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Design Specifications for Product To Estimate Manpower Requirements of System Designs

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Science Applications International Corp.

for

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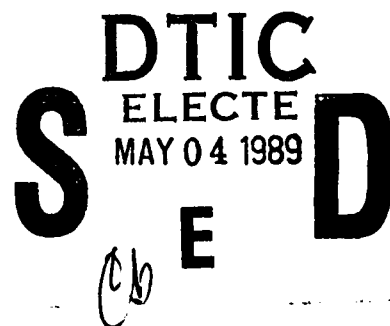
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DESIGN SPECIFICATIONS FOR PRODUCT TO ESTIMATE MANPOWER REQUIREMENTS OF SYSTEM DESIGNS

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DESIGN SPECIFICATIONS FOR PRODUCT TO ESTIMATE MANPOWER REQUIREMENTS OF SYSTEM DESIGNS

INTRODUCTION

MANPRINT Methods Program Overview

The 6 MANPRINT Products. The purpose of ARI's MANPRINT Methods research program is to design and produce six automated MANPRINT decision aids. Figure 1 illustrates the six decision aids.

Products 1 to 4 are concerned with the pre-design phase of system development. These products are intended to influence system designs by identifying constraints that will affect the new system's design. Product 1 defines system requirements, including system performance criteria and reliability, availability, and maintainability requirements. Product 2 estimates the maximum crew size that will be available to man the new system, Product 3 estimates the soldier characteristics of this crew, and Product 4 focuses on likely available training for new system personnel.

Products 5 and 6 are to be used once the system design is available. These products are intended to evaluate system designs. Product 5 (the subject of this paper) determines how many operators and maintainers will be required to man the system. Product 6 will determine the characteristics of these operators and maintainers, and will identify any deficit between required and available personnel.

The logical relationship among the products is evident. Their use flows from aiding the design process to evaluating designs. Nevertheless, each product must be able to operate as independently as possible and be convenient to use. These products will help the Army insure that its soldiers will be able to operate and maintain system hardware and software in required numbers and at levels of performance that will ensure mission success.

The Three-Phase Development Effort. This effort is being conducted in three phases: concept development, detailed design specifications, and implementation. (This document is the Phase 2 final report.) In response to the request for proposals, many contractor teams developed approaches for all six products. Some teams were then selected to develop concepts for certain products; three teams were selected for each product. Phase 1 (October 1986 to June 1987) was concept development. Each team produced a narrative design document for evaluation.

The government then selected certain concepts to be further developed in Phase 2 (June 1987 to March 1988). One contractor team was selected for Products 1, 2, and 4. Two teams were selected for Products 3 and 5. All three teams were selected for Product 6. The purpose of Phase 2 is to produce a design specification document. (It is expected that down-selecting will occur at the end of Phase 2 for Products 3, 5, and 6). Given

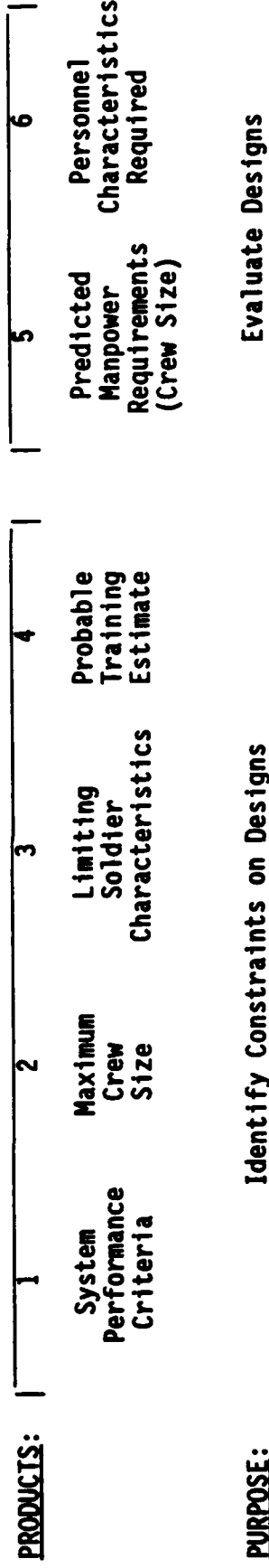


Figure 1. The Six Decision Aids in the MANPRINT Methods Program.

this document, a programmer could build the decision aid. Therefore, the Phase 2 document is unlike the usual Army Research Institute report; it contains information geared toward computer programmers.

Phase 3 (April 1988 to September 1989) will be product development. Operational decision aids will be produced. In addition, steps will be taken during Phase 3 to ensure the acceptance of the product by Army users. (The acceptance plan for Product 5 is described in this report.)

The Product 5 Concept

Product 5 is designed so that it will be accepted by Army users. This acceptance will depend on ease of use and accuracy of output. These two aspects of the Product 5 concept are described below.

Ease of Use. The Product 5 interface emphasizes consistency and places minimal memory demands on the user. Product 5 is menu driven; the menu format is consistent. Submenu and data entry form layouts are also consistent. In addition, Product 5 will incorporate vocabulary common to the other MANPRINT decision aids. Jargon will be avoided.

The Product 5 interface has been designed around a commercial off the shelf relational data base management package, R:BASE System V. This package was selected by the contractor teams as the preferred data base management package for the MANPRINT Methods decision aids. The interface and structure of Product 5 is compatible with R:BASE System V.

Product 5 will place minimal memory demands on the user. The user will always know where he is in the menu structure through use of a location indicator on the screen. The extensive help facility will also lessen memory demands. The help facility will provide a definition of all menu items. The help facility will also provide a definition of each block on a form so that the user will know what type of entry is required. Suggested source documents advising the user where to find pertinent or better input data will be available through the help facility.

Product 5 makes the user's task easy by providing structured data entry forms and default values which need only to be modified. We plan to construct templates of performance objective conditions, functions, tasks, and times, for each system type. This will structure the user's task, provide the required information to the Product, and the user will only have to modify the template as necessary. This templating avoids completely the myriad problems that would ensue if users were required to enter free text data.

Accuracy of Output. Accuracy of output is affected by two factors: quality of input data and quality of the process by which the manpower estimates are calculated.

Figure 2 presents the relation of input and output data quality. Input data quality improves over time as system designs become more refined. Users will be advised as to the level of confidence they can place in the

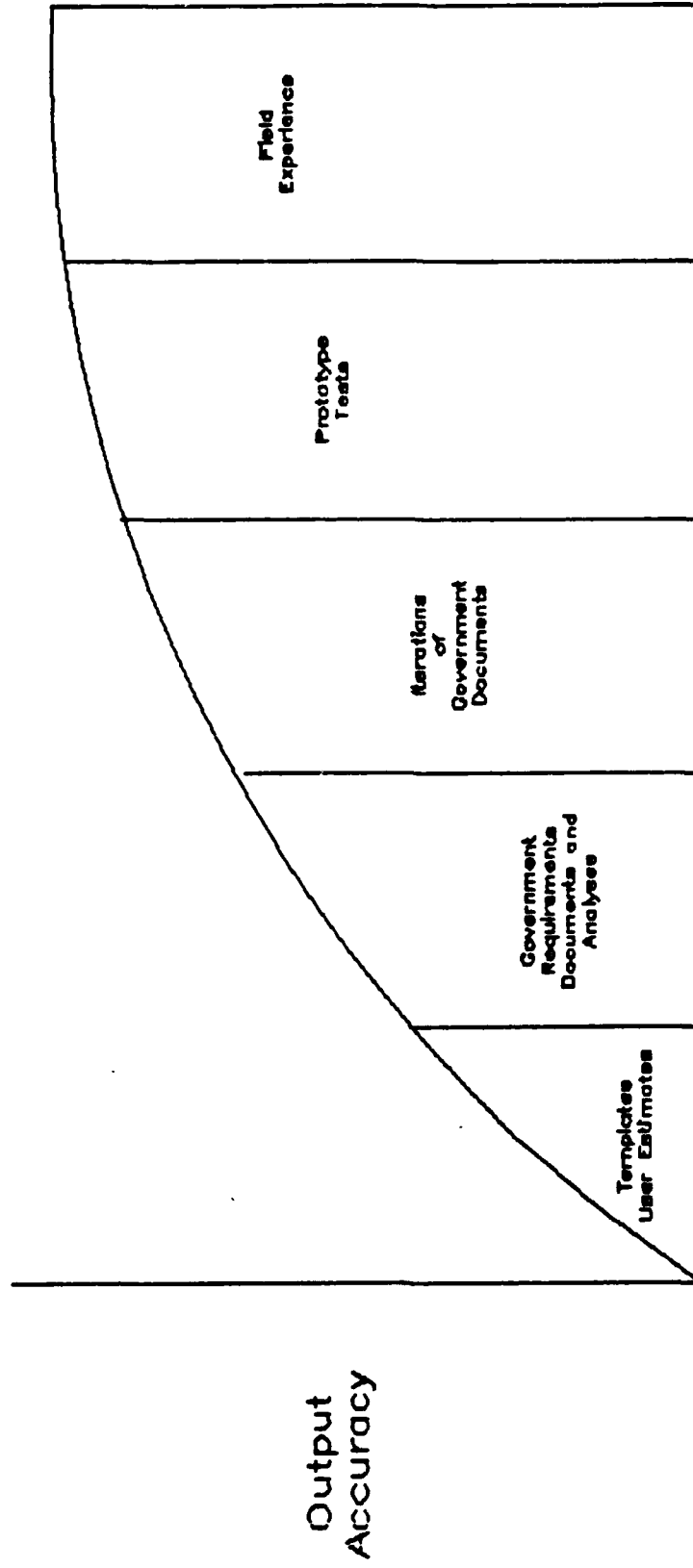


Figure 2. Product 5 Output Accuracy Relates to Input Data Quality.

accuracy of the output data, depending on the quality of their input data. Users will also be told which input data need improving.

Figure 3 presents the process by which Product 5 will estimate manpower requirements. Operator and maintainer manpower estimates are made differently.

The operator crew size calculation is based on the assumption that a job should be composed of tasks that are related to the same or similar functions, and that a person can only be one place at a time and can only do one thing at a time. Operator tasks are first grouped by function; a job is formed by using tasks within a function - this ensures that the job is built from tasks that are related. Next, the proximity relationships between functions are determined. The idea is that if a job is formed using tasks from Function X, but there is still space left in the job for more tasks, those tasks will be drawn from the next closest function. This minimizes movement for a soldier performing a job with tasks from more than one function. Product 5 assumes that a person can only be one place at a time, and that a job should contain tasks that are proximal. Next, unique jobs are formed using a standard network-precedence algorithm. This algorithm produces unique jobs, their tasks and task times, as well as an assessment of how well the job meets mission time criteria. If the design does not meet mission criteria, the user can test alternate designs until one or more is identified that appears feasible.

The maintainer crew size calculation is a straightforward multiplication of task times by yearly task frequencies divided by the number of work hours in a person year. The available data do not support the calculation of maintainer manpower using the network precedence algorithm.

Product 5 Phase 2 Design Considerations

Interface with Products 1 and 6. Product 5 is designed to be independent of the other MANPRINT products. This feature permits the Product 5 user to generate an output without having to refer to other products, which may or may not be located nearby. However, commonality in vocabulary and an understanding of how the products fit together will improve their functioning.

Product 1 generates system requirements. These requirements are stated in terms of mission, function, and task. The Kaplan and Crooks (1980) mission-function-task taxonomy was used as the basis for establishing a similar taxonomy to be used by Product 1. This taxonomy was provided to the Product 5 design team on August 3. The taxonomy is not ready for use, but an acceptable taxonomy will be developed during Phase 3. The use of some taxonomy (whether it be Kaplan and Crooks or the Product 1 taxonomy) in Product 5 is described later.

Product 5 generates the number of operator and maintainer jobs required by a system design. It lists these jobs with their associated tasks, and the criterion level at which the tasks must be performed.

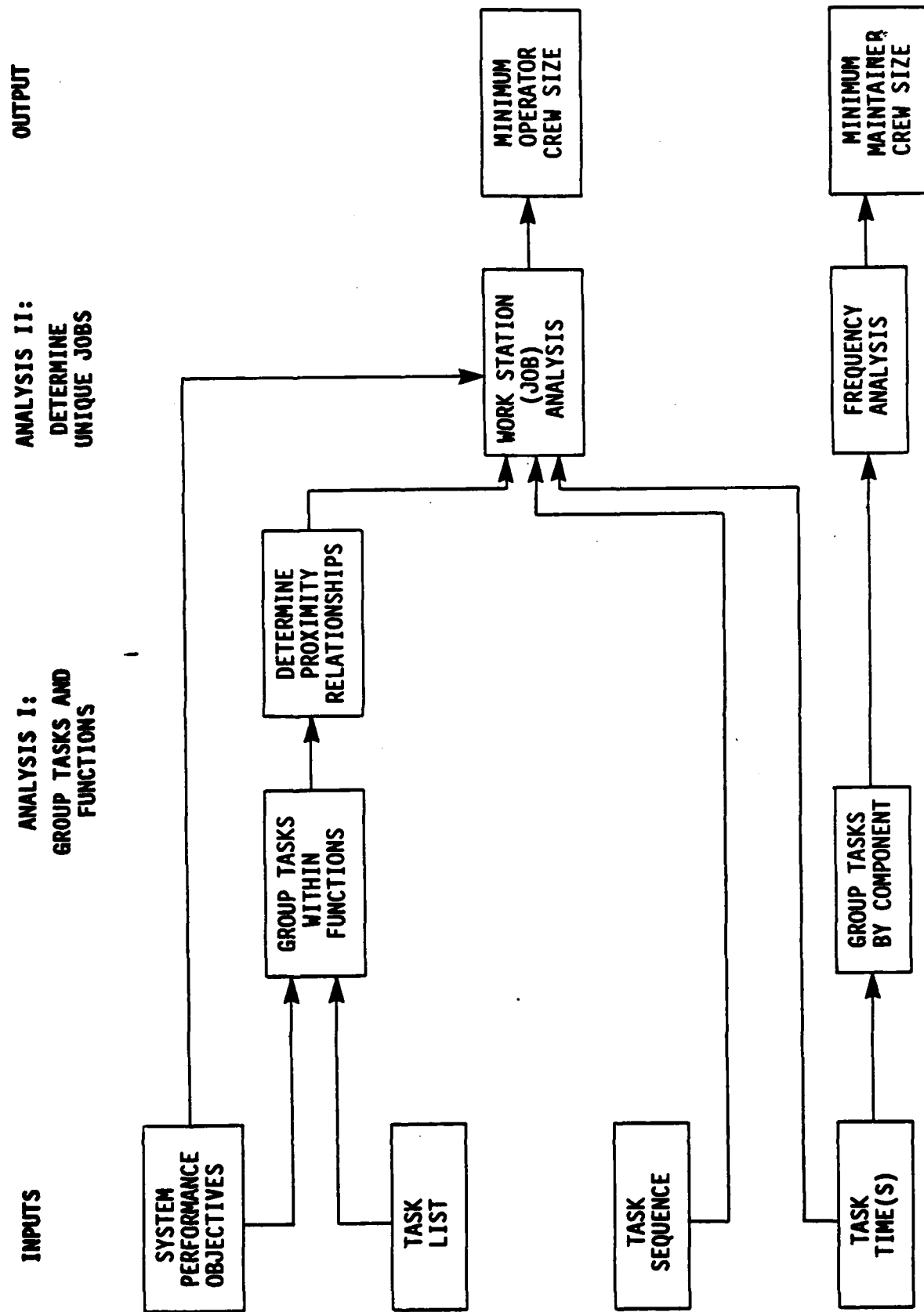


Figure 3. Product 5 Components and Process.

However, as mentioned above, the taxonomy to be used by the products is still in development. Product 6 then describes the soldier characteristics of these operators and maintainers. Product 6's analysis of Product 1 requirements and Product 5 manpower requirements allows Product 6 to state required soldier characteristics.

It is hoped that automatic communication between Products 1, 5, and 6 will save the time-consuming step of manually entering shared data. As a first step in this direction, the products will share many records in their data dictionary. Product 1 has provided its first-cut interface specification. It is not compatible with R:BASE System V in its present form, but it will be modified significantly early in the next phase so that it can easily pass on data to the other decision aids using R:BASE.

