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79-12-02

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The purpose of this document is to give a brief introduction to the hardware available in the Wharton Computer Center and the Decision Aiding Systems Laboratory (DASL), and to summarize the software which has been developed at Wharton under the Operational Decision Aiding Project. More detail about most of these features is available; in particular, some of the other software developed for use on the Wharton system may be of interest to other contractors, now that the system is easily accessible via the ARPANET.

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Decision Aiding Systems Laboratory

INTRODUCTION

This document provides a brief introduction to the resources available in the Decision Aiding Systems Laboratory (DASL), including a summary of software developed at Wharton under the Operational Decision Aids (ODA) project. Much of the software described below is accessible via the ARPANET, and may therefore be of interest to other contractors (see 1.2). Requests for additional information should be directed to Gerry Hurst of the Wharton Decision Sciences Department or to any other member of the Wharton ODA team.

This document is divided into three sections: section 1 describes the DASL environment, including relevant features of the Wharton Computer Center, which houses the host computer; section 2 describes the generalized decision aiding software developed under ODA; section 3 describes specific decision aids available.

1.0 ENVIRONMENT

The DASL environment includes the full resources of the Wharton Computer Center, an interface to the ARPANET, and a variety of specialized computer terminals and associated hardware.

1.1 Host Computer

The Wharton Computer Center houses a Digital Equipment Company DecSystem-10 (DEC-10) built around a KL10 processor. The system has 512K words of core storage, 600 megabytes of online disk storage on 4 disk drives, two 9-track, 1600 BPI tape drives, two line scanners which handle 128 terminal lines, a 300 line per minute printer, and IMP-10 and Pluribus VDA adapters which connect to the ARPANET.

The Wharton DEC-10 is currently running under version 6.03 of the TOPS-10 operating system, which uses disk "virtual memory" to increase direct storage capacity from the 512K words of "real" core storage up to the limit addressable by the KL10's 18-bit address space. Virtual memory not only enables the system to handle programs whose core requirements exceed the amount of core storage available, it also facilitates control of programs which would otherwise require nearly all of the system's core storage, and therefore hamper processing of other jobs running concurrently.

Operating system control of the user interface is based on personalized log-in. Individual users are identified independently of the project number(s) to which they have access, which enables the system to exchange messages between individual users (both synchronously and asynchronously), maintain histories of program use, and exercise budgetary controls.

The Wharton Computer Center currently supports APL, BASIC, BLISS, COBOL, FORTRAN, MACRO-10, PASCAL, and POP, and maintains an extensive library of FORTRAN and APL functions and programs. Canned program packages include BMDP, EMPIRE, IDA, LINDO, and SPSS. Also available is a wide assortment of unique experimental software for planning, office automation, database management, etc., in various stages of development.

1.2 ARPANET

An interface to the ARPANET allows programs running in the DEC-10 to use the ARPANET as a standard I/O device. It also permits users logged in at the DEC-10 to log in at remote hosts using the Telnet protocol. Similarly, users logged in to remote hosts may log in at the DEC-10. It is also possible to exchange messages and data files between host computers connected by the ARPANET.

1.3 Specialized Hardware

In addition to the resources of the Wharton Computer Center and the ARPANET, a variety of computer terminals and associated hardware especially useful in decision support applications is available in the DASL.

1. The Datamedia 1520A is a standard, 24 x 80 character, video compatible, white on black CRT terminal. One Datamedia 1520A is currently available.

2. The Concept 100 is a 24 x 80 character, black and white CRT terminal with a built-in microprocessor which provides local storage as well as a number of sophisticated operating features, such as reverse video, multiple input and output ports whose characteristics can be varied, function buttons, and a variety of control and programmer options. (In fact, this terminal was designed to include in its firmware many features, such as "windows", which were developed by the ODA project (see section 2).) Several Concept 100's are currently

available.

3. The ADDS MRD400 is an eight color display generator with an upper-case-only alphanumeric character set. It uses a standard red-green-blue (RGB) television monitor and generates a screen of 24 x 80 characters. It has a limited graphics capacity, which makes it suitable for displaying bar charts, trend curves, and the like. One ADDS MRD400 is currently available.

4. The Tektronix 4013 is a high resolution, direct-view storage display with the full ASCII and APL character sets. One Tektronix 4013 is available, together with a Tektronix 4010 hard copy unit for use with the 4013.

