	No	No	No	Yes
Data Analysis	Yes	Yes	Yes	No	Yes	No	No	No
Inquiry	Yes	No	Yes	No	No	No	No	No
Report Generation	Yes	No	No	No	No	No	No	No
Graphics	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Command Language	Yes	No	No	No	No	No	No	No
Multi-User Support	Yes	No	No	No	No	No	No	No
System Management	Yes	No	No	No	No	No	No	No
Distributed Data Processing	Yes	No	No	No	No	No	No	No
Meets All Criteria	Yes	No	No	No	No	No	No	No

questioned the customers closely using prepared questionnaires, not only about the product itself but about vendor support. Furthermore, because even careful reading of detailed documentation did not always lead to a clear understanding of product capabilities, the Air Force devised a set of questions about each product. It also wrote a description of a representative application and asked each company how its product might be used to support the application. (Appendix B contains the application description and the set of questions that were asked about EXPRESS.)

LENGTH OF SEARCH

Three important factors, other than our desire to do a careful and thorough search and evaluation, contributed to the time and effort required to acquire a DSS generator: federal procurement directives, the large number of products, and internal resistance.

Federal Procurement Directives

The Air Force has to comply with federal procurement directives, which impose very stringent requirements on ADP procurements, especially with regard to competition in the procurement process. There are few situations in which competitive bidding is not required (e.g., if only one vendor can meet all of the requirements, and all

requirements can be defended on a mission essential basis). Therefore, the Air Force had to proceed under the assumption that the DSS generator would be acquired competitively through the use of a Request for Proposal, which would be a detailed specification of the requirement sent to prospective vendors who indicated an interest in bidding on the contract.

It was our intent to build the specification for the DSS generator from the set of requirements that we had developed. We considered that an extensive investigation and evaluation process was essential if we were to insure that our requirements were effectively and efficiently met. We were very concerned that we not write a specification that would contain provisions no vendor could meet, or one that would cause the acquisition of a system that would not fully match our requirement. (To understand the dilemma the Air Force faced in this situation, imagine trying to write a specification for the English language.)

As the evaluation process progressed it became apparent that few products even came close to meeting requirements. Only one of the systems investigated seemed to have the full range of capabilities necessary to fulfill the criteria established for a DSS generator. This meant that the acquisition of a DSS generator might have to be on a sole source rather than a competitive basis. If true, the Air Force would have the burden of demonstrating that only the product selected had all of the features and capabilities necessary to meet the requirement. This meant extending the analysis process to any system that offered a possibility of meeting the requirement, to insure that a sole source action could be justified and defended based on a rigorous and systematic analysis of available products.¹ In the end, this turned out to be the case, and the results from our selection and evaluation process were used as the basis for building a sole source justification.

Large Number of Products

The many products purporting to be DSS generators, their wide range of capabilities and approaches to DSS generation, and exagger-

¹Even after a sole source acquisition is approved, vendors can challenge that decision and can force a competitive procurement by causing government decisionmakers to question the validity of the requirement as stated, or by demonstrating a potential for meeting the requirement. In the case of the EFMS, after the sole source acquisition of a DSS generator was approved, two other vendors raised questions about the decision. A protracted competitive procurement was avoided largely because the Air Force was able to demonstrate to them that the requirement was valid and that their products could not meet the minimum criteria.

ated vendor claims also added to the time and difficulties of selection. Associated with this problem is that the concept of a decision support system is ambiguous. It encompasses diverse approaches to, and types of tools to assist in, the decisionmaking process. Therefore, what may be a satisfactory DSS generator for one application may not meet the needs of another.