Specifications for all MANPRINT Products. The contractor Principal Investigators and our government manager, Dr. Kaplan of ARI, have agreed on hardware, software, and interface specifications for all the MANPRINT products. These are summarized below.

All products will run on an IBM AT type computer with hard disk with at least 20 megabytes of storage. The products will be equipped with: enhanced graphics display, enhanced graphics board, 80286 processor, Bernoulli Box with two removable 20 megabyte disks, 80287 board for intensive floating point computations, 1200/2400 baud internal Hayes-compatible modem, 360 KB floppy drives, and dot matrix printer with 132 characters per inch which can emulate IBM Graphics and Epson FX/LQ series printers.

DOS 3.2 will be the operating system. Requirements for extended memory beyond 640 KB up to four megabytes will be handled via the EMS standard. R:BASE System V will be the data base management package. Microsoft C will be the programming language. Programs and data bases will be available on Bernoulli disks.

Product operation will be simple and self-evident as possible. The user will not have to memorize command language. If hierarchically nested menus more than two levels deep are used, the user must know where in the menu structure he is; the menu locator must be common across all products (commonalities across products have not been agreed upon as of this writing). The present design for Product 5 calls for two levels of menu and a deeper level of template. If a complete product run takes more than three hours, the interface must be able to return the user to last point in previous session, and inform the user which steps have been completed and which are remaining. Computer and psychology jargon should be avoided, unless the word is now in the common domain. Function key and color codes must be standard across products (to be agreed upon later).

Housekeeping procedures (e.g., closing, saving, restoring) should be common across products (to be agreed upon later). File names must be displayed so that users can select them. Select file procedures should be common across products. Editing (entering, deleting, altering, moving, and copying text) conventions should be common across products. These

conventions include keys for moving cursor, deleting, entering, and copying. These conventions should be simple and self-evident.

Users should be able to change the foreground and background colors from light to dark. Each product must include an enhanced graphics driver and printer drivers that will operate IBM Graphics and Epson FX/LQ printers.

Training will be handled by a self-evident interface and/or built-in help facility; off-line training materials will be developed only if the training need can not be handled on-line. An on-line glossary will be provided.

Approach to Product 5 Detailed Design Specification

The SAIC Product 5 team has conducted two important activities during this phase of design specification. These activities are analysis and design. The objective of analysis is to create a detailed specification of system requirements, in other words to describe what Product 5 has to provide. The object of design is to derive a solution to the problem, in other words to describe how Product 5 is to be implemented in order to satisfy the requirements detailed during analysis.

The selection of techniques for analysis and design for implementation depend upon the specific nature of the product. Traditional techniques are appropriate for Product 5, which is an information-based application. The formalization of the human interface, software, and data bases are concurrent activities and serve to complement and feed one another. The resultant specifications produced by these activities share information, but depict it in different forms. Therefore, it is important that the specifications be consistent with one another.

Consistent displays for analysis in this report have been developed for the user interface, the software, and the data bases. The user interface is expressed in menu map with data entry templates and a high level state transition diagram. The software is expressed in leveled data flow diagrams and a structure chart (deMarco, 1978; Page-Jones, 1980). The data base is expressed using entity relationship diagrams and entity definitions. Table 1 presents the three Product 5 components (human interface, software, data bases) and the techniques chosen to describe them, in both analysis and design. These displays are described below. The specifications for the data base designs are directly implementable.

Menu Map and Data Entry Templates. The menu map presents the hierarchical menu structure. Two levels of menu are used, and a deeper level of data entry templates. The menu levels and data entry templates have been developed in accordance with R:BASE System V and are presented in this report.

State Transition Diagram. State transition diagrams are useful in modeling user-product interactions. They show computer action (states), user action (operators) which enable states to change, and indicate temporal

Table 1. Product 5 Components and Analysis/Design Techniques.

<u>Product 5 Components</u>	<u>TECHNIQUES</u>	
	<u>Analysis</u>	<u>Design</u>
Human Interface	Menu maps Data entry templates High level state transition diagram	Report templates
Software	Leveled data flow diagrams	Structure chart
Data Bases	Conceptual entity relationship diagrams Conceptual entity definitions (data dictionary)	Implementation entity relationship diagrams Implementation entity definitions

sequence with arrows as in a flow chart. We developed a high level state transition diagram for this document.

Data Flow Diagrams. Data flow diagrams are hierarchical graphical expressions of the exchange of information among logical data transformation objects of Product 5. Data flow diagrams consist of three symbols: circles which represent processes, parallel lines which represent data stores, and vectors which represent data flow (in the manner of DeMarco, 1978). Data flow diagrams are leveled. The highest level, Level 1, represents all of Product 5. The Level 2 and 3 diagrams expand on the most important processes (circles) in the Level 1 and 2 diagrams, respectively.

Structure Chart. The structure chart depicts the data flows in Product 5's primary algorithm. This is the network precedence algorithm used to create unique operator jobs.

Entity Relationship Diagrams and Data Dictionary. The entity relationship diagram depicts system data entities and the relationships among them. From this diagram, the entity definitions which depict entity attributes and their properties (e.g., type, precision) are developed. These are presented in tabular form in this report.

Relationship of Software and Data Base Design

The activities of software and data base analysis and design are concurrent activities. These concurrent activities serve to complement one another, and as the specifications for the two activities share data specifications (for software data stores, for data base entities), these specifications provide a means by which their consistency may be checked.

Software Design Feeds Data Base Design. The ability of software design to feed data base design is best described by showing that the relationship between (1) data flows and data stores of the data flow diagrams, (2) data stores and entity relationship models, and (3) data flows and entity relationship models.

The relationship between data flows and stores in the data flow diagram is a natural one. Data stores represent a time repository of data that provide for the communication of data among processes. The conventions of the methodology constrain the data store to assume the name of respective incoming/outgoing data flows.

The relationship between data stores and the information represented in entity relationship models is less direct. Data stores may represent some particular information about some data object entity, or they may represent the relationships between data object entities.

But data stores may also correspond to information that is not to be maintained in the data bases (e.g., message queues). Deriving entity models for the processes of the data flow diagram necessitates the need for a manual process during which the data stores that actually correspond to information to be maintained in the data base are identified. Further,

because data stores (individually) often represent only pieces of information about some specific data object, and (together) often reflect redundant information, data stores must be logically combined to non-redundantly reflect that information to be maintained about a data object.

There is, then, a transitive relationship between data flows and entity models. The sum of the data flows acting upon the data stores logically combined to form data object entities depicts the required user/application process transactions against the data object. These data flows represent transactions that create, delete, or use instances of the respective data object (or some subset of it), or relationships between it and other data objects. It is important to logically group and document these transactions according to data object and data object entity, because the global conceptual and implementation schemas must be specifically designed to support these transactions.

Data Base Design Feeds Software Design. Just as the activities of software design function to provide input to the data base design effort, so does the data base design activity help to feed the software design effort. The major input from data base to software design is the detailing of the composition of data objects.

As the data flow diagram is detailed along successively lower levels, software designers require more specific information about the detailed composition of data objects. In other words, at some time in the software design-effort, software designers will inevitably ask "Just what information comprises data object A?" For software designers, this information is necessary to understand the processing required to manipulate the specific data object in such a manner to support that functionality required by software. Later in the design of software, data base design provides the details to perform data access functions and the interface with module logic.

HUMAN INTERFACE ANALYSIS/DESIGN

Menu Map and Screen States

Levels of Menu. Product 5 uses a hierarchical menu structure. Figure 4 presents the Level 1 menu map (main menu). Figure 5 presents the Level 2 menu map.

Screen States/Data Entry Forms/Report Formats. Figures 6-12 present the data entry forms and screen states that correspond to each of the 5 Main Menu options used by Product 5. The screens meet R:BASE System V specifications. A summary of these specifications is presented in Appendix A, along with sample illustrations from the R:BASE System V manuals. Briefly, the screens support 1:1 and 1:Many relationships. The screens have two parts, the top part is the master (the 1 in the relationships), and the bottom part is the detail (the many in the relationships). The reader should note that the screens included in this report represent straightforward R:BASE designs. It is possible with R:BASE, however, to employ other interfaces. These will be studied as necessary, during Phase 3.

Figure 6 presents the main menu screen. Figures 7 and 8 corresponds to Main Menu 1: Enter/Edit System Description. Figures 7 and 8 present data entry forms for operator and maintainer manpower calculations, respectively.

Figure 9 corresponds to Main Menu 2: Generate Manpower Estimates. Screen states are shown for generating operator and maintainer manpower estimates.

Figure 10 corresponds to Main Menu 3: Generate/Print Reports. Reports are first generated, then they may be saved to a file. Subsequently, the report may be printed from the file and not generated again. A report is available for each data entry form and overall manpower estimate. There are also convenience options to allow a user to request all forms available for operators and maintainers for a given system.

Figure 11 presents the Training Menu which is Main Menu Option 4. Product 5 will include seven units of training, including four basic units and three advanced units. The lessons will be written during Phase 3, but will follow the scheme described below.

For each unit, specific instructional objectives will be identified. The instructional strategy used in addressing these objectives assumes: students must have frequent practice in the objective under study; student mastery progresses from knowledge about the concept, to a beginning-level application, to advanced level application; student progress should be measured from before to after training; student progress should be acknowledged with a certificate. The following is the general progression of each embedded training lesson.

1. Title screen

PRODUCT 5 MAIN MENU

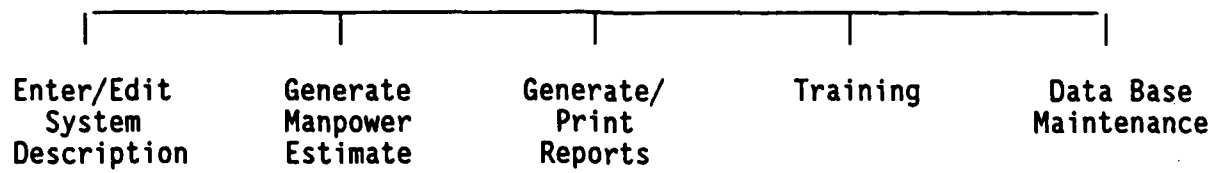


Figure 4. Menu Map, Level 1.

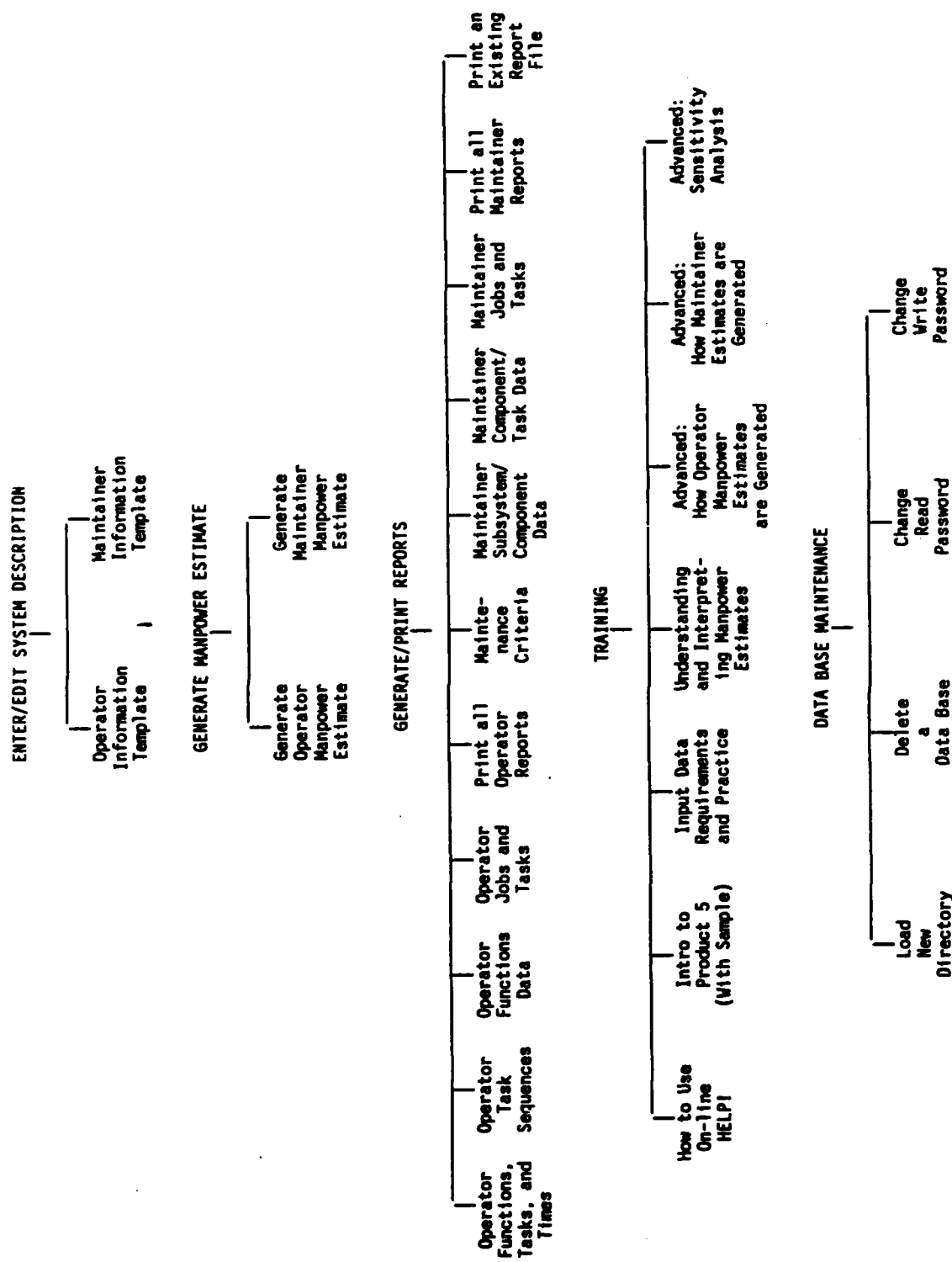


Figure 5. Menu Map, Level 2.

MANPRINT Manpower Estimation Aid Main Menu

- (1) Enter/edit a system description
- (2) Generate a manpower estimate
- (3) Generate/print reports
- (4) Training
- (5) Database maintenance
- (6) Exit

Enter USER password: xxxxx

Type the number of your choice and press ENTER.

Or use arrow keys, tab key or space bar to highlight number in the menu, and then press ENTER.

Press F10 for HELP.

Figure 6. Main Menu.

MENU 1 Form 1 Specify Source/Destination Data Base

Enter data base name: xxxxx

That data base does not exist. You will need to create one by modifying the default-system data base as necessary.

Specify read password: xxxxx

Specify write password: xxxxx

OR

The data base for your system exists.

Date of last session with that data base was xxxxx.

(ESC) Done (FX) Data base directory (F10) Help (Shift F10) More

Figure 7. Option 1: Operator Input Data.

MENU 1 Form 2 Specify System Type and Taxonomy

Enter system type: xxxxx

Enter system name: xxxxx

(Only for new data bases) This decision aid is designed with a standard system-function-task taxonomy. We strongly advise you to use the taxonomy, rather than delete the decision aid's taxonomy and type in your own. (Of course, you may need to enter an occasional important function or task name if you do not find it listed, or delete functions and tasks that do not apply).

Do you wish to use the standard terms and taxonomy? xxxxx

(ESC) Return (FX) System type directory (F10) Help

Figure 7 (Continued). Option 1: Operator Input Data.

Menu 1.1 Enter/Edit Operator or Maintainer Information

(1) Enter/edit operator information	
(2) Enter/edit maintainer information	
(3) Exit	

(F10) Help

Figure 7 (Continued). Option 1: Operator Input Data.

Menu 1.1.1 Enter/Edit Operator Information

- (1) Enter/edit operator performance conditions
- (2) Enter/edit operator functions, tasks, and times
- (3) Enter/edit operator task sequences
- (4) Enter/edit operator functions data
- (5) Exit

Enter user password: xxxxx

Enter modify password: xxxxx

Maximum number of operators possible: xxxxx

(ESC) Done (F10) Help

Figure 7 (Continued). Option 1: Operator Input Data.