5. There are several hard copy terminals of various kinds on which reports such as this one are produced.

6. The Grinnell GMR-26 is a 480 x 512 color raster graphics device which is driven by an LSI-11 microcomputer. The LSI-11 has 32K words of core storage and dual floppy disk drives, and is currently running under version 3 of the RT-11 operating system. It has a serial link to the DEC-10, and a bidirectional interface to the GMR-26. The combination of the GMR-26 and the LSI-11 provides a full range of graphics capabilities.

   Associated with the GMR-26 is a trackball device, which permits the user to manually position a visible cursor anywhere on the face of the graphics screen with a high degree of precision. The trackball can be used to draw continuous contours on the screen, and to select from program-generated menus.

7. The VOTRAX Voice Synthesizer can produce 64 different phonemes at four inflection levels on the basis of commands issued by the computer. It may be used to redirect the user's attention to the screen, or to inform the user of some condition not currently being displayed. The VOTRAX does not function in any way as an input device. One VOTRAX is currently available.

8. The Advent Videobeam Projector is used to enlarge displays to dimensions suitable for group viewing. It is a seven-foot commercial color television which projects onto a specially constructed reflective screen, and accepts input from an

ordinary television tuner, from standard video, or from RGB video signals such as are produced by the Grinnell graphics system described above. The Advent may be used to project both "live" and videotaped material. Two Advent Videobeam Projectors are available.

9. There are also facilities for videotaping displays. Several recording and playback units are available, along with sophisticated editing equipment, which enables contractors to produce videotapes of demonstrations, mixing signals from two terminals (e.g. graphics and alphanumeric) together with signals from color or black and white cameras. The standard is the U-matic cassette, a 3/4 inch color (or black and white) videotape with two audio tracks. Though most of the equipment is SONY, it is compatible with the products of most other manufacturers, such as JVC and Panasonic. (Note: Betamax is a 1/2 inch cassette, and therefore incompatible.)

2.0 DECISION AID SUPPORT SOFTWARE

Much of the work done at Wharton under ODA has been directed at enhancing the interface between the user and specific computer decision aids by developing generalized software which, though largely transparent to the user, nevertheless improves the user's command of the decision-aiding resources available. Because the software described below is independent of specific decision aids, it is of use in development and testing of decision aids as well as in their use. Figure 1 shows the four major components of the aid support system, each of which is considered separately.

2.1 Window Management

The window package is designed to overcome limitations upon the effectiveness of specific computer decision aids which follow from the fact that the user is restricted to interacting with one computer process at a time. The drawbacks of this restriction are obvious when the use of a single computer decision aid is contrasted to a more conventional decision-making environment: here, the decision-maker has access to a variety of different sources of information such as books, maps, charts, graphs, and notes jotted down earlier in the process, and may express the results of various stages of the process in a variety of forms on any number of blank sheets of paper, chalkboards,