Internal Resistance

We encountered some organizational reluctance to accepting a DSS generator as a means of developing and operating the EFMS. Part of this reluctance stemmed from the fact that DSS generators were a new concept to many, and a certain amount of education was required before gaining acceptance of the idea. The selection of the generator was driving the supporting hardware options, and in all probability the generator would require equipment that was incompatible with the systems currently in use. There was an understandable concern about assuming the additional burden of operating and maintaining these computer systems. Also, historically, the emphasis had been on developing and maintaining computer systems that emphasized transaction processing—updating and retrieving records and data—against files containing thousands of individual records. The unique needs of the Air Staff—which emphasized flexibility, user control, quantitative and analytical capabilities, responsiveness, and the use of summary data—were not immediately apparent. In the end, the compelling nature of the arguments won most people over, and many Air Force personnel worked diligently to acquire and implement EXPRESS. Their support was critical to the success of the project.²

It was not until September 1983 that the Air Force felt confident it could make a justifiable and defensible case for a sole source procurement that could meet in-house scrutiny and gain procurement approval from the General Services Administration (GSA), i.e., a Delegation of Procurement Authority (DPA). GSA approved the acquisition in February 1984. EXPRESS was initially used on a time-sharing basis. It was purchased and installed on an Air Force computer in August 1985.

²Few people were required to conduct the evaluation and selection of a DSS generator and gain approval for its use (only two people did most of the work). But the procurement process and the installation of hardware, software, and communications required the dedicated efforts of many people within the information systems organization. This organization was also the source for the personnel who ultimately worked on development and implementation of the system. As outlined in the conclusions, many aspects of DSS implementation and operation require the expertise and active participation of experienced systems professionals.

IV. CONCLUSIONS

When selecting a DSS generator for use in building and operating a decision support system, the process of selection should carefully match the specific features and capabilities of the generators under consideration with the characteristics and requirements of the applications to be supported. To do this, there is no substitute for a thorough technical evaluation of alternative products. In the case of the EFMS, it was well worth the time and effort expended. Because of its complexity, it would have been impossible to develop the EFMS with a less capable DSS generator. Many of the features that distinguish EXPRESS from the other products we considered are the very features that permit the EFMS to be developed at all using a DSS generator as the primary development tool. For example, the sophisticated data management facilities and powerful programming features of the EXPRESS language are being driven to their limits by the requirements of the EFMS models.

We have already been able to verify the hypothesis that a DSS generator can markedly improve productivity. Building the EFMS would have been an impossible task using a traditional high-level language such as COBOL or FORTRAN as the primary programming language, given the manpower available for the project. Gains in productivity have been derived from simplifying the design process and program structure as well as reducing the number of lines of code that a programmer must write. By using appropriate documentation techniques, such as adaptations of James Martin's (1983) Logical Access Mapping and Action Diagraming, specifications have been efficiently created prior to programming. The simple nature of the resulting documentation has made it easier to catch errors at the specification point rather than later in the development process where delays may be longer and more damaging to development schedules. These features have also supported the use of prototyping in the application development process, with an accompanying reduction in the need for detailed design specifications that could have added considerably to development time.

Although many vendors marketing DSS generators emphasize the nonprocedural nature of their programming languages, the Air Force found that the complexity and size of the EFMS models mandated a heavy reliance on the procedural features of the EXPRESS language—e.g., IF . . . THEN . . . ELSE statements, DO WHILE logic, and nested looping. So, for sophisticated applications there is an

advantage to a generator that incorporates both procedural and nonprocedural characteristics. The nonprocedural characteristics help users perform such tasks as structuring flexible inquiries and generating reports. The procedural aspects of the language are required by system developers for building complex models.

It proved quite easy for those individuals without an extensive programming background to learn enough about the EXPRESS language and capabilities to generate operating models. However, designing models is only one of the tasks to be carried out to develop an operational EFMS. Database design and creation, the naming of variables, program documentation, security measures, system management, utilities, etc. are extremely important. The degree to which a DSS generator can facilitate these tasks should be considered in the evaluation process. In fact, we believe that the single most important criterion to be considered in the selection process is the quality of the generator's database management system. It should combine an active data dictionary and powerful data manipulation capabilities with a sophisticated inquiry system, and be fully integrated with all of the features of the DSS generator.

The performance of a model or program within a decision support system can be improved through efficient program and database design. One of the keys to maximizing performance is understanding how the specific commands actually operate inside the computer and how data are operated upon in addition to understanding what the commands themselves do. Powerful applications can be powerfully slow and inefficient. For example, poorly programmed EXPRESS applications can capture an extremely large amount of computer resource, mismanage disk file space, or lead to an inordinate amount of data swapping between disk and main memory.