1.1.1.1a Enter/Edit Operator Performance Conditions

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Do you want to accept benign performance conditions? xxxxx

ENVIRONMENT conditions you wish to consider

xxxxx
xxxxx
xxxxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 7 (Continued). Option 1: Operator Input Data.*

*Enter Operations are Add, Duplicate, Edit Again, Discard, and Quit.

1.1.1.1b Enter/Edit Operator Performance Conditions

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

TERRAIN conditions you wish to consider

XXXXX
XXXXX
XXXXX

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 7 (Continued). Option 1: Operator Input Data.

1.1.1.1c Enter/Edit Operator Performance Conditions

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

TARGET/THREAT conditions you wish to consider	

xxxxx	
xxxxx	
xxxxx	

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 7 (Continued). Option 1: Operator Input Data.

1.1.1.1d Enter/Edit Operator Performance Conditions

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

FRIENDLY conditions you wish to consider	

xxxxxx	
xxxxxx	
xxxxxx	

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 7 (Continued). Option 1: Operator Input Data.

1.1.1.2 Enter/Edit Operator Functions, Tasks, and Times

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Function: xxxxx

Function time requirement: xxxxx

Tasks	Number of soldiers required to do this task	Task Time (Actual)
xxxx	xxxxx	xxxxx
xxxx	xxxxx	xxxxx
xxxx	xxxxx	xxxxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 7 (Continued). Option 1: Operator Input Data.

1.1.1.3 Enter/Edit Operator Task Sequences

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Function: xxxxx

Task: xxxxx

	Tasks below must be completed before?	Same soldier must do both tasks?	Different soldier must do both tasks?
Task 1	xxx	xxx	xxx
Task 2	xxx	xxx	xxx
Task 3	xxx	xxx	xxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 7 (Continued). Option 1: Operator Input Data.

1.1.1.4a Enter/Edit Operator Functions Data

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Function: xxxxx

Functions in order, nearest to farthest

xxxxx
xxxxx
xxxxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 7 (Continued). Option 1: Operator Input Data.

1.1.1.4b Enter/Edit Operator Functions Data

Edit Operations					
Save	AddNew	Delete	Reset	Previous	Next Quit

Function: xxxxx

(For management/surveillance functions only): What percent of a crew member's time must be committed to this function? xxx

Crew must be capable of performing other functions at the same time?	

Function 1	xxx
Function 2	xxx
Function 3	xxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 7 (Continued). Option 1: Operator Input Data.

MENU 1.1.2 Enter/Edit Maintainer Information

- (1) Enter/edit maintenance criteria
- (2) Enter/edit maintainer subsystem/component data
- (3) Enter/edit maintainer component/task data
- (4) Exit

Enter user password: xxxxx

Enter modify password: xxxxx

Enter maximum number of maintainers possible: xxxx

(ESC) Done (F10) Help (Shift-F10) More

Figure 8. Option 1: Maintainer Input Data.

1.1.2.1 Enter/edit maintenance criteria

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Unit Maintenance: xxxxx

Intermediate Direct Support: xxxxx

Intermediate General Support: xxxxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 8 (Continued). Option 1: Maintainer Input Data.

1.1.2.2 Enter/Edit Maintainer Subsystem/Component Data

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Subsystem: xxxxx

System components	Quantity per application
-----	-----
xxxxxx	xxxxxx
xxxxxx	xxxxxx
xxxxxx	xxxxxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 8 (Continued). Option 1: Maintainer Input Data.

1.1.2.3a Enter/Edit Maintainer Component/Task Data for Unit

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Subsystem-component: xxxxx

Tasks	Task time (Actual)	Number of times task is performed	Per unit of measure
-----	-----	-----	-----
xxxxx	xxxxx	xxxxx	xxxxx
xxxxx	xxxxx	xxxxx	xxxxx
xxxxx	xxxxx	xxxxx	xxxxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 8 (Continued). Option 1: Maintainer Input Data.

1.1.2.3b Enter/Edit Maintainer Component/Task Data for Direct Support

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Subsystem-component: xxxxx

Tasks	Task time (Actual)	Number of times task is performed	Per unit of measure
-----	-----	-----	-----
xxxxx	xxxxx	xxxxx	xxxxx
xxxxx	xxxxx	xxxxx	xxxxx
xxxxx	xxxxx	xxxxx	xxxxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 8 (Continued). Option 1: Maintainer Input Data.

1.1.2.3c Enter/Edit Maintainer Component/Task Data for General Support

Edit Operations						
Save	AddNew	Delete	Reset	Previous	Next	Quit

Subsystem-component: xxxxx

Tasks	Task time (Actual)	Number of times task is performed	Per unit of measure
-----	-----	-----	-----
xxxxxx	xxxxxx	xxxxxx	xxxxxx
xxxxxx	xxxxxx	xxxxxx	xxxxxx
xxxxxx	xxxxxx	xxxxxx	xxxxxx

(F5) Reset field (F7) PrevRow (F8) NextRow (F10) Help (Shift-F10) More

Figure 8 (Continued). Option 1: Maintainer Input Data.

MENU 2 Generate a Manpower Estimate

- (1) Generate operator manpower estimate**
- (2) Generate maintainer manpower estimate**
- (3) Generate operator and maintainer manpower estimates**
- (4) Exit to Main Menu**

(ENT) Select (F10) Help

Figure 9. Option 2: Generate Manpower Estimate.

2.1 Generate operator Manpower Estimate

Enter data base name: xxxxx

(ESC) Done (Fx) Data base directory (F10) Help (Shift-F10) More

Figure 9 (Continued). Option 2: Generate Manpower Estimate.

2.2 Generate maintainer Manpower Estimate

Enter data base name: xxxxx

Maintenance level, unit? xxx

Maintenance level, direct support? xxx

Maintenance level, general support? xxx

(ESC) Done (Fx) Data base Directory (F10) Help (Shift-F10) More

Figure 9 (Continued). Option 2: Generate Manpower Estimate.

2.3 Generate Operator and Maintainer Manpower Estimates

Enter data base name: xxxxx

All maintenance levels? xxx

Maintenance level, unit? xxx

Maintenance level, direct support? xxx

Maintenance level, general support? xxx

(ESC) Done (Fx) Data base directory (F10) Help (Shift-F10) More

Figure 9 (Continued). Option 2: Generate Manpower Estimate.

MENU 3. Generate/Print Reports

- (1) Operator functions, tasks, and times
- (2) Operator task sequences
- (3) Operator functions data
- (4) Operator jobs and tasks
- (5) Print all operator reports

- (6) Maintenance criteria
- (7) Maintainer subsystem/component data
- (8) Maintainer component/task data
- (9) Maintainer jobs and tasks
- (10) Print all maintainer reports

- (11) Print an existing report file
- (12) Exit to Main Menu

User password: xxxxx

Read password: xxxxx

(ENTER) Select (F10) Help

Figure 10. Option 3: Generate/Print Reports.

3.1 Operator Functions, Tasks, and Times Report

Enter data base name: xxxxx

Specify (P)rinter, (S)creen, (F)ile: x
(If F) Enter file name: xxxxx

(ESC) Return to menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.

3.1 OPERATOR FUNCTIONS, TASKS, AND TIMES REPORT

Date: xxxxx

Page: xxxxx

System: xxxxx System type: xxxxx

File name: xxxxx

Data base name: xxxxx

Function: xxxxx

Function time requirement: xxxxx

Tasks	Number of soldiers required to do this task	Task Time (Actual)
-------	--	--------------------

xxxxx	xxxxx	xxxxx
-------	-------	-------

xxxxx	xxxxx	xxxxx
-------	-------	-------

xxxxx	xxxxx	xxxxx
-------	-------	-------

Figure 10 (Continued). Generate/Print Reports.

3.2 Operator Task Sequences Report

Enter data base name: xxxxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu

(ENTER) Select (Fx) Data base directory

(F10) Help

Figure 10 (Continued). Generate/Print Reports.

3.2 OPERATOR TASK SEQUENCES REPORT

Date: xxxxx

Page: xxxxx

System: xxxxx System type: xxxxx

File name: xxxxx

Data base name: xxxxx

Function: xxxxx

Task: xxxxx

Tasks below must be
completed before?

Same soldier
must do both tasks?

Different soldier
must do both tasks?

Task 1	xxx	xxx	xxx
Task 2	xxx	xxx	xxx
Task 3	xxx	xxx	xxx

Figure 10 (Continued). Generate/Print Reports.

3.3 Operator Functions Report

Enter data base name: xxxxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.

3.3 OPERATOR FUNCTIONS REPORT

Date: xxxxx

Page: xxxxx

System: xxxxx System type: xxxxx

File name: xxxxx

Data base name: xxxxx

Function: xxxxx

Functions in order, nearest to farthest

xxxxx

xxxxx

xxxxx

What percent of a crew member's time must be committed
to this function? xxxxx

Crew must be capable of performing
other functions at the same time?

Function 1 xxx

Function 2 xxx

Function 3 xxx

Figure 10 (Continued). Generate/Print Reports.

3.4 Operator Job/Task Report

Enter data base name: xxxxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.

3.4 OPERATOR JOB/TASK REPORT

Date: xxxxx
Page: xxxxx

System: xxxxx System type: xxxxx
File name: xxxxx
Data base name: xxxxx

Environment: Terrain: Target/Threat: Friendly:
xxxxx xxxxx xxxxx xxxxx
xxxxx xxxxx xxxxx xxxxx

Function: xxxxx Minimum number of jobs estimated: xxxxx
Maximum manpower constraint: xxxxx
Criterion time to complete function: xxxxx
Actual time to complete function: xxxxx

Task Time	Job xxxxxx	Job xxxxx	Job xxxxx	Job xxxxx
nnnnn	xxxxx	xxxxx	xxxxx	xxxxx
nnnnn	xxxxx	xxxxx	xxxxx	xxxxx
nnnnn	xxxxx	xxxxx	xxxxx	xxxxx

System: Minimum number of jobs estimated: xxxxx
Maximum manpower constraint: xxxxx
Criterion time to complete all functions: xxxxx
Actual time to complete all functions: xxxxx
List of functions where criterion not met: xxxxx
Percent default values used: xx

Task Time	Job xxxxxx	Job xxxxx	Job xxxxx	Job xxxxx
nnnnn	xxxxx	xxxxx	xxxxx	xxxxx
nnnnn	xxxxx	xxxxx	xxxxx	xxxxx
nnnnn	xxxxx	xxxxx	xxxxx	xxxxx

Figure 10 (Continued). Generate/Print Reports.

3.5 All Operator Reports

Enter data base name: xxxxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.*

*System returns specified report 3.1 through 3.4.

3.6 Maintenance Criteria Report

Enter data base name: xxxxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.

3.6 MAINTENANCE CRITERIA REPORT

Date: xxxxx

Page: xxxxx

System: xxxxx System type: xxxxx

File name: xxxxx

Data base name: xxxxx

Unit: xxxxx

Direct support: xxxxx

General support: xxxxx

Figure 10 (Continued). Generate/Print Reports.

3.7 Maintenance Subsystem/Component Report

Enter data base name: xxxxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.

3.7 MAINTENANCE SUBSYSTEM-COMPONENT REPORT

Date: xxxxx

Page: xxxxx

System: xxxxx System type: xxxxx

File name: xxxxx

Data base name: xxxxx

Subsystem: xxxxx

System components

Quantity per application

xxxxxx

xxxxxx

xxxxxx

xxxxxx

xxxxxx

xxxxxx

Figure 10 (Continued). Generate/Print Reports.

3.8 Maintenance Component/Task Report

Enter data base name: xxxxx

Do you want unit? xxx

Do you want direct support? xxx

Do you want general support? xxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.

3.8 MAINTENANCE COMPONENT/TASK REPORT FOR XXXXX MAINTENANCE LEVEL

Date: xxxxx
Page: xxxxx

System name: xxxxx
System type: xxxxx
File name: xxxxx
Data base name: xxxxx

Subsystem-component: xxxxx

<u>Tasks</u>	<u>Task time (Actual)</u>	<u>Number of times task is performed</u>	<u>Per unit of measure</u>
xxxxx	xxxxx	xxxxx	xxxxx
xxxxx	xxxxx	xxxxx	xxxxx
xxxxx	xxxxx	xxxxx	xxxxx

Figure 10 (Continued). Generate/Print Reports.

3.9 Maintenance Job/Task Report

Enter data base name: xxxxx

Do you want unit? xxx

Do you want direct support? xxx

Do you want general support? xxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.

3.9 MAINTAINER JOB/TASK REPORT

Date: xxxxx

Page: xxxxx

System: xxxxx System type: xxxxx

File name: xxxxx

Data base name: xxxxx

Maintenance Level: xxxxx

Subsystem: xxxxx

Minimum number of jobs estimated: xxxxx

Maximum number of jobs constraint: xxxxx

Criterion maintenance ratio: xxxxx

Actual maintenance ratio: xxxxx

<u>Job xxxxx</u>		<u>Job xxxxx</u>		<u>Job xxxxx</u>		<u>Job xxxxx</u>	
<u>Tasks</u>	<u>Freq</u>	<u>Tasks</u>	<u>Freq</u>	<u>Tasks</u>	<u>Freq</u>	<u>Tasks</u>	<u>Freq</u>
xxxxx	nnnnn	xxxxx	nnnnn	xxxxx	nnnnn	xxxxx	nnnnn
xxxxx	nnnnn	xxxxx	nnnnn	xxxxx	nnnnn	xxxxx	nnnnn
xxxxx	nnnnn	xxxxx	nnnnn	xxxxx	nnnnn	xxxxx	nnnnn

Time/Yr nnnnn

nnnnn

nnnnn

nnnnn

System:

Minimum number of jobs estimated: xxxxx

Maximum number of jobs constraint: xxxxx

Total criterion maintenance ratio: xxxxx

Total actual maintenance ratio: xxxxx

List subsystems criterion not met: xxxxx

Percent default values used: xx

Figure 10 (Continued). Generate/Print Reports.

3.10 All Maintenance Reports

Enter data base name: xxxxx

Do you want unit? xxx

Do you want direct support? xxx

Do you want general support? xxx

Specify (P)rinter, (S)creen, (F)ile: x

(If F) Enter file name: xxxxx

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.*

*System returns specified report 3.6 to 3.9.

3.11 Print an Existing Report File

Specify file name:
Specify (P)rinter or (S)creen: x

(ESC) Return to Menu (ENTER) Select (Fx) Data base directory (F10) Help

Figure 10 (Continued). Generate/Print Reports.*

*System returns specified report 3.1 to 3.10.

MENU 4. Training

Select the lesson you want to use:

- (1) How to use the on-line HELP!
- (2) Introduction to MANPRINT Manpower Estimation Aid, with sample
- (3) Input data requirements and practice
- (4) Understanding and interpreting manpower estimates
- (5) Advanced: How operator manpower estimates are generated
- (6) Advanced: How maintainer manpower estimates are generated
- (7) Advanced: How system design changes affect manpower
- (8) Exit to Main Menu

(ENT) Select (F10) Help

Figure 11. Option 4: Training.

2. Statement of instructional objectives
3. Pretest (may be automatically scored or self-assessment type)
4. General sequence for each instructional objective:
 - a. Present concept
 - b. Require a student interaction
 - c. Automatic evaluation of student response; branch as required
 - d. Present concept/interaction/evaluation/branch sequence again as needed
 - e. Require an acquisition-level application interaction, with evaluation and branching
 - f. Require a generalization-level application interaction, with evaluation and branching
5. After Step 4 has been accomplished for all instructional objectives, provide mixed (e.g., concept, acquisition application, generalization application) practice with feedback over all the objectives. Three practice items are available for each objective.
 - Evaluate and branch as required.
6. Unit posttest (automatically scored; includes two or three items per objective)
7. Print certificate of completion

Figure 12 corresponds to Main Menu Option 5: Data Base Maintenance. Screen states are shown for data base loading and deleting, and changing passwords.