DECISION AID SUPPORT SYSTEM

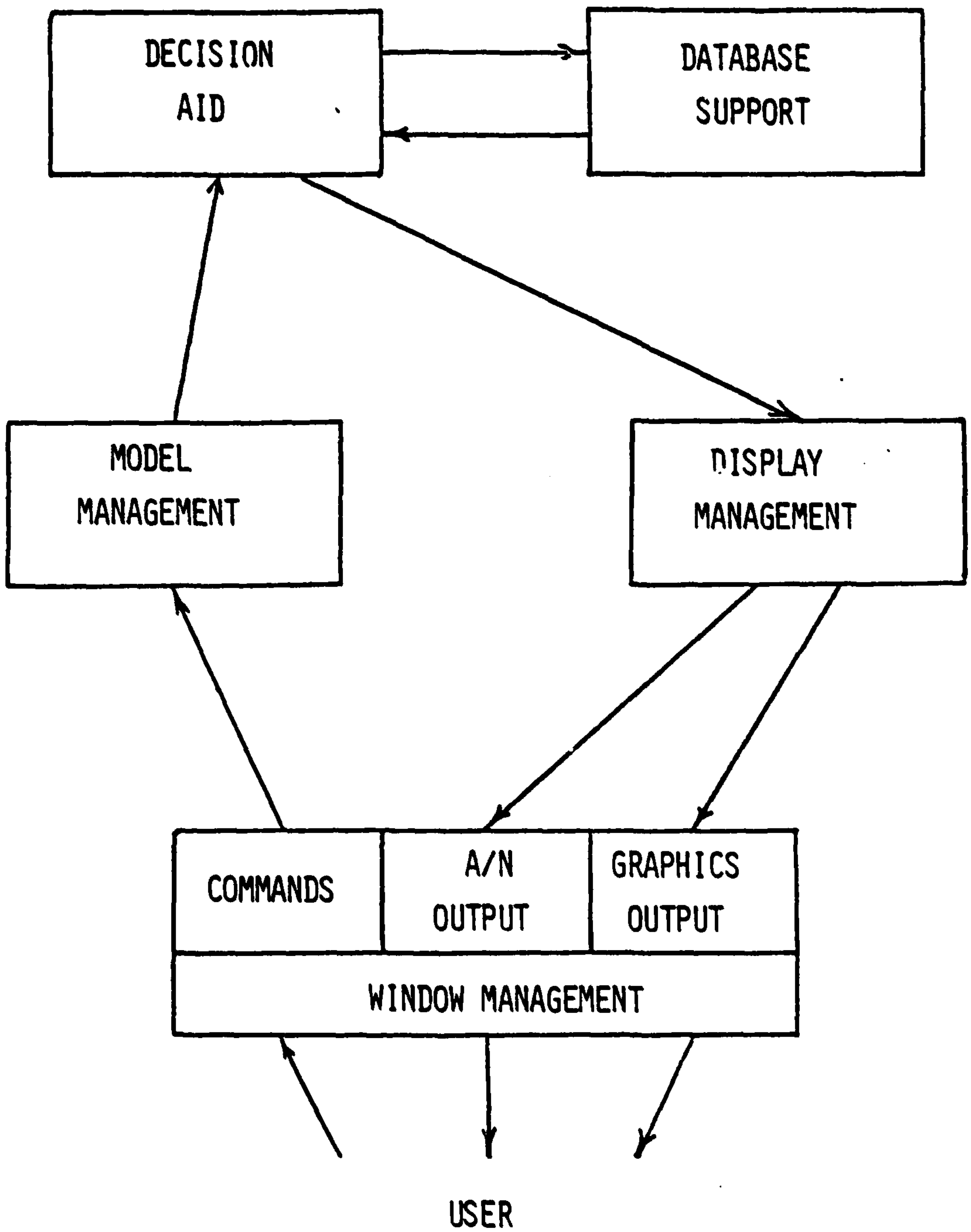

Figure 1

etc, some of which will be consulted later in the decision making process, some preserved in formal reports, and some discarded.

The window approach aims at approximating this diversity and flexibility of inputs and outputs by allowing the user to interact with more than one computer process at a time from a single terminal. This is accomplished by providing for the dynamic definition of several logical windows, each of which functions as an independent communication path between the user and a computer process. The information in a logical window is displayed through a physical window, which is a user-defined subset of the physical display area of the computer terminal. Thus, the user may enter commands or input data for one computer process, while at the same time receiving output from other computer processes, with the output of each different computer process appearing in a different area of the terminal screen.

Logical and physical windows are defined independently of one another, and may be reconfigured at any time by entering simple command strings. Logical windows are variable with regard to height and width, I/O function, prompting, and the retention of data no longer in the physical window. User-defined properties of physical windows include dimensions and location on the screen, border character, and fore- and background colors.

In addition to providing for the definition of logical and physical windows, the command language enables the user to transfer from one logical window to another, create computer processes and connect them to specified logical windows, clear individual physical windows, display a specified logical window thru a specified physical window, and query the status of both physical and logical windows. Frequently used command sequences (such as window definitions) may be loaded from pre-established disk files by entering a single command.

2.2 Model Management

Model management involves the development of a methodology for the analysis of both structured and unstructured problems which is of sufficient generality to be effective in a range of applications. The basis of this approach is the separation of user, problem definition, and problem solution, and the establishment of standard interfaces between them. The primary objectives of model management software are first to assist the user in structuring the problem at hand so that available analytical tools can be brought to bear in generating possible solutions, and then to facilitate the processing and analysis of resulting structural representations of the problem.