One of the major objectives of a DSS is to put the power of the computer directly into the hands of the user. However, our experience in developing a system using a DSS generator has led us to conclude that the successful implementation and operation of a complex and sophisticated DSS, especially one operating in a multi-user environment, demands the support of experienced data processing professionals. DSS generators represent in many respects a new generation of technology, but many of the traditional principles for effective system design still apply. The flexibility, responsiveness, and ease of use of an application are likely to be the product of a structured and disciplined approach to the design of the underlying system.

Potential users of a decision support system generator such as EXPRESS should expect a significant learning curve if they intend to implement sophisticated and complex applications or are designing an

integrated system to serve the needs of many users. Questions involving database design, management of disk space and memory, programming conventions, etc. need to be addressed "up front" and resolved. If not, bad decisions, or the absence of design decisions, can cause major problems as systems expand and mature. Immediate and rapid implementation of applications can create an image of progress that is more illusory than real. Time must be taken from the beginning to learn to effectively and efficiently build and manage the decision support systems being created. This situation presents somewhat of a dilemma, because in many cases it is not possible to learn how to use the DSS generator without applying it to real world problems. This means that during the learning period, developers should be prepared to go back and do it over after learning how to do it right. Fortunately, the productivity gains possible with a good DSS generator make this a not too painful effort.

A DSS generator should be chosen before the system's hardware is chosen. Most generators can be used on only a limited number of computer systems. Most of the Air Force's personnel systems use Honeywell computers. There was great pressure on us to select a DSS generator that could be used on this equipment. However, there were few such products and they were unable to satisfy the requirements for the EFMS. This fact was of critical importance in persuading the Air Force to procure IBM-compatible equipment for the EFMS.

In summary, the Air Force is satisfied that it made the right choice in selecting a DSS generator. That choice was made using the process described here. A DSS generator is not a panacea for solving the problems of creating an effective decision support system. It is a management tool. The benefits it produces will depend on its fit to the job to be done and the skill with which it is used.

Appendix A

EVALUATION OF DECISION SUPPORT SYSTEM GENERATORS

Colonel Robert G. Walker
Lieutenant Colonel Robert S. Barnhardt
December 13, 1983

Numerous software products on the market call themselves a DSS. Only the eight systems listed in Table A.1 were identified as potentially able to meet the minimum requirements of the Enlisted Force Management System (EFMS).¹ These eight systems were examined in detail over a period of nine months.

Each of the systems listed in Table A.1 were evaluated against the requirements listed in Attachment 1 of the Express Sole Source Justification, based on research of product documentation and visits or demonstrations by vendors. Of the eight, five systems (DSS C through DSS G) were disqualified on the basis of their obvious deficiencies in data management (Category 1), inquiry (Category 4), and systems management (Category 9).

The three remaining candidate systems were further evaluated against the criteria through further research of product documentation, additional vendor visits or demonstrations, and interviews with product customers. The results of the evaluation of EXPRESS, DSS A, and DSS B against each requirement in the ten major categories are summarized in Table A.2. Both DSS A and DSS B failed to meet nearly one-third of the requirements, and both failed to meet at least one requirement in seven of the ten major categories. Only EXPRESS met all requirements.

¹Only the DSS generator that was ultimately chosen (EXPRESS) is identified. The other systems are labeled DSS A, DSS B, etc. to protect their identities.