State Transition Diagrams

State transition diagrams are specifically useful in modeling human-computer interactions. A sample state transition diagram for a Data Entry/Modification operation is found in Figure 13. As shown, boxes correspond to states of the computer dialogue, which are acted upon by user stimuli to transition to other computer states.

User Dialog

This section provides a brief walk-through of the user dialog. (The Product 5 team will present an example walk-through using the M109 system at the final briefing in January.)

MENU 5. Data Base Maintenance

- (1) Load new taxonomy
- (2) Delete data base
- (3) Change read password
- (4) Change write password
- (5) Exit to Main Menu

User password: xxxxx

(ENT) Select (Fx) Data base directory (F10) Help

Figure 12. Option 5: Data Base Maintenance.

5.1 Load New Taxonomy

Specify directory location of files: xxxxx

(F10) Help

Figure 12 (Continued). Option 5: Data Base Maintenance.

5.2 Delete Data Base

Specify data base name: xxxxx

(F10) Help

Figure 12 (Continued). Option 5: Data Base Maintenance.

5.3 Change Read Password

Enter new password: xxxxx

(F10) Help

Figure 12 (Continued). Option 5: Data Base Maintenance.

5.4 Change Write Password

Enter new password: xxxxx

(F10) Help

Figure 12 (Continued). Option 5: Data Base Maintenance.

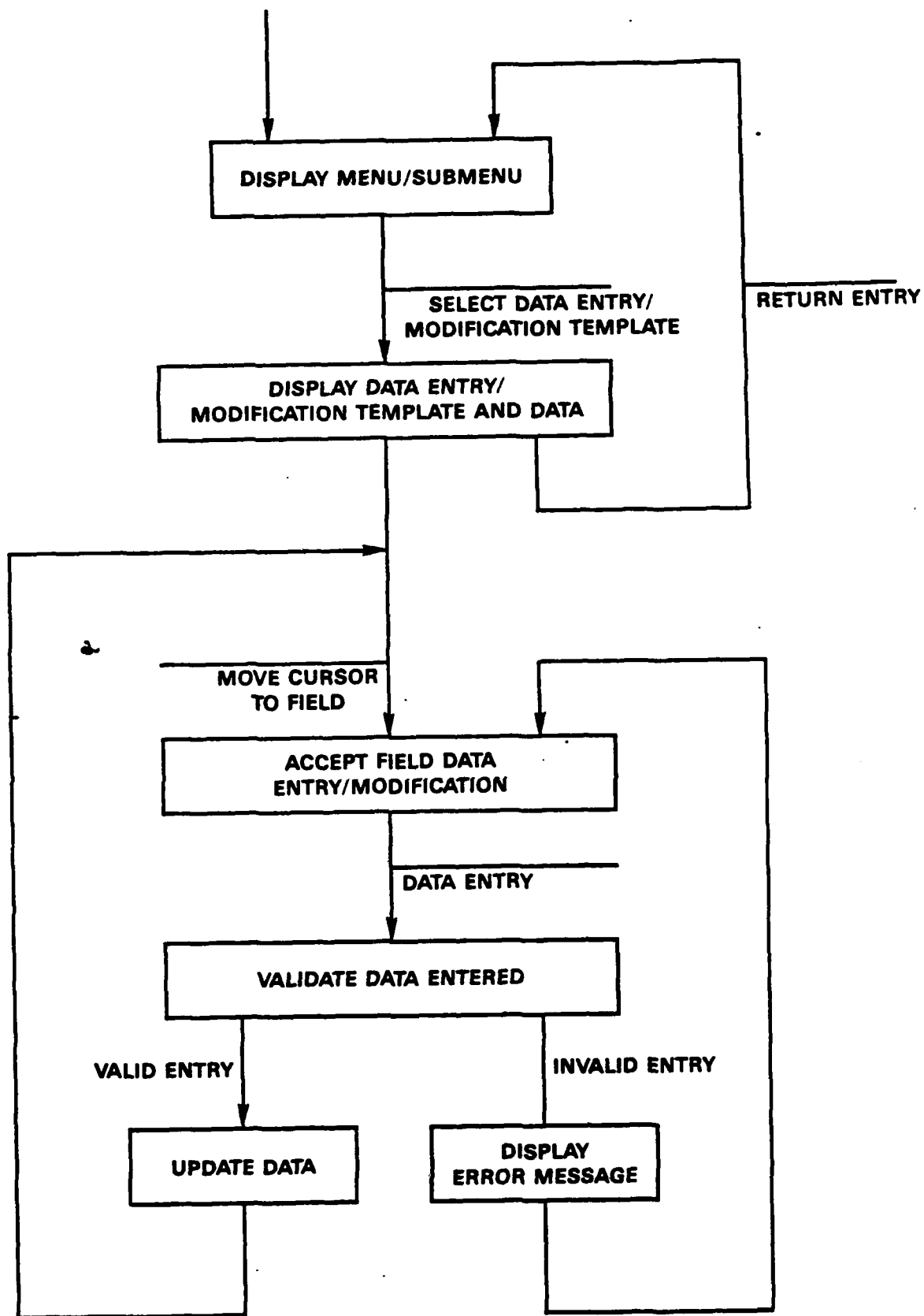


Figure 13. Sample State Transition Diagram of User Interface.

Main Menu. Upon selecting options 1, 2, or 3 (see Figure 6), but before the requested submenu is displayed, the screen is cleared, and the following prompt is given: "Enter User Password:" to which the user supplies an R:BASE- USER Password.

Menu 1: Enter/Edit a System Description (refer to Figure 7). Upon selecting this option, 2 forms are displayed in sequence, after which Menu 1.1 is displayed. On Form 1, the user identifies the data base name. If data base name exists, then intent to edit existing system description is recognized, or else intent to enter a new system description is inferred. Forms are driven with R:BASE "EDIT" or "ENTER" accordingly.

On Form 2, the user identifies system type and name. The item concerning user acceptance of the standard taxonomy is displayed if "data base name" for this USER password is not found, indicating the intent is to enter rather than edit.

Form 2 includes a function key (noted on the status line) associated with a query to display list of all system types. A user is not permitted to modify the system type of a system description data base which has already been populated based on the standard taxonomy.

Menu 1.1.1: Enter/Edit Operator Manpower Calculation (refer to Figure 7). If user has accepted the standard taxonomy, then a copy of the portion of the taxonomy pertaining to the system type is made to "data base name" with OWNER password set to USER password. There is no problem if the user at a later time wishes to add maintainer information to operator information, or vice versa.

If USER password does not equal OWNER password, after the user selects an option from Menu 1.1.1 or Menu 1.1.2, but before the respective form is displayed, the user is prompted for a modify password. If the USER password does not equal modify password, then a message is displayed and the user never sees the requested form.

There are four data entry forms for operator manpower calculations: designating performance conditions; editing functions, tasks and times; determining task sequences; and, determining distance between functions.

Product 5 uses as a default benign performance conditions (Menu 1.1.1.1). The user may accept these, or select conditions he or she wishes to consider. The four categories of performance conditions shown in the screens come from the draft Product 1 conditions taxonomy. Product 5 will categorize performance conditions and combinations into three categories: low, medium, and high. Low means that the environment is not severe and performance times are shortest. Medium is a medium severe environment, and there will be some degradation, i.e., increase in task time. High is a severe environment, and task times will be even longer. We will use degradation factors developed from Siegel, Pfeiffer, Kopstein, Wilson, and Ozkaptan (1979). In addition, we will degrade task times for tasks that are susceptible to degradation, to be developed from Siegel et al. (1979).

Next the user enters/edits operator functions, tasks, and times (Menu 1.1.1.2). One function is presented per screen. The function time requirement comes either from Product 1 or a default. The tasks in the function (from the taxonomy) are listed, and the user edits the number of soldiers required to perform the task (default is "1") and the task time (default is the time associated with the latest representative of the system type). (NOTE: During Phase 3, we plan to work very closely with the Product 1 taxonomy revision effort. We would like to see the taxonomy include only one-person tasks, to the extent possible, and we would like to assure that the task list and sequence is acceptable to military experts.)

Next the user enters/edits operator task sequences (Menu 1.1.1.3). One function and one task are presented per screen. For each task, the user specifies which tasks MUST be completed before the target task can begin. The user must also specify if the same or different soldiers MUST perform this task as well as others. This information is important to the network precedence analysis. The default values will indicate that there are no constraints on either job formation as a result of task precedences or the same/different soldier question (e.g., no tasks MUST precede this one), and thus the algorithm is free to assign this task to whichever job it best fits.

Next the user enters/edits operator functions data (Menu 1.1.1.4). One function is presented per screen, and the user determines the physical proximity of that function to other functions. The user also indicates if a soldier must be assigned for management/surveillance. The user also indicates if some functions MUST be performed simultaneously; this factor affects the total operator manpower estimate, which is a result of combining the manpower estimates for each function. This question determines if the system manpower estimate is additive or can be done more economically.

Menu 1.1.2: Enter/Edit Maintainer Information (see Figure 8). The user first edits the maintenance criteria (e.g., maintenance ratios: maintenance manhours per system operating hour) for each maintenance organizational level. The defaults come from Product 1 if available, or come from previous system requirements as determined by the Product 5 team and provided in the default data base. Next, the user specifies the hardware design, by determining the system components by subsystem. The defaults come from a standard taxonomy (e.g., will be determined by the product teams during the next phase). Finally, the user determines the tasks, task times, and number of times the task is performed per unit time (e.g., per year). The default values for tasks and task times come from Maintenance Allocation charts available in Technical Manuals on representative systems. The number of times the task is performed per unit time comes from the Sample Data Collection (SDC) data base. This data base covers approximately 80 systems.

Menu 2: Generate Manpower Estimates (see Figure 9). The user indicates if he or she wants an operator, maintainer, or both manpower estimate, and enters the date base name.

Menu 3: Generate/Print Reports (see Figure 10). The user is required to enter a password to gain access to this menu option. If the USER

password does not equal the OWNER password, he or she is asked for a READ password. If the USER password does not equal the READ password, then a message is displayed and the user does not gain access to the report. If the user has access, he or she indicates the data base name is generating a report, and indicates a file name to print a previously generated report.

Menu 4: Training (see Figure 11). This item was described above. A user does not require password access to this option.

Menu 5: Data Base Maintenance. This menu option is for the system manager. Option 5.1 is to load a new taxonomy into system tables. The user specifies the directory location of the files. This action uses the R:BASE Filegateway utility. Action is not permitted if the USER password does not equal the OWNER password of the taxonomy. The owner of the taxonomy is assumed to be the system manager.

Option 5.2 is to delete a data base. The user specifies the data base name to be deleted. If the USER password does not equal the OWNER password of the specified data base name, then a message is displayed, and the data base is not deleted.

Option 5.3 and 5.4 permitted an allowed user to change the READ and WRITE password.

Help Function

The help function will have a minimum of three levels. Level 1 help is invoked by a function key. This help produces a definition of a term or procedure, with an example. Level 2 help refers to the filling in of templates. This level produces options to restart, cancel, backup, and change data before entering. Level 3 help produces the on-line glossary.

SOFTWARE ANALYSIS

Data Flow Diagrams

As mentioned in the Introduction, data flow diagrams are hierarchical graphical expressions of the exchange of information among logical data transformation objects of Product 5. (Sequence is not explicitly reflected in a data flow diagram). The diagrams are made of three symbols: circles which represent processes, boxes which represent data stores, and arrows which show data flows. Three levels of data flow diagrams are used to describe Product 5, with main process only decomposed to the third level.

Overview. Figure 14 presents the Level 1 data flow diagram for Product 5. As shown, the three high level processes of Product 5 are User Dialogue, Derive Unique Jobs, and Generate Reports. Note that the process numbering scheme reflects the hierarchies of processes.

The single external sink and source is the user, not shown, but conceptually the farthest left element. Through User Dialog, Product 5 collects data and forms three data stores. As shown, these stores are: Test system components/task function data/performance objectives/conditions; Task sequences/times/descriptions, and the Kaplan-Crooks (or whatever taxonomy is used) taxonomy.

The Derive Unique Jobs process derives input from the Task sequences/times/description store. It provides output to the Jobs store. The process also interacts directly with User Dialogue when detecting Feasibility Errors, e.g., when the user enters constraints of time and distance which affect the construction of unique jobs.

The Generate Reports process accepts report requests from User Dialogue, extracts necessary information from various stores, generates the requested report, then either stores the report or returns it to the user (through User Dialogue) for review. Previously generated reports are returned to User Dialogue directly without processing.

User Dialogue. All the functionality of User Dialogue is provided by R:BASE. Therefore all User Dialogue software will not be written from scratch. Figure 15 presents the Level 2 data flow diagram for User Dialogue. The four processes involved in User Dialog are: Sequence Control, Data Entry/Modification, User Guidance, and Information Presentation.

Sequence Control controls the sequencing of menus/submenus, ultimately passing control to Data Entry/Modification onto Information Presentation, depending upon the user's intention. It has direct interaction with User Guidance for the display to users of help and errors related to menus and submenus.

The Data Entry/Modification process takes input from the user as shown and outputs to the three input data stores. It interacts directly with User

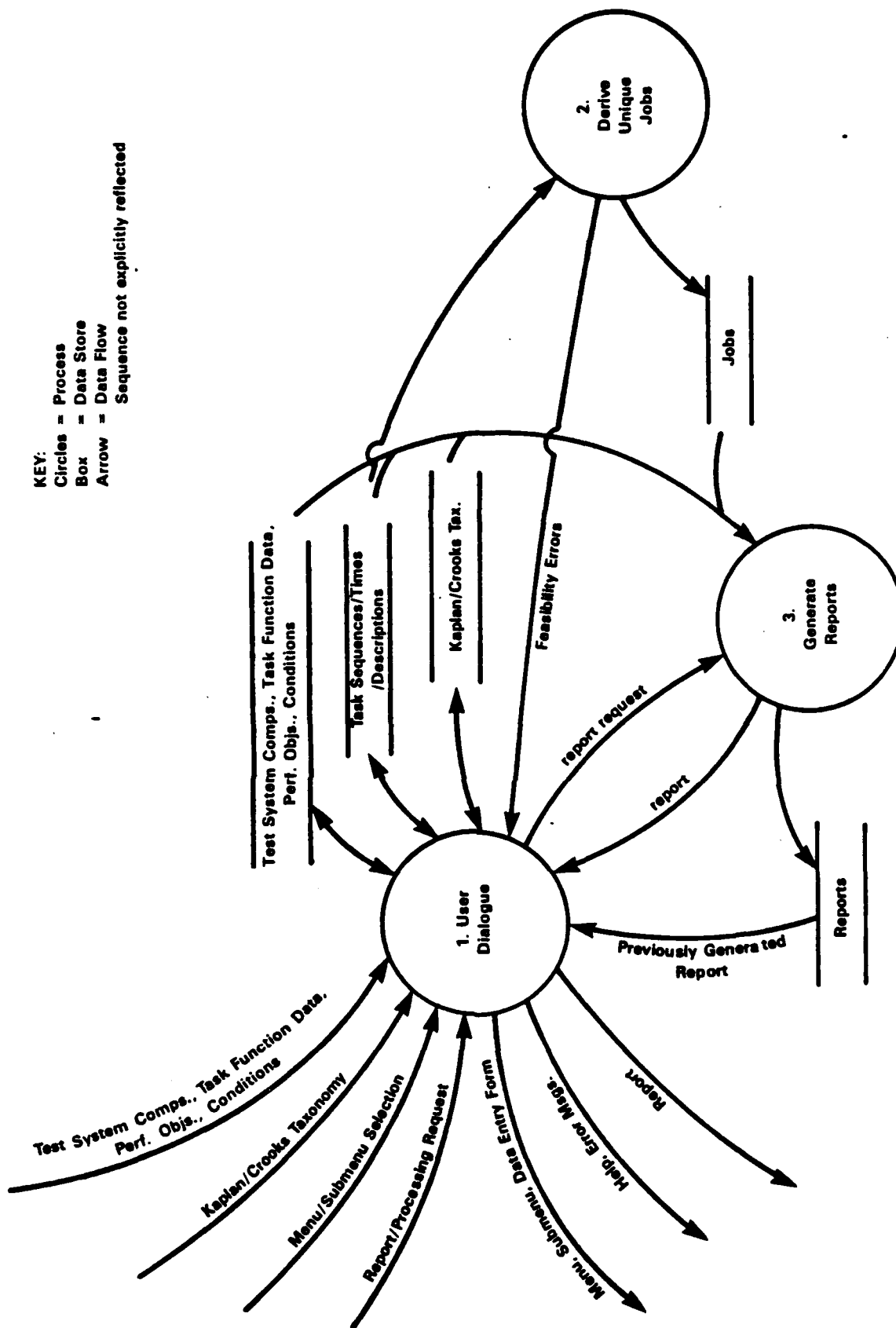


Figure 14. Level 1 Data Flow Diagram.