A prototype model management system (MMS) is being developed within the ONRODA context to support the use of various analytical techniques provided by the contractors. It consists of three major functional subsystems, namely model development, model processing, and model administration, all of which interact directly with a "model knowledge base". This MMS database includes a number of general models, each of which is the logical representation of of a well-structured and easily identifiable process, such as linear programming or inventory analysis, in terms of a set of entities, a set of relationships, and a set of assumptions. Entities and relationships are defined in terms of a set of attributes, each of which represents either an input or an output of the general model. Associated with each general model is a solution process which represents the actual programming code needed to solve the model.

The model develoment function is based on model building, a process which involves the generation of one or more model structures, each of which is a specific instance of a general model identified as applicable to some aspect of the problem at hand. The model structure projects the general model onto the problem at hand by providing a logical link between attributes of the general model and both input data supplied either by the user or by some previous model building process, and output data to be stored, reported, or supplied to a subsequent model building process.

Model processing is a matter of generating the actual programming code required to solve the problem at hand. This is accomplished by linking each model structure to a solution process via the corresponding general model. Because the input and output requirements of each solution process are specified in terms of a general model, the same solution process may be used for many different model structures.

Model administration is concerned with the validation and maintenance of models, including monitoring processing for violations of model assumptions, and informing users of such violations as they occur.

Development efforts to date have focused on design of the database and implementation of preliminary features of the dictionary function. The dictionary function is an important aspect of the model building process in that it assists the user in determining what types of model structures, general models, and solutions processes exist.

ASTDA models and solution software have been "dictionaried" and represented in the model knowledge base (see 3.1).

2.3 Display Management

A family of generalized graphics software developed under ODA serves as an interface between decision aiding systems and the DASL graphics hardware described above in section 1. These utilities make it possible for both computer decision aids and users to exploit a wide range of graphics capabilities by issuing simple commands. In this way, decision aids can benefit from sophisticated graphics hardware without incurring the cost of specialized graphics programming.

2.3.1 Graphics Primitives - DASL graphics software is based on a library of graphics primitives designed to support the Grinnell graphics system (see 1.3). Though these "G-routines" are implemented in FORTRAN and reside on the LSI-11, they are normally referenced by programs which are running on the DEC-10, and which may be written in any language for which a "G-interpreter" program is available (currently APL, FORTRAN, PASCAL, and POP).

The basic graphics vocabulary includes lines, empty or solid polygons and discs, and alphanumeric characters, all of which may be displayed in any color and size. By combining commands, displays of arbitrary complexity can be achieved.

2.3.2 Paging - This feature of the graphics support software enables the user to treat the graphics display area as several independent "pages", each of which is constructed using the graphics primitives described above, just as if it were an actual display. Since the construction of a graphics page is distinct from its being displayed, it is possible to store and quickly retrieve several different displays, much as one uses a slide projector to view a number of slides one at a time.

It is also possible, however, to treat the various pages as if they were transparencies which can be superimposed to yield a composite picture. As in the case of such transparencies, the order in which graphics pages are "stacked" can easily be changed by the user. Moreover, since one or more pages can be inserted into or removed from the display stack while the rest are held fixed, it is easy to produce displays in which variable foreground figures such as solid bars, are viewed against a constant background, such as labelled coordinates, to dramatize comparisons.

Although a given page may contain the full range of colors (i.e. 512) provided by the Grinnell system, the number of pages available is limited by the number of colors to be used on each page. Paging is available both to programs which reference G-routines and to SLIDES users.

2.3.3 Slides - The SLIDES program puts the full range of DASL graphics capabilities at the user's fingertips by providing for the construction of graphic displays from an alphanumeric terminal. Following start-up procedures which establish the interface between the DEC-10 and the Grinnell graphics system, the user creates each slide by entering the text to be displayed along with certain control information. This control information includes graphics commands which specify figures to be drawn, text size, position, and color, and formatting commands patterned after the DEC Runoff package for document preparation.

The user may choose just to display each slide as it is constructed, or in addition to "record" a series of slides in a file which may be "played back" at some later time. Since the Grinnell system is video compatible, displays produced by SLIDES may be videotaped directly, photographed from the screen, or transmitted to any reproduction process which accepts video input. The strength of this approach to the production of slides for formal presentation lies in its direct connection with the decision aids and other DASL software.