Table A.1
SUMMARY EVALUATION OF DSS GENERATORS BY GENERAL CAPABILITIES

Category	EXPRESS	DSS A	DSS B	DSS C	DSS D	DSS E	DSS F	DSS G
1. Data Management	Yes	No	No	No	No	No	No	No
2. External Interfaces	Yes	Yes	Yes	No	No	No	No	Yes
3. Data Analysis	Yes	Yes	Yes	No	Yes	No	No	No
4. Inquiry	Yes	No	Yes	No	No	No	No	No
5. Reports Generation	Yes	No	No	No	No	No	No	No
6. Graphics	Yes	Yes	No	Yes	Yes	Yes	Yes	No
7. Command Language	Yes	No	No	No	No	No	No	No
8. Multi-user Support	Yes	No	No	No	No	No	No	No
9. Systems Management	Yes	No	No	No	No	No	No	No
10. Distributed Data Processing	Yes	No	No	No	No	No	No	No
Meets All Requirements	Yes	No	No	No	No	No	No	No

Table A.2

EVALUATION OF DSS GENERATORS BY SPECIFIC CAPABILITIES

Specific Capability	DSS Generator			Remarks
	EXPRESS	DSS A	DSS B	
1. Data Management				
Build and maintain data in structures that allow the data to reflect the natural relationships of data elements—e.g., AFSC, grade, years of service, and time. This includes capabilities to delete, add, and rearrange fields and records.	Yes	No	Yes	DSS A forces definition of a multi-dimensional problem into a two-dimensional solution.
Give system managers the capability to control and manage data and data structures as part of an integrated database.	Yes	No	No	DSS A and DSS B lack data dictionary functions.
Permit the user to operate on multiple structures and perform transformations—combine, compare, consolidate, extract from, and copy.	Yes	No	Yes	DSS A forces structures to be merged for comparison.
Allow the user to determine the organization and content of the data.	Yes	Yes	Yes	
Permit the storage of other than numeric information in structures.	Yes	Yes	Yes	
Allow the use of data names that provide consistency with Air Force naming conventions and are descriptive of the data.	Yes	No	No	DSS A restricts names to FORTRAN rules. DSS B does not allow all numeric data use identifiers, e.g., AFSC 73290.

Table A.2—continued

Specific Capability	DSS Generator			Remarks
	EXPRESS	DSS A	DSS B	
2. External Interfaces				
Read data from an externally generated file.	Yes	Yes	Yes	
Write data to an external file.	Yes	Yes	Yes	
Exchange data between the DSS and external programs—a user generated program or routine written in FORTRAN—through a "calling" mechanism.	Yes	Yes	Yes	
3. Data Analysis/Mathematical Functions				
Perform in-system statistical analysis and forecasting processes ranging from simple—e.g., totaling, averages, and standard deviations—to more complex functions—e.g., time series and seasonal analysis, simultaneous equations, regression, and curve fitting.	Yes	Yes	Yes	
Provide other common quantitative analysis functions such as "what if," risk and sensitivity analysis, and goal seeking.	Yes	Yes	Yes	
Provide cross tabulation features.	Yes	Yes	Yes	
4. Inquiry				
Allow interactive selection and retrieval of data by content—i.e., selecting and retrieving data items based on multiple criteria in a single inquiry, and location in the data structure.	Yes	No	Yes	DSS A could not access data elements in a data structure by both a name and a row, column reference.

Table A.2—continued

Specific Capability	DSS Generator				Remarks
	EXPRESS	DSS A	DSS B		
Permit multiple selection criteria within a single inquiry using relational operators (equal, not equal, greater than, greater than or equal to, less than, less than or equal to, between), conditional logic (if . . . then), and logical operators (and/or).	Yes	Yes	Yes	Yes	
5. Reports Generation					
Allow designing and formatting of formal reports, to include quality of output, for presentation.	Yes	Yes	Yes	Yes	
Provide facilities to produce informal reports using default titles, headings, and labels.	Yes	Yes	Yes	Yes	
Permit line and column totaling and subtotalling.	Yes	Yes	Yes	Yes	
Support the on-line creation of CRT screen formats.	Yes	No	No	No	Neither DSS A nor DSS B supports CRT formatting.
6. Graphics					
Contain an on-line capability to display data using the following graphics forms: bars, pies, lines, scatter plots, histograms, and text.	Yes	Yes	No	No	DSS B has no text-only graphics capability.
Provide both monochrome and color graphics.	Yes	Yes	No	No	DSS B has no color graphics capability.
Store a graph specification that can be recalled and combined with the appropriate data in the system to produce a graphic representation without modifying the specification.	Yes	Yes	Yes	Yes	