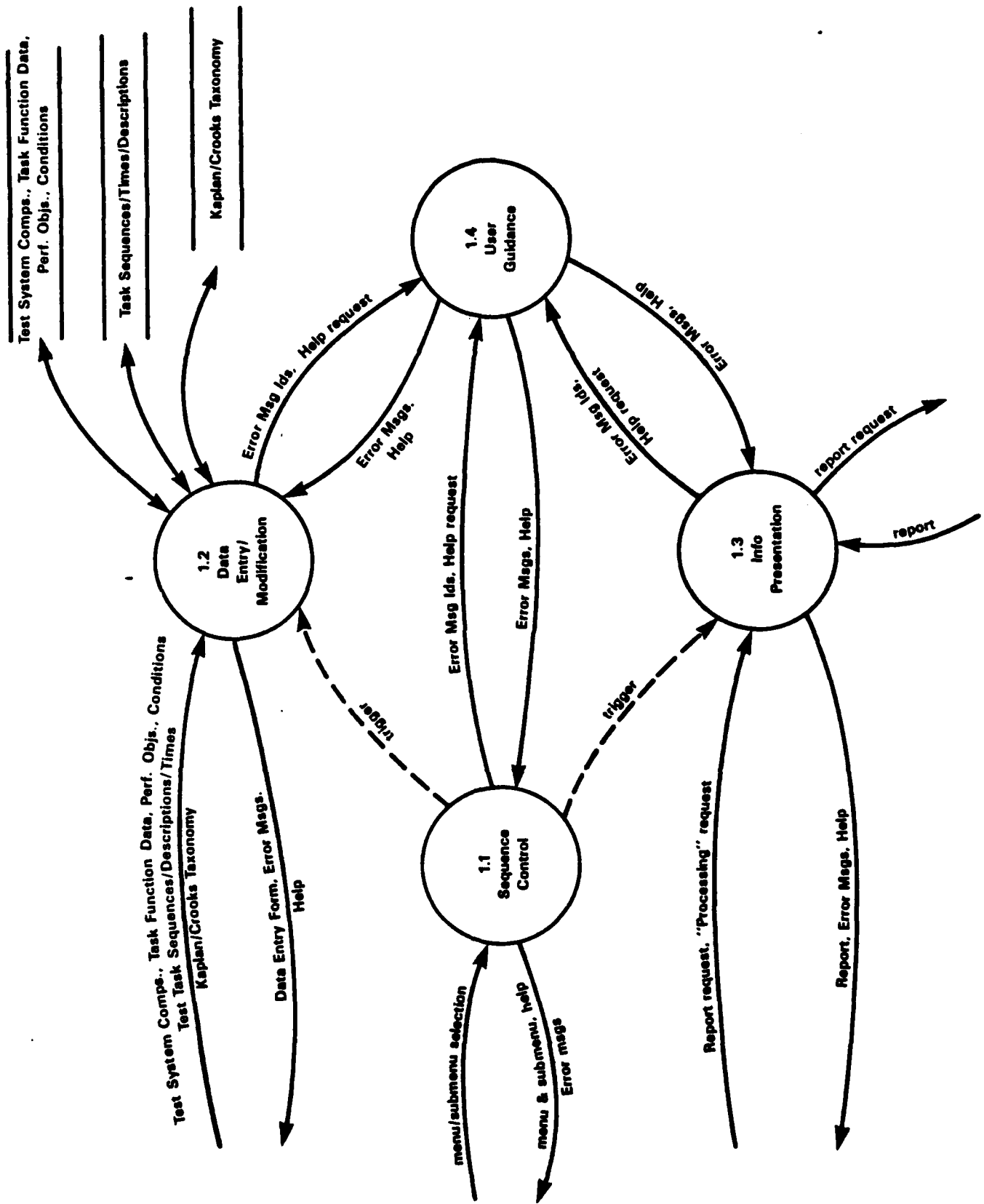


Figure 15. Level 2 Data Flow Diagram for User Dialog.

Guidance in the form of error messages and help requests related to data entry or modification.

The Information Presentation process interacts with User Guidance concerning error and help messages. It also interacts with the user in the report request sequence.

Derive Unique Jobs. Figure 16 presents the Level 2 data flow diagram for Derive Unique Jobs. The processes involved are: Classify Tasks; Establish Precedence Relationships; Test Feasibility; and Assign Tasks to Jobs.

Classify Tasks will group the tasks according to the way time is used to specify required performance. Category 1 tasks are those operator tasks with performance objectives related to response time requirements (e.g., time on target). Category 2 tasks are those maintenance tasks with performance objectives related to maintaining a constant rate or frequency of activity over some designated time period. Tasks with performance objectives related to maintaining constant activity over some designated time period (e.g., supervising monitoring, guarding) will be considered as "add-ons" to the operator or maintainer jobs most closely related. This categorization is necessary because the way in which jobs are formed differs depending on the type of performance objectives to be addressed.

Establish Precedence Relationships involves organizing and coding the tasks to reflect the sequence in which tasks must be completed in order to properly achieve the performance objective. This relationship is necessary for Category 1 tasks only. This process will be accomplished by developing a precedence network that shows which tasks must be completed before a given task can begin.

Test Feasibility determines the "critical path" through the network of tasks in order to determine whether or not the performance objective can be achieved given the task sequence and task times. If the critical path time exceeds either the response time required (for operator tasks), the user is informed that the performance objective can not be achieved and is transferred out of the job forming process so that either task times or sequence can be revised or the performance objective can be relaxed.

There are two types of tasks. Category 1 tasks are time-based, mission-oriented operator/field personnel tasks. These tasks must be completed within a specified time. Category 2 tasks are output-based, maintainer tasks (e.g., inspect, remove) and can be aggregated into maintenance ratios that are compared to the maintenance performance criteria (also in maintenance ratios). These tasks are performed continuously over time and result in the production of some countable output (e.g., parts replaced). A third task type, not covered in the current Product 1 taxonomy but nonetheless important are cognitive or monitoring tasks. These tasks are performed constantly, but do not result in measured output and include tasks such as surveillance, security, and supervision. These may be operator or maintenance tasks.

Job construction using Category 1 tasks will be accomplished using Brook's algorithm. (A narrative description for this process excerpted from the concept paper for Phase 1 of this project as well as a listing of FORTRAN code for the algorithm is presented in Appendix B. We will extract those portions of this code that support Product 5, and translate them to the "C" language of Product 5.) This process assumes 1) that tasks are ordered according to the amount of time each controls in the precedence network (i.e., the "critical path" time beginning with each activity), and 2) that tasks are assigned to jobs such that the required response time or production rate is achieved.

Job construction using Category 2 tasks will be accomplished by multiplying maintenance task times by their expected frequencies to determine total time (over a specified time period) required for each maintenance task. Maintenance tasks at each maintenance level will be summed to determine total maintenance manpower requirements.

Tasks such as management/surveillance or other cognitive tasks are overlaid on the jobs resulting from Category 1 and 2 tasks such that, to the extent possible, they are combined with jobs that already exist.

We felt that it was important to further define the "Assign Tasks to Jobs" process in the Level 2 data flow diagram. Figure 17 presents the Level 3 data flow diagram for this process. The Level 3 processes are: Determine Critical Path Times; Rank Tasks by Critical Path Times; Assign Tasks to Jobs Based on Criticality and Resource Availability (Category 1 jobs); Determine Total Time for Each Task at Each Maintenance Level, Compute Number of Maintainer Jobs at Each Level (Category 2); and Determine Potential for Combining Coverage Tasks with Existing Jobs. The three data stores, System Performance Objectives, Precedence Network, and Task Times, all input to the formation of operator and maintainer jobs.

Generate/Print Reports. Much of the functionality of Generate Reports is provided by R:BASE. Figure 18 presents the Level 2 data flow diagram for generate/print reports. The diagram includes one user-related process, select report type, and eight report-type processes. These report-type processes are: operator functions, tasks, and times; operator task sequences; operator functions data; operator jobs and tasks; maintenance criteria; maintainer/subsystem/component data; maintainer component/task data, and maintainer jobs and tasks.

Structure Chart

Figure 19 presents the structure chart for the algorithm used for forming unique jobs. The inputs to the algorithm are task sequence, task times, and resource constraints. The algorithm calculates the critical path, that is, the path that traverses the network in the longest amount of time. The path incorporates user-entered constraints about simultaneity and single/multiple operator requirements. Next the algorithm assigns tasks to jobs, using tasks within a function, then taking tasks from the next most proximal function. The output is unique jobs and tasks with their times.

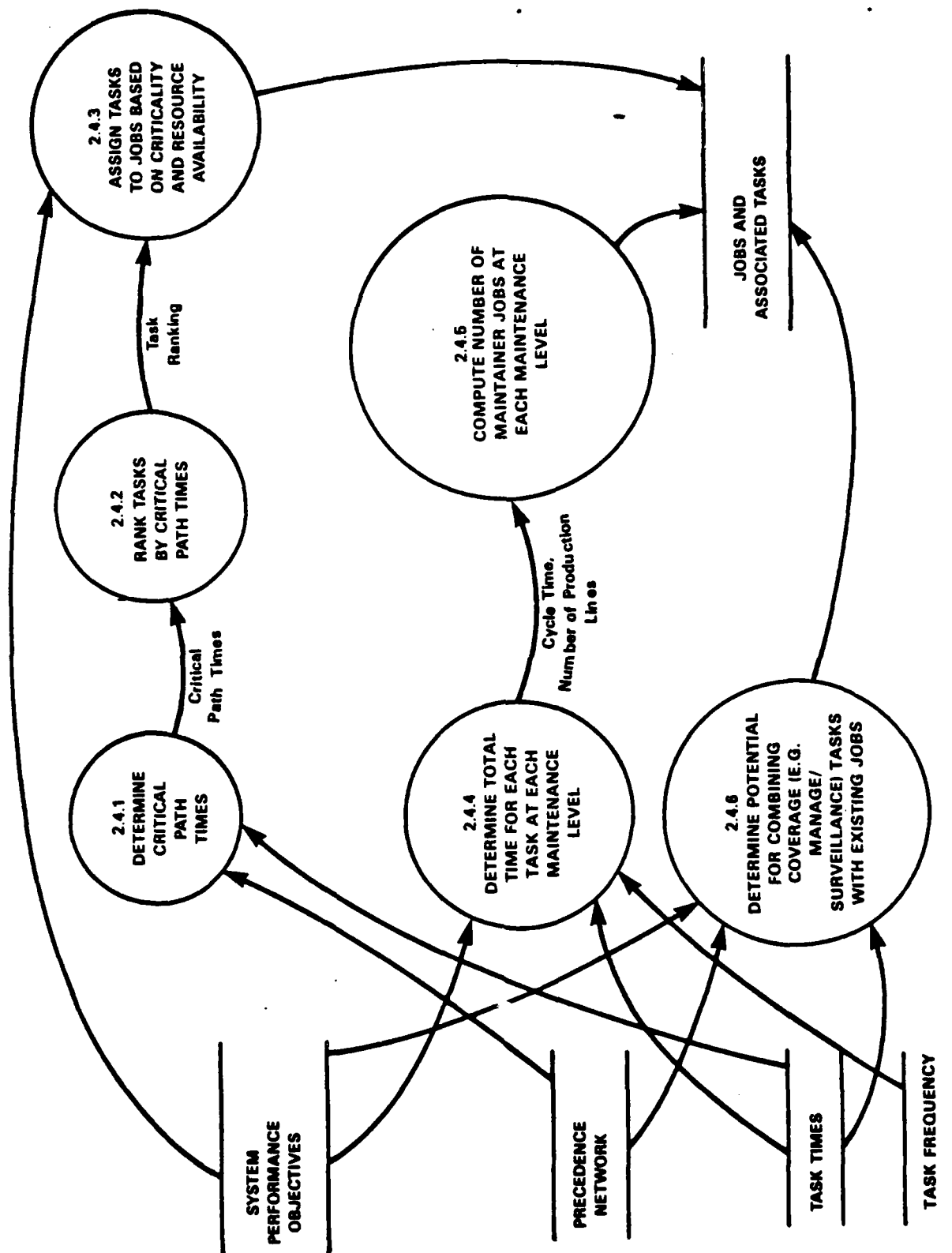


Figure 17. Level 3 Data Flow Diagram for Assign Tasks to Jobs.

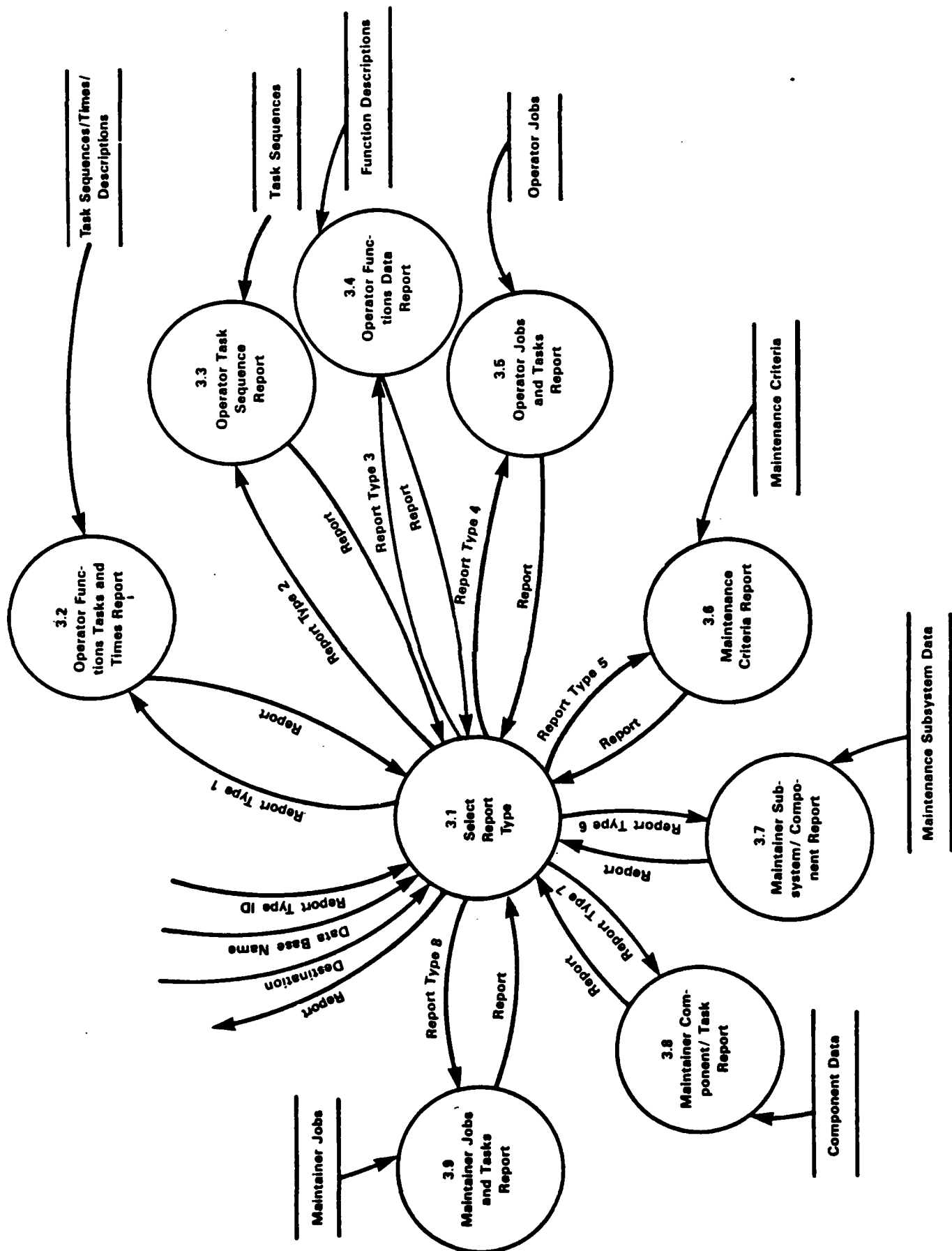


Figure 18. Level 2 Data Flow Diagram for Generate Reports.