2.4 Database Support

To support the development and testing of decision aiding software, the DASL has available an experimental database which is maintained on a CODASYL-like database management system.

2.4.1 ONRODA Database - Under contract to ONR, CTEC Inc. [2] has developed a data set suited to testing decision aids which address ONRODA Strike and Amphibious Warfare Scenarios. The data, which have been structured by the Wharton ODA project team, fall into six categories.

1. Operations Area: Physical data on terrain, oceanographic, and meteorologic characterisics of the operations area, and economic data on the location, size, and density of population centers and major economic assets.

2. Technical Data: Specifications and performance characteristics of ships, submarines, aircraft, satellites (own and enemies), and associated weapons, communications, and surveillance systems.

3. Naval Order of Battle: Information on actual and possible targets.

4. Naval Status of Forces: Data on the operational readiness of own forces, including information on personnel, ships, and equipment.

5. Logistics: Information on the current supply and inventory situation, together with projected replenishment schedules for fuel, ammunition, spare parts, food, medical supplies, and miscellaneous stores.

6. Plans and Contingencies: Records of daily operations, planned movement of own ships, contingency plans, as well as the content, location, status and probable objectives of enemy forces in the operations area.

2.4.2 SEED - SEED [7] is a CODASYL-compatible, network type database management system which supports all aspects of database design, implementation, maintenance, and use. Design functions are supported by a pair of File Definition Processors (FDP & SUBFDP) which generate both the overall database structure, or schema, and various user-specific sub-schemas through which the database is accessed. There are a variety of ways of accessing SEED databases, including Data Manipulation Languages (DML) for use in both FORTRAN and COBOL programs, as well as an interactive DML (DBLOOK), and an English-like query language/report writer (HARVEST). Database maintenance software includes a transaction oriented loader (SPROUT), plus utilities for database initialization and trouble shooting (DBINIT, DBDUMP, SCDUMP, and DBSTAT).

The user defines the database structure by entering Data Definition Language (DDL) commands which specify elementary data items, together with their physical groupings into records, pages, and areas, and their various logical groupings into sets. Items may be members of any number of sets, and may stand to one another in one-one, one-many, many-one, and many-many relationships. Schema DDL commands also specify the order in which records are added.

Sub-schema DDL commands specify the subset of the database which a given user intends to access, as well as the programming language which will be used to access it.

SEED databases can be accessed by FORTRAN and COBOL programs which include appropriate DML commands. These commands enable the user program to open, close, search, update, query the status of, and report error conditions in the database. DBLOOK is an interactive DML which provides, in addition to data retrieval and manipulation capabilities of the FORTRAN and COBOL DML's, access to information on the structure and status of the database.

The HARVEST query language/report writer [5] makes any SEED database accessible to users who have no knowledge of the structure of the database. In response to simple English-like commands, HARVEST retrieves data and either displays it immediately, or generates a report in which the information is selected, sorted, and formatted as requested by the user. Also available are user-defined variables and summaries such as totals and averages.

The creation and updating of SEED databases is facilitated by SPROUT [8], a utility which automatically loads data from a transaction file on the basis of simple commands entered in the Transaciton Definition Language (TDL). These commands associate the transaction file with a particular sub-schema of the database to be updated, define relevant data fields in the transaction file, and specify how the new data are to affect the database. The TDL is flexible enough to permit any number of database records to be created or updated by any number of transaction file records. It also allows for the processing of hierarchically structured and clustered data.

Other SEED utilities include DBINIT, which initializes a new database prior to the entry of data; DBDUMP, which displays the contents of selected database pages; SCDUMP, which displays encoded representations of schemas and sub-schemas; and DBSTAT, which displays database usage statistics.

3.0 SPECIFIC DECISION AIDS

Two decision aids developed by ONR contractors have been implemented and tested, and are currently available in the DASL.