Table A.2—continued

Specific Capability	DSS Generator			Remarks
	EXPRESS	DSS A	DSS B	
7. Interactive Command Language English-syntax oriented, nonprocedural, and common to all major functions of the DSS—inquiry, data management, applications reports generation, statistical and mathematical functions, and graphics.	Yes	No	No	DSS A does not have common syntax for all major functions. DSS B requires use of external graphics.
Suitable for use by non-ADP personnel to accomplish basic tasks—simple modeling, inquiry, applications generation, reports generation, graphics, and data analysis.	Yes	Yes	Yes	
Comprehensive enough to accomplish complex model building, in-depth data analysis, and applications generation associated with specialized data analysis and ADP programming.	Yes	Yes	Yes	
Allow sequences of commands and routines to be stored and later executed by user-named commands.	Yes	Yes	Yes	
8. Multi-user Support				
Provide for simultaneous access to data for inquiry purposes.	Yes	Yes	Yes	
Not constrain the total number of simultaneous users, subject to computer hardware capacity.	Yes	Yes	Yes	
Allow the users to create their own data structures.	Yes	Yes	Yes	
Provide safeguards for the security and protection of data at the record level or below.	Yes	No	No	Neither DSS A nor DSS B provides data access and privacy protection below file.

Table A.2—continued

Specific Capability	DSS Generator			Remarks
	EXPRESS	DSS A	DSS B	
<p>9. System Management</p> <p>Have facilities to control access to and use of selected features and data within the system.</p> <p>Integrate functions of the system—e.g., inquiry, graphics, and analysis—so as to make the transfer of data between the functions transparent to the user.</p> <p>Provide facilities to manage the description and organization of the data used and maintained by the DSS through indexes of data elements and attributes and cross-references to the usage of data in logic.</p> <p>Furnish facilities that aid the user in detecting, locating, and correcting errors of data and logic while using the DSS.</p> <p>Contain facilities to manage data and logic files in the system including making copies, renaming, and deleting files within the limits of the user's security permissions.</p>	Yes	Yes	Yes	
	Yes	No	No	DSS A has not integrated all data management functions. DSS B requires external interface for minimum graphics.
	Yes	No	No	Neither DSS A nor DSS B has a data dictionary; thus both are unable to support these critical functions.
	Yes	Yes	Yes	
	Yes	Yes	Yes	
<p>10. Distributed Processing</p> <p>Provide a means whereby the data can be transferred between the decision support system operating on the host computer and other computer equipment in an on-line interactive mode.</p>	Yes	No	No	Neither DSS A nor DSS B has a distributed processing capability.

Appendix B

QUESTIONS AND TEST APPLICATION FOR VENDORS

Because careful reading of detailed documentation on the contending DSS generators did not always lead to a clear understanding of each product's capabilities, Air Force personnel devised a set of questions about the products. They also designed a representative application that illustrated some of the ways in which they envisioned using the EFMS.

They then sent a package containing the questions, the application descriptions, and a list of the specific capabilities they desired in a DSS generator to each of the contending vendors. Subsequently, they met with the vendors to obtain the information they needed to perform their evaluation. The remainder of this appendix is a copy of the package sent to Management Decision Systems, Inc., the marketers of EXPRESS in June 1983.¹

¹Management Decision Systems, Inc. merged with Information Resources, Inc. in June 1985.



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D. C.

Mr. Wally McKenzie
Management Decisions Systems, Inc.
200 Fifth Avenue
Waltham, MA 02254

14 JUN 1983

Dear Mr. McKenzie:

I want to thank you for the opportunity to visit your firm on June 28 to discuss EXPRESS. I will be accompanied by Major Robert Barnhardt and Major Charles Looney. Through our previous contact with you and other members of your organization and from reading selected documentation, my associates and I have gained some insight into the capabilities and operation of EXPRESS. However, there are still some questions concerning the appropriateness of the system for our specific management needs. We hope to gain answers to most of these during our visit with you.