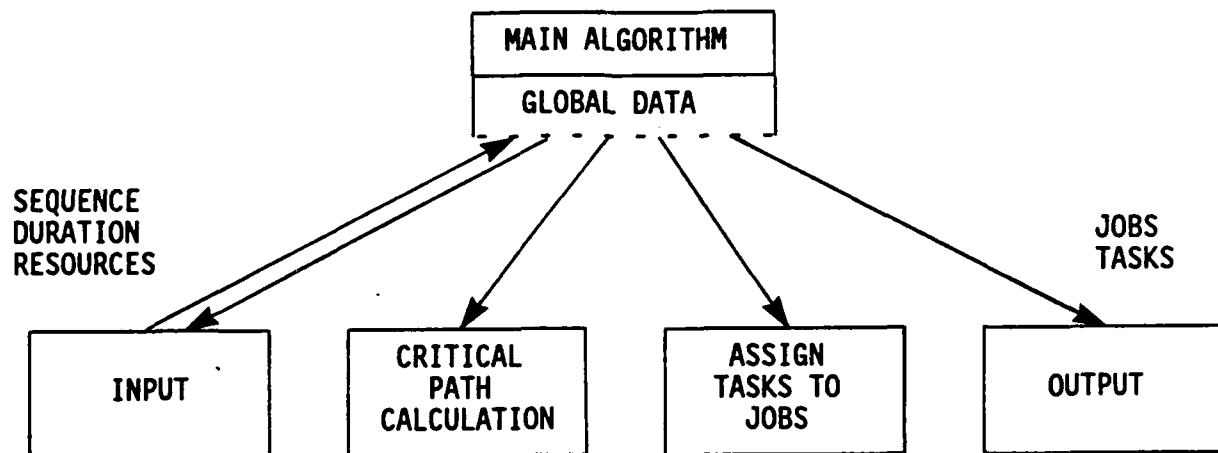


Figure 19. Structure Chart for Forming Unique Jobs.

We have considered two standard industrial engineering algorithms for the operator manpower calculation for Product 5. They are the Resource Allocation (RESALL) and Branch and Bound Assembly Line Balancing (BABALB) algorithms. We have decided to use the RESALL algorithm based on the following.

The RESALL program in the "Balance" mode determines the minimum number of jobs necessary to complete a category 1 (operator) function within a given response time. RESALL in the "Allocate" mode determines the minimum amount of time in which a given number of resources (of various types - up to 20) can accomplish a function. In both cases, RESALL assigns specific tasks to resource units (jobs), but the model as currently constructed does not track the tasks assigned to each resource unit. The BABALB program determines the number of workstations necessary to accomplish a function given a desired cycle time. However, this program assumes that cycles can overlap such that each workstation may be working on a different cycle of the function. Consequently, the assignment of tasks to workstations given by BABALB is appropriate for functions with "production" requirements (e.g., maintenance tasks), but not those with "response time" requirements. The task assignments for response time (category 1, operator) tasks will have to be accomplished by modifying the RESALL program to compare the actual task assignments to resource units. This approach will give a feasible solution to the problem.

Integration of R:BASE System V

Product 5 is primarily an information-based application that requires a robust user-interface to ease use by analysts. As such, many of Product 5's requirements can be achieved readily through the utilization of a commercial off-the-shelf data base management system. Dr. Kaplan of ARI has encouraged the contractor teams to use the same data base management system to promote consistent user interfaces among products. We have elected to use R:BASE System V by Microrim, a data base management system chosen by other contractor teams.

Many of the significant decisions regarding the approaches for developing Product 5, as well as design implementation decisions for the operational Product 5, are directly related to the integration of R:BASE. A proper software solution for Product 5 (as well as other products) will integrate R:BASE application development and operational capabilities. The following discussion overviews those capabilities of R:BASE which will be integrated into the developmental and operational aspects of Product 5.

Application Development. R:BASE provides application development tools to define menus/submenus, as well as forms for data base entry/modification and report generation. These are implemented in separate programs that interactively guide the developer through definition dialogues, after which R:BASE procedural language code may be generated. Subsequent modifications to the generated code can be made either automatically (using the interactive definition dialogue), or manually (to customize).

The application development tools of R:BASE will aid the development of Product 5 considerably. They will permit the rapid development of prototype versions of Product 5 (with increasing functionality). This prototyping will enable ARI to become more involved in Product 5 development by providing recurrent feedback to developers as the implementation evolves.

Application Express is R:BASE's tool for creating menus, organizing them into a tree of menus/submenus, and for associating actions (other than submenus) to menu options. These other actions include: entering, modifying, and displaying data using a form; printing a report; displaying a help screen; and invoking an R:BASE procedure or external language (e.g., "C") program.

Menu options can be defined to be displayed both horizontally and vertically. Users make menu selections by moving the cursor direction keys or striking the number corresponding to the option (horizontal options only), following by a carriage return.

Through Application Express, users also define data base records and their fields, as well as the types and precisions of fields.

Forms Express is R:BASE's tool for interactively defining forms used for data entry, deletion, or modification. Developers use a variety of function keys that correspond to actions which enable forms to be "painted."

Permissible options (e.g., add, modify) are associated with the form during form definition. The interactive dialogue prompts the developer to stipulate record attributes to be displayed, how they are to be sorted prior to being displayed, and conditions (attribute values) for selecting attribute values to be displayed. The conditions may be either hard-coded with the form or user-specified (at run time).

R:BASE's tool through which developers interactively define reports is Reports Express. As with the other application development tools, developers use a variety of function keys that correspond to actions which enable (here) reports to be defined easily. R:BASE reports are comprised of a number of reports sections (that are individually defined): the actual data to be extracted from the data base; report/page/break headers; and report/page/break footers. This variety of report sections enable complex and attractive reports to be interactively defined. Again, as with the other application development tools, the generated code can be manually customized.

Operational Capabilities. Through Forms Express, R:BASE provides a variety of mechanisms that will help to insure the integrity of data provided for entry/update to the underlying Product 5 data bases. These include testing 1) numeric data to be within a specified range, 2) character data to be of specified enumerated values, and 3) referential integrity against values in other tables. Other related R:BASE features will be used that define default values for fields and fields for which data must be filled, as well as double entry verification for data that are entered or modified. In addition, as data are displayed through a form,

users may move through instances of the single record type or extractions from multiple records types (views) using function keys.

Forms are displayed with menu name at top, so that users maintain a sense of "where they are." A status line is available at the bottom of a form screen for displaying messages relating to the success or failure of user-submitted operations.

R:BASE supports a rich set of 89 commands as part of its procedural command language. Most significant of these is the variety of commands used to navigate through and manipulate data in data bases. Further, R:BASE provides a set of 70 math and string functions that are available in the command language. Errors resulting from command or function executions (on behalf of users) can be trapped and acted upon (e.g., security violations logged).

Data Base Security

For data base security, R:BASE supports the notion of a data base owner (i.e., superuser), with ability to assign read and modify passwords to individual tables or views. Backup and load utilities are available for logging data base files and reconstituting versions of the data bases.

In its newest release R:BASE provides a run-time, host language interface from the C programming language. This set of routines will be used in those portions of Product 5 that do not lend themselves to being written in the R:base procedural command language. R:BASE also provides the "Filegateway" facility for importing/exporting data in a textual representation to/from the underlying data bases.

The security mechanisms provided by R:BASE: USER PASSWORD, OWNER PASSWORD, READ PASSWORD, and MODIFY PASSWORD will be used to implement Product 5 security. All users initiating use of Product 5 are prompted for a USER PASSWORD (see Figure 6), which makes that user known to R:BASE. System description data bases are created with OWNER PASSWORD equal to USER PASSWORD.

READ PASSWORD and MODIFY PASSWORD, rather, are explicitly established by system description data base definers (owners). These enable users to protect their data bases (in their workareas) from unauthorized access by other users.

When a user specifies his or her intentions to use an existing data base, a knowledge of whether he/she owns that data base is ascertained by R:BASE by comparing the USER PASSWORD to the OWNER PASSWORD of the target data base. Given the data base to be used is not owned by the user and the user proceeds to attempt to read the data base, Product 5 will prompt for the user to specify a READ PASSWORD to which the USER PASSWORD is then temporarily assigned. R:BASE will then not allow a user to read portions of the data base unless the USER PASSWORD is equal to the READ PASSWORD established for the data base. The mechanism to protect other users from modifying a data base owned by a user is accomplished in a

analogous manner using the MODIFY PASSWORD. The utilization of READ/MODIFY enables owners to assign different READ/MODIFY PASSWORDs for each data base, as well the ability to modify existing READ/MODIFY PASSWORDs.

User Workareas

User workareas, run-time components of R:BASE System V, the Kaplan/Crooks Taxonomy, and elements of the Product 5 application (e.g., menus, forms) will be segregated to different directories in the hierarchical file system.

A "\users" directory will be established, beneath which a subdirectory will be established for each user using his/her name (i.e., for user 1: "\users\'user 1 name\'"; for user 2: "\users\'user 2 name\'", etc.). This provides a separate workarea for each user, beneath which further subdirectories are created to maintain data bases generated by separate Product 5 "runs" for a specific user. These subdirectories are assigned the name of the data base prompted for by Product 5 when a new run is initiated.

Within these subdirectories ("\users\'user name\'\'data base name\'\"), the actual R:BASE data base for a new run is maintained (1 System Type data base), as well as all reports generated from that data base. By default, these reports are stored in file names that identify the type of report content (e.g., "oftt.rpt" corresponds to the "Operator Functions, Tasks, and Times" report, although users may specify target files of their own choice.

R:BASE maintains information for a data base in three files: 1) the (actual) data base, 2) the data base structure, and 3) the indices. Only the actual data bases are maintained in separate user workareas. Files containing the data base structure and indices are shared by all users and maintained in the directory containing elements of the Product 5 application.

DATA BASE ANALYSIS/DESIGN

Data Base Entity Relationship Diagrams

Entity modeling (Teorey & Fry, 1982) has been used to formalize the analysis of Product 5 data. This methodology employs entity relationship diagrams and entity definitions.

Entity relationship diagrams are used to graphically express the relationship between data objects. In these diagrams, data objects in the data bases may take any of five relationships. These are one to one (1:1), one to many (1:M), many to one (M:1), many to many (M:M), or not related. Data objects not related are not connected with arrows. 1:1, 1:M, M:1, and M:M relationships are shown with arrows. A single arrowhead denotes the "1" side and a double arrowhead denotes the "M" side of relationships.

Product 5 data bases employ high-level entity relationship diagrams for the Kaplan Crooks taxonomy (or whatever taxonomy is chosen) and Working/Derived Data. These two entity relationships, each one presented from conceptual and implementation views, are presented in Figures 20-23, respectively.

Entity Definitions: The Data Dictionary

The data dictionary is developed from the entity relationship diagrams, described above. The data dictionary is a listing in tabular form of all the data elements in the data bases with a definition of the attributes and properties (e.g., type, precision) of each.

Table 2 presents the data dictionary for Product 5. It contains four columns: RECORD/Field Name; Type/Precision; Range; and, Unit of Measure. The RECORD/Field name is an abbreviated identification. The Product 5 data base contains 32 records (names in all caps), each with associated fields of the records, 12 are associated with the taxonomy, the remainder with working/derived data. The asterisk indicates a record type key (sometimes composite keys), which uniquely identifies a record type instance. The "Type/Precision" indicates type I, F, or C, for integer, fixed, or character string. Precision of an integer indicates how many digits are required. Fixed are expressed as x:y, where x:y indicates digits to the right and left, respectively. Precision of a character string indicates the number of characters allowed. "Range" indicates allowed values. Product 5 "Units of Measure" are seconds, times per second, and percent.

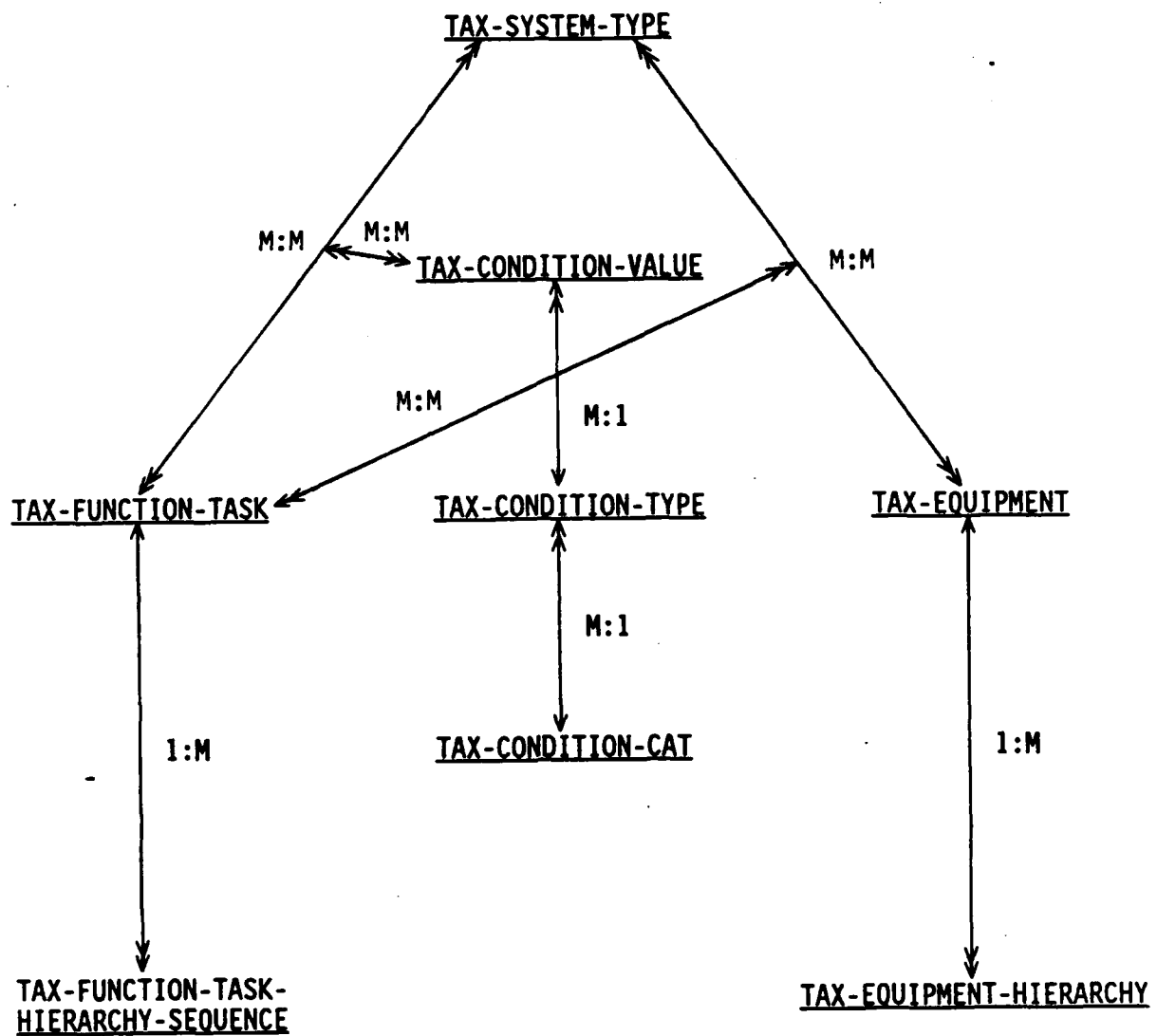


Figure 20. Kaplan-Crooks Taxonomy - Conceptual View.