3.0.1 EWAR - The Electronic Warfare decision aid (EWAR) is a research prototype developed by Decision Science Applications [6] to explore the value of computerized decision aids in the construction of emission control (EMCON) plans for naval task forces. The objective of an EMCON plan is to optimize the tradeoff between the surveillance advantage to be gained by having electronic detection and communication devices turned on, and the protection advantage to be gained by turning such devices off, thereby denying to the enemy information on the location and identity of ships. A complete EMCON plan is thus a specification of the state (i.e. on or off) of each such device. Alternative EMCON plans are developed in the context of an hypothetical enemy strike capability, and evaluated on the basis of projections of the relative effective task force "values" surviving such an attack. All data referenced by EWAR resides on the ONRODA database and is accessed via SEED (see 2.3 above).

EWAR assists the user in developing EMCON plans by placing at his or her disposal a wide variety of visual representations designed to highlight features of the situation relevant to the comparison of alternative EMCON plans, and by providing quantitative bases for, and carrying out calculations necessary to, such comparisons. Among the graphics available are map-like displays of task force disposition upon which are superimposed maximum radar detection range or cumulative probability of detection contours. Tabular displays supply relevant technical data on enemy weapons and task force radar systems, plus the results of calculations of the effects of specific EMCON plans on the probabilities of enemy identification of task force elements, consequent allocation of strike capabilities, and projected outcomes in terms of surviving task force value. The tradeoff between surveillance and information denial involved in a given EMCON plan is represented by a graph in which both surveillance and information denial "scores" are plotted against the relative weights assigned to information and surveillance in such a way that the user can determine, for any choice of relative weights of surveillance and information denial, which EMCON plan is best.

EWAR was tested in the DASL during July and August of 1979 by Applied Psychological Services [1]. The experiments compared the quality of EMCON plans developed with and without benefit of EWAR. The subjects were 16 Annapolis officers, each of whom worked 8 problem scenarios. The experimental design involved two levels of subject training, two levels of problem difficulty, and two levels of aid sophistication. A within subject design was employed, in which each subject was exposed to both levels of problem difficulty and both levels of aid sophistication. A complete report of these experiments is available in [1].

3.1 ASTDA

Analytics Strike Timing Decision Aid (ASTDA) [3] addresses the hypothetical attack of blue forces against orange forces on ONRODA Island. The strike mission is divided into five segments--launch, enroute to target, over target, return to base, and landing. Conditioning factors, some of which are discrete and some continuous, include own force readiness, enemy air defenses, weather at target, and weather at carrier. ASTDA incorporates two algorithms based on state and outcome calculator approaches which provide, for each of several possible launch times, both an expected value, and a spread of realizable values for utility. Both algorithms can perform sensitivity analysis on any of the conditioning elements.

Six different types of visual output are provided, including both tabular data for alphanumeric terminals, and graphics for the Grinnell system. These displays show weather probabilities, initial force numbers, force losses, or resulting utilities as a function either of launch time or of misssion segment for a given launch time.

ASTDA has been tested in the DASL environment by Applied Psychological Services [4]. The experimental design involved five ASTDA variations, two levels of problem difficulty, and two levels of operational experience on the part of subjects. 60 subjects were tested, the inexperienced group being NROTC members, and the experienced group being lieutenants and captains having some flight experience. Reference [4] describes the methods, procedures, and results of these experiments.

CONCLUSION

Ongoing DASL research includes further development of existing decision aid support software, implementation and testing of additional decision aids, and beginning work on the integration of existing decision aids through incorporation in the evolving model management system.

The window package will be enchanced by the inclusion of a more sophisticated user interface which facilitates both configuration and use of windows, provides different levels of prompting for different types of users, and automatically logs all traffic going through a window for study at a later time. Attention will also be given to increasing compatibility with specific aids.

Development of the model management system will continue, with emphasis on improving the dictionary function and implementing aid-independent control options which would permit the user to decide whether (e.g.) simulation or optimization is to be done for a given model. A control mode of special interest would be a "deviation inquiry" mode, in which actual data could be compared to their projected values so that decision makers could be alerted to the occurance of problem conditions.

A primary focus of new work in display management will be the development of a general strategy for the linking of human decision maker, computer decision aid, and the various kinds of terminal devices so as to maximize human effectiveness. In addition, higher level or "macro" calls will be implemented for the graphics library, and display formats for the Grinnell system will be augmented to maintain DASL graphics capability at the state of the art.

In general, current DASL research is aimed at consolidating scattered results obtained to date, enhancing linkages between them, and generalizing existing human-machine interfaces across all of the decision aids developed under ODA.

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