To provide you with a better idea of our specific concerns, I have developed a representative application, illustrating some of the ways in which we envision using a decision support system. It is obviously not all encompassing, but it does focus on some of the capabilities which we feel are important in meeting our objectives. We would like you to determine how EXPRESS might be used to satisfy this particular application, and answer the accompanying questions during our visit.

In addition to this application, there are also some other issues related to EXPRESS which are of concern to us. I have incorporated these into a set of questions also enclosed with this letter.

I am also including a list of capabilities and attributes which describes the "ideal" decision support system, i.e. one that would meet all of our needs. This may be of help to you in preparing for our visit. As you can see from this list, we are not targeting the decision support system to a specific application but envision it as a general purpose tool which could be used in many different situations.

The United States Air Force assumes no liability, expressed or implied, from this visit or any other discussions or correspondence. While we are interested in learning more about EXPRESS, and believe that it might be of benefit to us, our interest at this point should not be interpreted in any way as a commitment or obligation to procure services or software.

If there are any questions concerning our visit or the materials provided to you, please feel free to telephone me at 202-697-7558.

Sincerely yours

R.G. WALKER
Lt Col, USAF
Chief, Information Resources Management
Directorate of Personnel Programs

- 3 Atch
1. Application
2. Questions
3. Desired DSS
Capabilities

DSS EVALUATION PROBLEM

To fully evaluate the capabilities of EXPRESS as it could be used in our particular situation, we have constructed a representative management application which we would like you to address using the capabilities of EXPRESS. The situation has been simplified to a significant degree, but we feel that it is descriptive of some of the important uses for which we would be acquiring a decision support system.

DESCRIPTION OF THE SITUATION:

One of the major responsibilities of the Air Staff is to manage the active duty enlisted force of the United States Air Force. As part of this responsibility the staff must maintain information on the status of that force. At the Air Staff level, it is not important to maintain data on each individual, but it is important to maintain data which describes the characteristics of the force. To fully ascertain the status of the enlisted force, three primary categories of data must be available to staff personnel. One type describes the force itself, i.e., the inventory. The second describes the requirements against which that force is matched, i.e., the authorizations. But the inventory and authorization data are changed via transactions, e.g., gains, losses, and promotions, so that any projection of the future status of the enlisted force will be determined by the current inventory and authorizations and the transactions forecast against them.

DESCRIPTION OF THE DATA

Inventory Data:

Enlisted career specialties are described by a five digit number. There are approximately 300 of these individual specialties. For this problem we will choose only three career fields.

431X1 Aircraft Maintenance

732X0 Personnel

751X0 Education

The "X" in the fourth position of the specialty code denotes a number which is filled in to indicate the level of skill possessed by an individual in the career field. There are five skill levels:

0 Level Manager
9 Level Superintendent
7 Level Technician
5 Level Specialist
3 Level Semi-skilled

In the aircraft maintenance career field, for example, personnel at the superintendent level would be identified with the code 43191. Personnel in this field at the specialist level would be coded 43151.

Air Force enlisted personnel are also identified by grade. These grades are:

E-9
E-8
E-7
E-6
E-5
E-4
E-3
E-2
E-1

Within each grade there are pay categories determined by the number of years of service which an individual has. These categories are:

Over 26 years
Over 22 years
Over 20 years
Over 18 years
Over 16 years
Over 14 years
Over 12 years
Over 10 years
Over 8 years
Over 6 years
Over 4 years
Over 3 years
Over 2 years
Under 2 years

To fully describe an individual in this situation you can do so using four attributes: career field, skill level within that career field, grade, and years of service within that grade. Therefore an individual might be described as being in the aircraft maintenance career field at the

superintendent level, in the grade of E-8 with over twenty years of service.

The enlisted force of the Air Force, past, current, and projected configurations, can be described in a five dimensional matrix, with the following dimensions:

Point in time
 Career field
 Skill level
 Grade
 Years of service

Note: For this problem, the points in time will be the months in Fiscal Years 1983 (October 82-September 83) and 1984 (October 1983-September 1984).