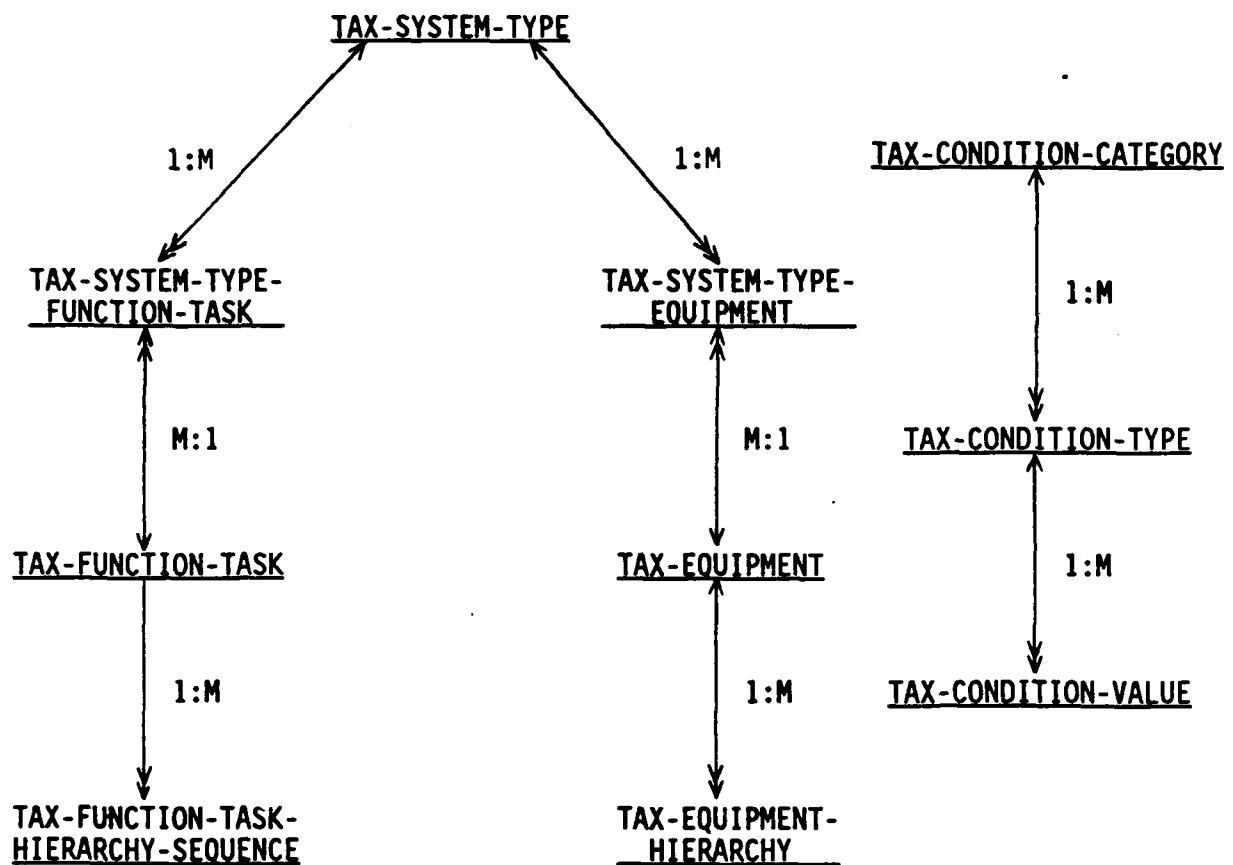


Figure 21. Kaplan-Crooks Taxonomy - Implementation View (1 of 2)

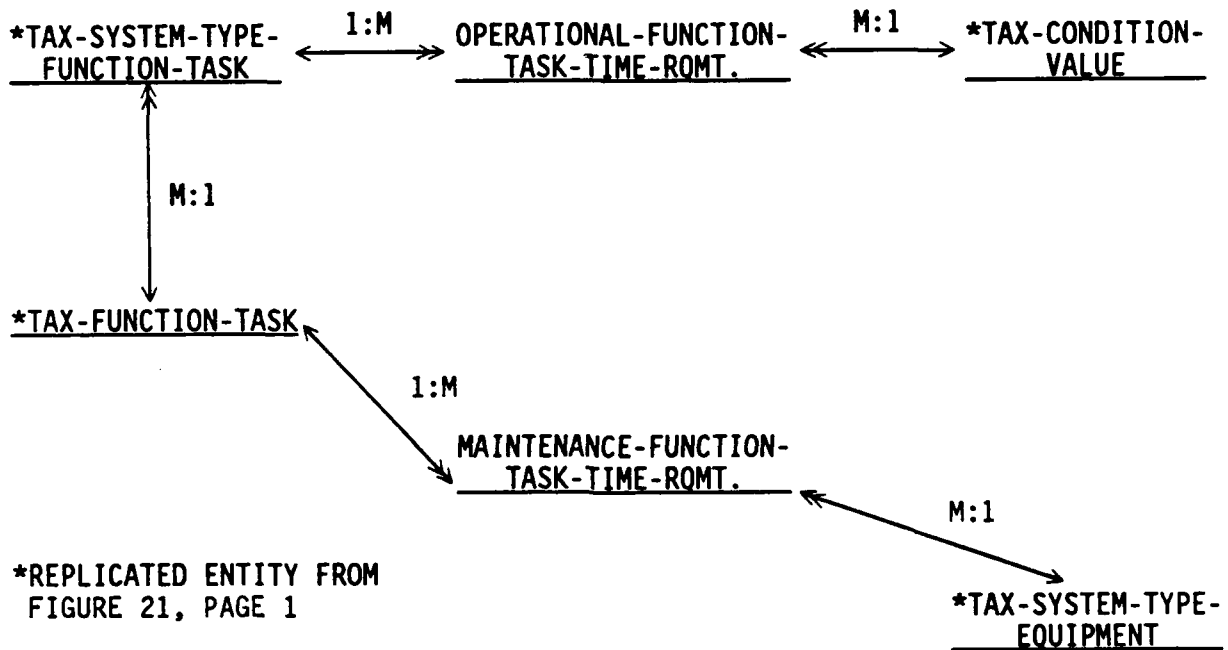


Figure 21 (Continued). Kaplan-Crooks Taxonomy - Implementation View (2 of 2)

SYSTEM-TYPE

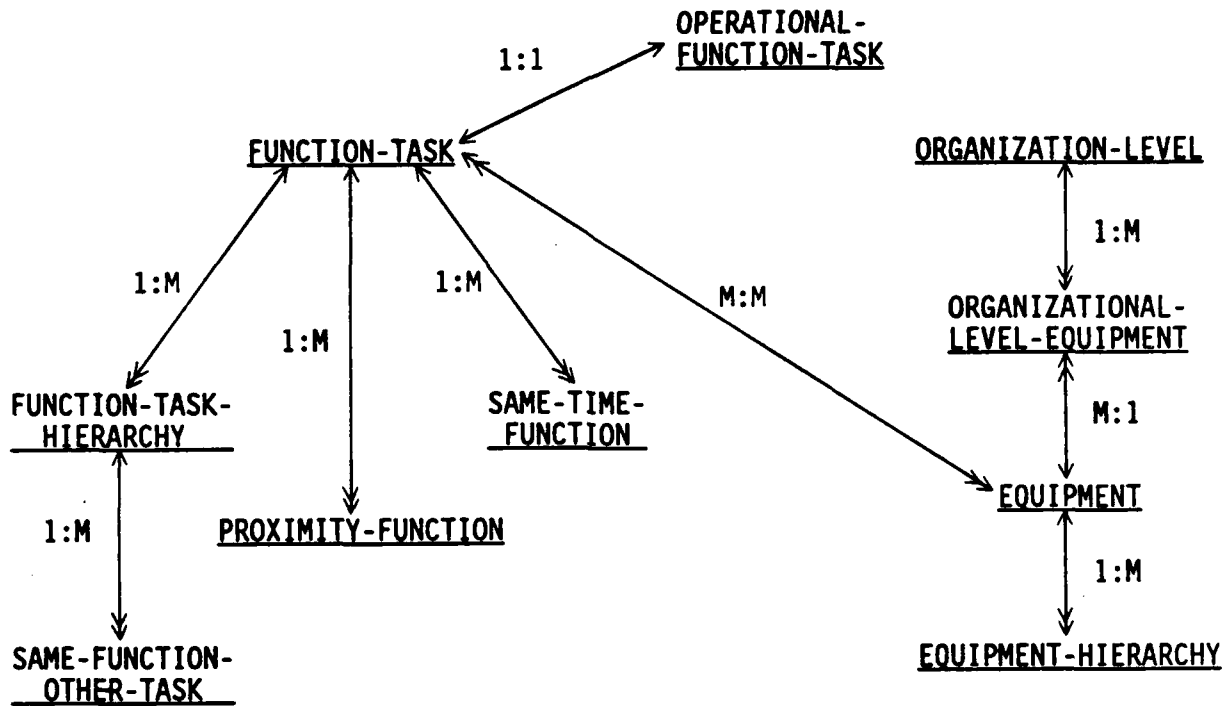


Figure 22. Working/Derived Data - Conceptual View (1 of 2).

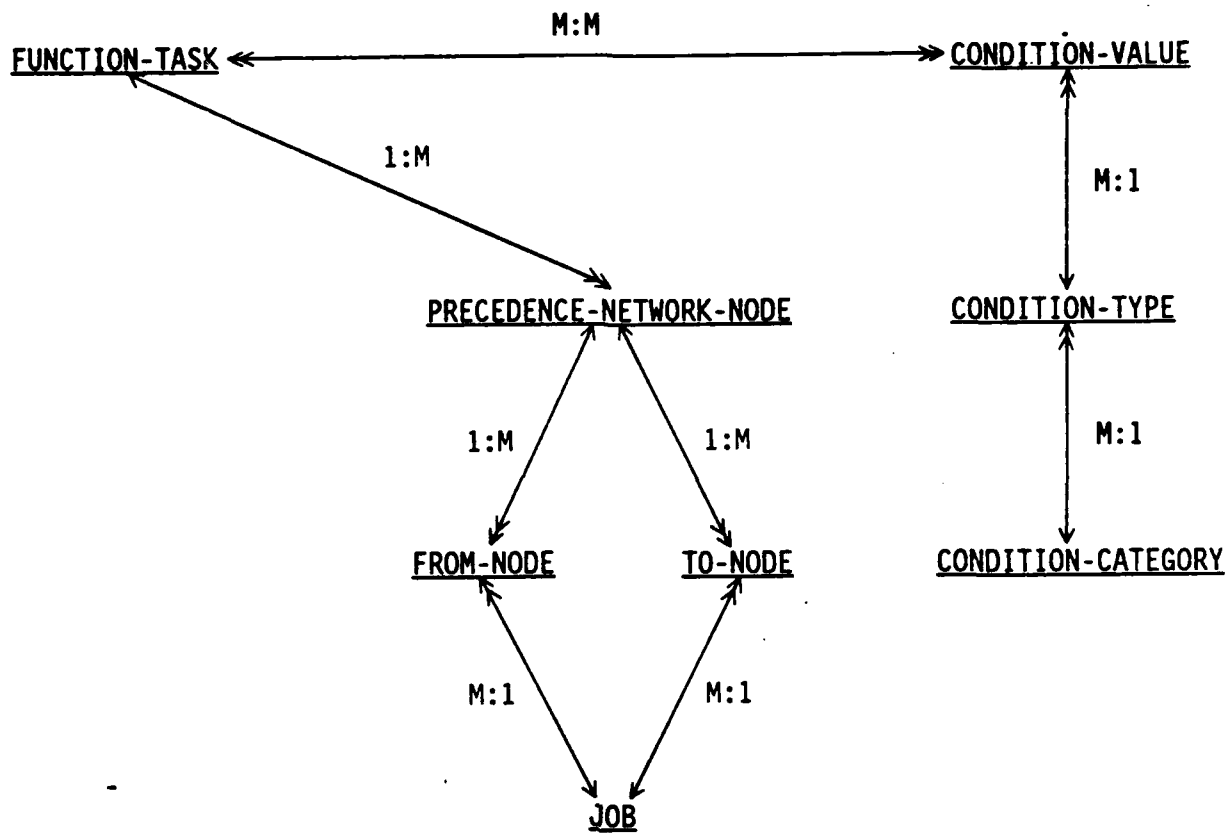


Figure 22 (Continued). Working/Derived Data - Conceptual View (2 of 2).

SYSTEM-TYPE

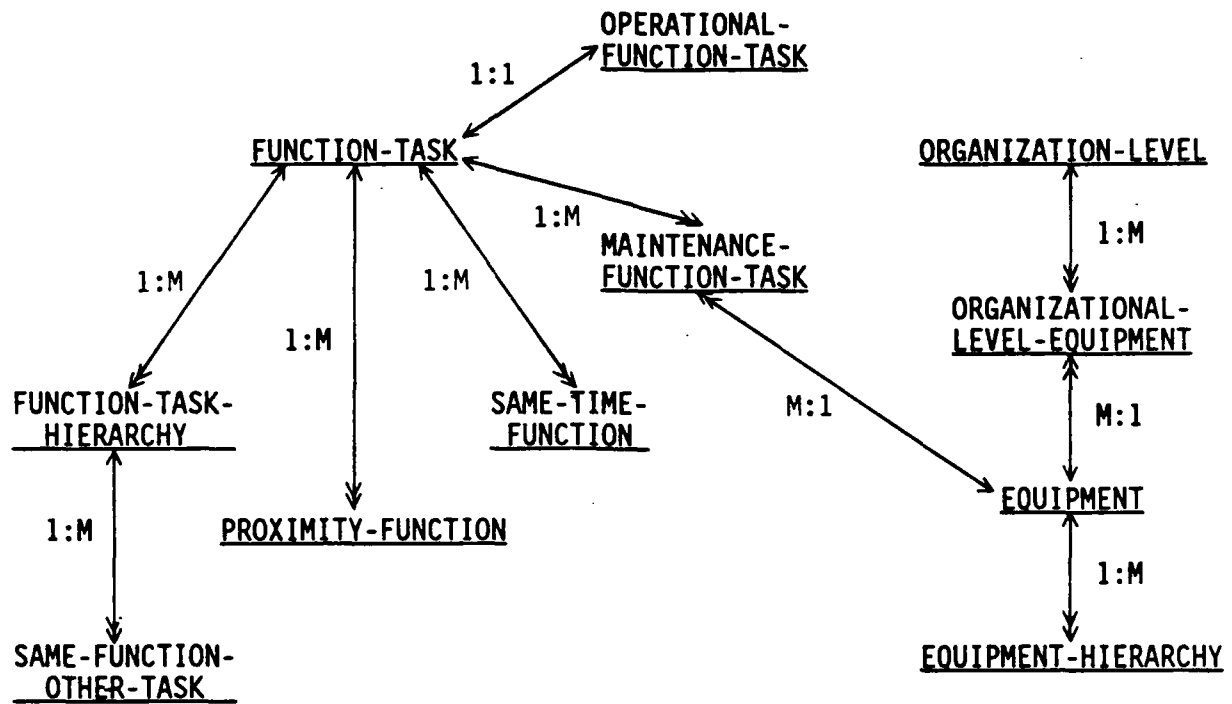


Figure 23. Working/Derived Data - Implementation View (1 of 2).