The identity of the individuals in each cell of the matrix is not important. The important fact to record is the number of people who fall into each of those cells. The problem may also be portrayed as a hierarchy, with levels corresponding to the dimensions of the matrix shown above.

Point in time
 Career field
 Skill level
 Grade
 Years of service

Authorization Data:

The authorized structure of the enlisted force can be described in a manner similar to the inventory, although there are important distinctions. There is no Years of Service dimension in the authorization structure. And while skill levels and grades are generally related in describing the inventory, there is a mandatory relationship in the authorized structure. Authorizations within each career field are described by both skill level and grade. Each skill level has between one and three grades associated with it. For example, an authorization identified as being at the seven level would also have an E-6 or E-7 grade attached to it. The specific structure is:

0 Level
 E-9
 9 Level
 E-8
 7 Level

E-7
 E-6
 5 Level
 E-5
 E-4
 3 Level
 E-3
 E-2
 E-1

In summary, the authorization structure can also be described as a matrix with four dimensions which are:

Point in time
 Career field
 Skill level
 Grade

Alternately, it could also be described as a hierarchy with the following categories.

Point in time
 Career field
 Skill level
 Grade

For this problem, the array(s) portraying authorizations in the database should be maintained separately from the array(s) depicting the inventory.

Transaction Data:

As mentioned above, both the authorization structure and the inventory are changed at points in time via transactions. This problem will assume that no changes are made against the authorization structure. There are three types of transactions which can be made against the inventory—gains, losses, and promotions. Transactions contain five attributes.

Point in time
 Career field
 Type of transaction (gain, loss, or promotion)
 Sign (plus or minus)
 Number

Note: A promotion to a given grade is a gain to that grade. This transaction also automatically generates a loss to the previous grade. That

is, a promotion to E-7 is treated like a gain to that grade, and a loss to E-6.

Questions to be Answered:

1. How would you set arrays, files, data sets, etc. in EXPRESS to record and maintain inventory and authorization data?
2. How would this data be portrayed both physically and logically in the system?
3. What capabilities does EXPRESS have to allow us to ask the following kinds of question?
 - (a) At the end of June 1983, how many enlisted personnel were in career field 732X0, at the level, in the grade of E-8, with less than 20 years of service?
 - (b) Which cells of the inventory matrix have a value of zero, i.e., no personnel fall into that cell?
 - (c) Which cells in the matrix contain 100 or more personnel?
 - (d) Which career fields are manned at less than 100 percent (the number in the inventory for that career field is less than the number of authorizations) at any point in time.
 - (e) How does the manning at the 9 level in the personnel career field for each month in Fiscal Year 1984 compare to the corresponding authorizations at the 9 Level? That is, identify the number authorized at the 9 level by grade, the number assigned at the 9 level by grade, the number over or under the authorized, and the ratio of assigned to authorized by grade.
4. Describe the procedure for entering inventory, authorization, and transaction data into the system using an external file. Describe the format of this file.
5. Assuming that you wanted to graph assigned vs. authorized manning for the personnel career field, how would you specify this data for use by the graphic subsystem?
6. How would you specify this data for use in a model in the DSS?
7. Describe the procedure for communicating a cell or subset of cells to a FORTRAN program.

QUESTIONS CONCERNING EXPRESS

1. What are your plans, if any, to provide versions of EXPRESS which will operate on computers manufactured by other than IBM and Prime?
2. What modifications, if any, have been made to the Primos operating system to accommodate EXPRESS? Who maintains the operating system?
3. What are your plans for a microcomputer version of EXPRESS? How would this version be related to the current version?
4. How much computer resource is required to adequately operate EXPRESS in multi-user configurations? Is there a reentrant version planned or existing?
5. Does EXPRESS allow full screen editing and data entry?
6. How does EXPRESS provide for data inquiry based on content?
7. Can mixed forms of data be stored in the same array?
8. What would be involved in modifying EXPRESS to operate with a graphics terminal not currently supported?

DECISION SUPPORT SYSTEM CAPABILITIES AND ATTRIBUTES

1. Data Management
 - Build and maintain complex multi-dimensional arrays, including capabilities to delete, add, and rearrange fields and records encompassing several dimensions, e.g. AFSC, Grade, Years of Service, and Time expressed in fiscal years or months.
 - Permit the user to operate on multiple arrays, and perform transformations, e.g. combine, compare, consolidate, extract from, and make copies, etc.
 - Allow the user to readily determine the organization and content of the data.
 - Permit the storage of other than numeric information in arrays.
2. External Interfaces
 - Read data from an externally generated file
 - Write data to an external file
 - Exchange data between DSS and external programs, e.g. a user written FORTRAN program or routine, via a "calling" mechanism
3. Data Analysis/Mathematical Functions
 - Perform in-system statistical analysis and forecasting processes ranging from simple, e.g. totaling, averages, etc., to more complex functions, e.g. time series and seasonal analysis, simultaneous equations, regression, and curve fitting.
 - Allow other common quantitative analysis functions such as "what if," risk and sensitivity analysis, and goal seeking.
 - Provide cross tabulation features.
4. Inquiry
 - Allow interactive selection and retrieval of data by content, e.g. selecting and retrieving data items based on multiple criteria in a single inquiry, and location.
 - Permit multiple selection criteria, e.g. equal, not equal, greater than, less than, range of values, if....then, and/or within a single inquiry.

5. Reports Generation

- Allow significant flexibility in designing and formatting formal reports, to include quality of output for presentation.
- Provide facilities to produce informal reports using default titles, headings, labels, etc.
- Permit line and column totaling and subtotaling.

6. Graphics

- Contain an on-line capability to display data using commonly required graphic forms, e.g. bar, pie, line.
- Provide both simple medium resolution monochrome and high resolution color graphics constrained only by the capabilities of the output device.
- Furnish the capability to store a graph specification which can be recalled and combined with the appropriate data in the system to produce a graphic representation without modifying the specification.
- Provide an interface to a variety of commonly used high resolution color graphic terminal devices.

7. Interactive Command Language

- English syntax oriented and common to all major functions of the DSS, e.g. simple modeling, inquiry, reports generation, graphics, and data analysis.
- Powerful enough to accomplish more sophisticated tasks, such as complex model building, in depth data analysis, and applications programs, when used by professional analysts and ADP programmers.
- Classified as a very high level programming language.
- Allow sequences of commands and routines to be stored and later executed by a single user-named command.

8. Multi-user Support

- Provide for simultaneous access to data for inquiry purposes.
- Not constrain the total number of simultaneous users.
- Allow the users to create their own data arrays, and provide safeguards for the security and protection of that data.

9. Resource Requirements

- Cost-effective in comparison to other systems with similar capabilities.

10. System Management

- Have facilities to control access and use of selected features and data within the system.
- Integrate functions of the system, e.g. inquiry, graphics, analysis, in such a way as to make the transfer of data between the functions transparent to the user.
- Furnish facilities which aid the user in detecting, locating, and correcting errors of data and logic while using the DSS.
- Contain facilities to manage data and logic files in the system including capabilities to make copies, rename, and delete files within the limits of the user's security permissions.

11. Transportability

- Have a potential for application in a distributed processing environment, i.e. the DSS can operate in a distributed processing mode utilizing microcomputers with shared data (and possibly shared processing) facilities, the vendor has specific plans to develop this capability, or the operating environment of the DSS host computer does not preclude the integration of the DSS into a distributed processing system incorporating microcomputers with commonly used operating systems, e.g. CP/M, MS DOS, UNIX, etc.


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Many of the software requirements for a decision support system (DSS) are not specific to an application (e.g. database management and report generation). Developing the software to provide such general capabilities might take more effort than developing the software for the specific application. In order to facilitate the building of the Air Force's Enlisted Force Management System, it was decided to acquire a general-purpose off-the-shelf software package (called a DSS generator) in which the specific system models could be embedded. This report explains how the DSS generator was obtained. It presents the objectives that were defined for the generator, and the requirements that were derived from these objectives. It then describes the structured evaluation process that led to the ultimate selection.



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