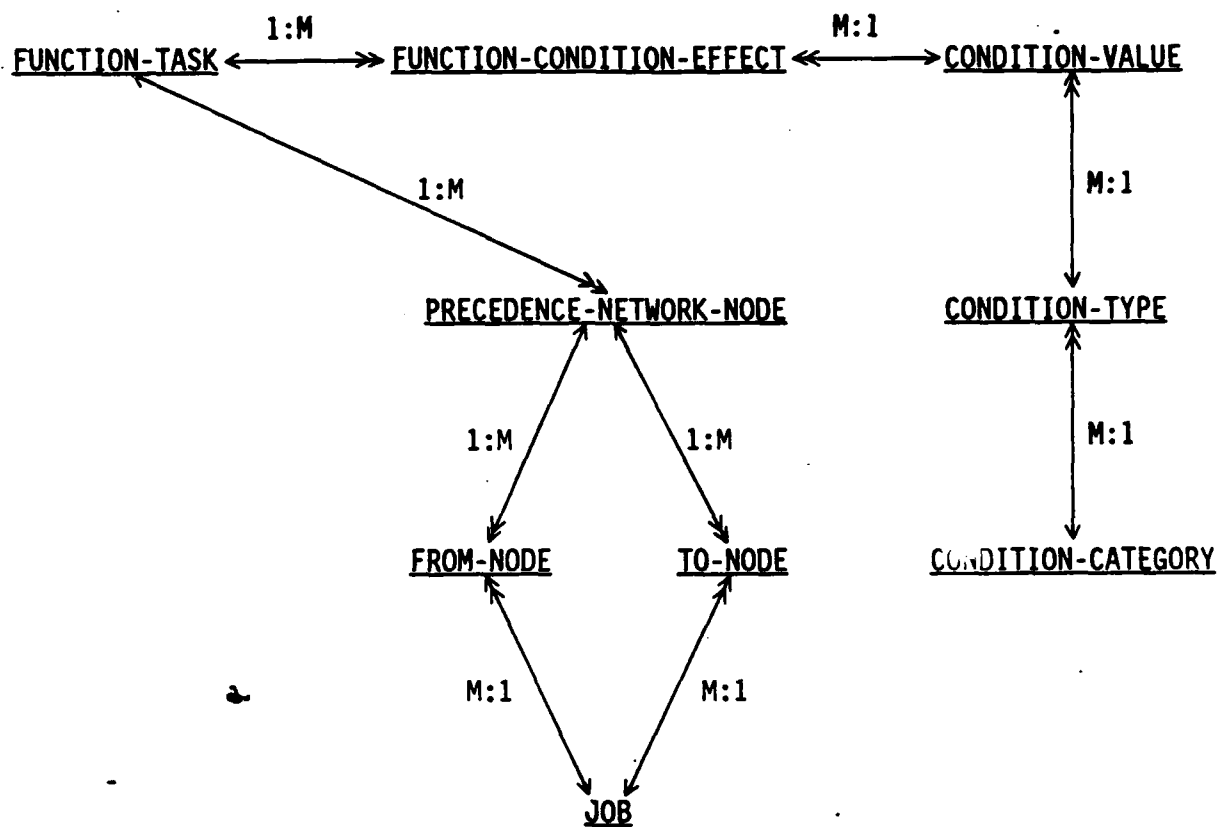


Figure 23 (Continued). Working/Derived Data - Implementation View (2 of 2).

Table 2. Product 5 Entity Definitions.

<u>RECORD/Field Name</u>	<u>Type/Prec.</u>	<u>Range</u>	<u>U/M</u>
TAX-SYSTEM_TYPE			
* System_type_id	I/2	1-21	n/a
System_type_name	C/30	n/a	n/a
TAX-SYSTEM_TYPE-FUNCTION_TASK			
* System_type_id	I/2	1-21	n/a
* Func_task_id	I/4		n/a
TAX-FUNCTION_TASK			
* Func_task_id	I/4		n/a
Func_task_name	C/30	n/a	n/a
Func_task_type	C/1	0,M	n/a
TAX-FUNCTION_TASK-HIERARCHY-SEQUENCE			
* Func_task_id	I/4		n/a
* Child_func_task_id	I/4		n/a
Task_sequence	I/2		n/a
TAX-SYSTEM_TYPE-EQUIPMENT			
* System_type_id	I/2	1-21	n/a
* Equipment_id	I/3		n/a
TAX-EQUIPMENT			
* Equipment_id	I/3		n/a
Equipment_nm	C/30	n/a	n/a
Criteria_maint_ratio	F/3.2		
TAX-EQUIPMENT-HIERARCHY			
* Equipment_id	I/3		n/a
* Component_equipment_id	I/3		n/a
TAX-CONDITION_CATEGORY			
* Condition_category	C/20	n/a	n/a
TAX-CONDITION_TYPE			
* Condition_type_id	I/3		n/a
Condition_category	C/20	n/a	n/a
Condition_type_name	C/30	n/a	n/a

Table 2 (Continued). Product 5 Entity Definitions.

<u>RECORD/Field Name</u>	<u>Type/Prec.</u>	<u>Range</u>	<u>U/M</u>
TAX-CONDITION_VALUE			
* Condition_value_id	I/3		n/a
Condition_type_id	I/3		n/a
Condition_value_name	C/30	n/a	n/a
OPERATIONAL_FUNCTION_TASK_TIME_RQMT			
* System_type_id	I/2	1-21	n/a
* Task_id	I/4		n/a
* Condition_value_id	I/3		n/a
Performance_reqmt_time	I/6		secs
-- Operational performance requirements are defined by a combination of System Type, Task, and Condition.			
MAINTENANCE_FUNCTION_TASK_TIME_RQMT			
* System_type_id	I/2	1-21	n/a
* Equipment_id	I/3		n/a
* Task_id	I/4		n/a
Performance_reqmt_time	I/6		secs
-- Maintenance performance requirements are defined by a combination of System Type, Equipment, and Task.			
SYSTEM_TYPE			
* System_type_id	I/2	1-21	n/a
System_type_name	C/30	n/a	n/a
Max_nm_operators	I/3		n/a
Max_nm_maintainers	I/3		n/a
FUNCTION_TASK			
* Func_task_id	I/4		n/a
Func_task_name	C/30	n/a	n/a
Func_task_type	C/1	n/a	n/a
Perc_crew_member_commtd	I/2	0-100	%
Number_operators_reqd	I/2		n/a
FUNCTION_TASK-HIERARCHY			
* Func_task_id	I/4		n/a
* Child_func_task_id	I/4		n/a

Table 2 (Continued). Product 5 Entity Definitions.

<u>RECORD/Field Name</u>	<u>Type/Prec.</u>	<u>Range</u>	<u>U/M</u>
SAME_FUNCTION-OTHER_TASK			
* Func_task_id	I/4		n/a
* Child_func_task_id	I/2		n/a
* Same_func_other_task_id	I/4		n/a
Completed_before	C/1	Y,N	n/a
Same_soldier	C/1	Y,N	n/a
Different_soldier	C/1	Y,N	n/a
PROXIMITY_FUNCTION			
* Func_id	I/4		n/a
* Prox_func_id	I/4		n/a
Closeness_ranking	I/2		n/a
SAME_TIME_FUNCTION			
* Func_id	I/4		n/a
* Same_time_func_id	I/4		n/a
OPERATIONAL_FUNCTION_TASK			
* Func_task_id	I/4		n/a
Performance_reqmt_time	I/6		secs
Task_time	I/6		secs
ORGANIZATION_LEVEL			
* Organization_level	C/30		n/a
ORGANIZATIONAL_LEVEL-EQUIPMENT			
* Organization_level	C/30		n/a
* Equipment_id	I/3		n/a
EQUIPMENT			
* Equipment_id	I/3		n/a
Equipment_nm	C/30	n/a	n/a
Quantity	I/3		n/a
Criteria_maint_ratio	F/3.2		
EQUIPMENT-HIERARCHY			
* Equipment_id	I/3		n/a
* Component_equipment_id	I/3		n/a

Table 2 (Continued). Product 5 Entity Definitions.

<u>RECORD/Field Name</u>	<u>Type/Prec.</u>	<u>Range</u>	<u>U/M</u>
MAINTENANCE_FUNCTION_TASK			
* Equipment_id	I/3		n/a
* Task_id	I/4		n/a
Performance_reqmt_time	I/6		secs
Task_time	I/6		secs
Frequency	I/3		n/a
Unit_of_measure	C/10	n/a	
CONDITION_CATEGORY			
* Condition_category	C/20	n/a	n/a
CONDITION_TYPE			
* Condition_type_id	I/3		n/a
Condition_category	C/20	n/a	n/a
Condition_type_name	C/30	n/a	n/a
CONDITION_VALUE			
* Condition_value_id	I/3		n/a
Condition_type_id	I/3		n/a
Condition_value_name	C/30	n/a	n/a
Default	C/1	Y,N	n/a
FUNCTION-CONDITION-EFFECT			
* Func_id	I/4		n/a
* Condition_value_id	I/3		n/a
Effectuated	C/1	Y,N	n/a
PRECEDENCE_NETWORK_NODE			
* Func_id	I/4		n/a
* Node	I/3		n/a
FROM NODE			
* Func_id	I/4		n/a
* Node	I/3		n/a
* From_node	I/3		n/a
Task_time	I/6		secs
Job_id	I/3		n/a

Table 2 (Continued). Product 5 Entity Definitions.

<u>RECORD/Field Name</u>	<u>Type/Prec.</u>	<u>Range</u>	<u>U/M</u>
TO NODE			
* Func_id	I/4		n/a
* Node	I/3		n/a
* From_node	I/3		n/a
Task_time	I/6		secs
Job_id	I/3		n/a
JOB			
* Job_id	I/3		n/a

USER ACCEPTANCE PLAN FOR PRODUCT 5

User Concerns

The purpose of a user acceptance plan is to identify potential sources of resistance to automation use and develop remedies for the problems prior to the introduction of the automation into the work setting. When a user is presented with an automated aid or tool for use in his or her job, that user is likely to ask a number of questions. The questions asked by a user will fall into two categories: (1) questions relating to getting started with the automation; and (2) questions relating to the performance with the automation. The questions relating to getting started with automation that a user might ask include:

- What is it going to take to get my paper files over to the computer?
- How much time is it going to take for me to learn to use this aid?
- How long will it be before I can actually get some work done with this aid?

These questions relate to the "start-up" costs associated with bringing new tools or techniques, particularly automated ones into the work environment. The areas of concern to the user relate to the transition and learning requirements associated with incorporating an automated aid into his or her work setting. In essence, the user is attempting to do a cost trade-off analysis, where "start-up" costs are typically paid for by time away from doing the day-to-day job. It is anticipated that the user's perceived "start-up" cost will be directly proportional to his or her resistance to incorporating the aid into the job.

Once a user is familiar with the use of the automated aid, other questions will arise relating to the performance of the aid, including:

- Is the aid doing something that I would rather do?
- What's going on inside the "black box"?
- Is the aid performing to my satisfaction?
- Is there enough time to accomplish my task with the aid?
- Is the aid improving the quality of my performance?
- Does this aid accommodate my increasing understanding and skill?
- How do my colleagues and supervisors view this aid?

Each of these questions reflects an area of user concern that may impact the acceptance or rejection of an automated aid in the job environment. These areas of concern are briefly discussed below.

Credibility. The first three questions relate to the credibility a user will assign to an automated aid. Credibility associated with automation may be partitioned into two aspects: belief that automation is capable of the functions allocated to it; and understanding in how automation is doing what it is doing. The two aspects of credibility are

associated with the allocation of functions to humans and automation and the user-computer interface facets of automation design, respectively.

During the front-end analysis phase of automation design, functions are allocated to automation for performance. If functions are allocated to automation that a user in the non-automated environment exerts control over, the credibility of automation performing such functions may influence the user acceptance of the automation. In particular, functions that require skill, judgment, or creativity may not be viewed by the user as credible if assigned to automation. This user perception may be based on his or her desire to retain control over the function or a perceived inadequacy of automation to perform the function. Regardless of the underlying reason, the result is a problem for the design developer in terms of gaining acceptance of the automation by the user.

The second aspect of credibility relates to the design of the user-computer interface. In particular, for automation to be credible to the user, the user needs some understanding of how automation is accomplishing the functions. Users cannot assign credibility of automation performance if the operation has the appearance of a "black box." The underlying issue here concerns the user's need to evaluate performance of an automated aid. The amount of information needed for evaluation is directly proportional to the expertise of the user, with the expert requiring the most and the novice requiring the least.

The ease of use of an automated aid is also likely to influence credibility assignment. If an automated aid is difficult to use the potential for user resistance of the aid is increasing. For example, an aid which forces the user to adopt new and different methods for accomplishing his or her task is likely to be resisted. Computer jargon is another example where the designer is likely to meet with resistance on the part of the user by asking that the user adjust to new or different terminology.

Quality of Job Performance. For an aid to gain user acceptance, the aid cannot be perceived as reducing the quality of the user's job performance. There are a number of ways in which the quality of job performance may be influenced by the introduction of an automated aid to the job environment. Functions allocated by the designer may result in user tasks that are viewed as unacceptable tasks to the user. In such a situation user rejection of the aid is likely. From a different perspective, unreliable performance by automation may require extra time and effort on the user's part to address the problems created; user acceptance is likely to be low for the perceived source of the problem, the automation.

Expertise Levels. There are two different types of expertise levels that should be considered in an attempt to gain user acceptance of an automated aid. First, there is the range of expertise inherent in the target user group. Second, there is the changing skill level of an individual user as he or she gains familiarity and proficiency with the use of the aid.

The concern about expertise level within the target user group focuses on the domain knowledge of users that the automated aid supports. When the

target user group is relatively homogeneous in their domain knowledge and skill levels, this concern is not a viable issue. On the other hand, if the target user group is heterogeneous, a potential problem exists. The underlying question facing an aid designer is "what level of proficiency in the job performance should we assume a user will have?" The higher the proficiency assumed, the fewer users in a heterogeneous group of users will actually be able to benefit from the use of the aid in their work environment.

The second part of the expertise level issue concerns the manner in which the user is able to interact with an automated aid as he or she gains experience. Novice users are only novices for a brief period of time. Frequently, friendly interface designs are optimized for the novice user and become a source of frustration as the user transitions from novice to experienced user. An automated aid which is designed solely for a novice user is only optimal for an environment where the aid does not become an integrated part of an individual's job environment. Such a situation would be characterized as a continually changing set of users who due to lack of repeated exposure do not transition beyond the novice stage of automated aid use. User acceptance of an automated aid requires that the transitional nature of user be accommodated unless the situation clearly indicates that users will not have repeated exposure or opportunities to use the aid.

Views of Colleagues and Supervisors. While the acceptance of an aid is not likely to be made solely on the basis of the opinion of others, opinions will be an influencing factor. Enthusiasm among colleagues, in particular, for an automated aid in the job environment will help to lead to acceptance. Propensity for automation in the work place is frequently driven from the top-down. A top-down push for acceptance may work in the short term, but tends to be effective only while the proponent is in place; when the proponent leaves so does the enthusiasm.

The early involvement of the target users in the design and development process is one method for creating support for an automated aid. Users tend to view their involvement as an opportunity to achieve a positive influence on the impending changes to their work setting. The development of user interest groups serves as a mechanism for bringing the users into the process to benefit themselves as well as the automated design.

User Concerns and Product 5 Acceptance

To gain user acceptance of Product 5, it is important to identify the nature of the concerns discussed in the first section and their importance to Product 5 users. The first step is the identification of potential Product 5 users. When identifying the users of Product 5, we should consider that there may be two different sets of users. The most obvious set of users are those that will actually interact with Product 5 in the process of estimating manpower requirements for a target system. The concerns of this first set of users are likely to be those identified earlier in the section. A second set of users are those that will use the manpower estimates generated by the first user group. These individuals are

likely to be concerned with how the automation aids in arriving at the manpower estimate.

First Look for and at Users. Those users who are likely to directly interact with Product 5 in the process of estimating manpower requirements are likely to be found within the Directorate of Combat Developments at the numerous TRADOC schools. Preliminary efforts have been made to locate potential users at these locations. Specifically, contact has been established with individuals at Fort Rucker and Fort Knox based on names provided by TRADOC Headquarters. The purpose of exploring contacts at this stage of design is to begin to identify potential concerns for the user acceptance of Product 5. From our preliminary discussions with potential users a number of issues have surfaced that may influence the user acceptance of Product 5.

Individuals involved in manpower estimation are not likely to be prepared to devote an extensive amount of time transitioning to and learning to use an automated aid. One individual indicated that if he couldn't learn to use an aid in one day, he would be hesitant to use it. In terms of user acceptance, they are likely to balance the time required to learn to use the aid against the cost of time taken from their on-going job. In addition, at least some users will not be responsive to reading manuals, particularly lengthy ones, in order to learn to use the aid.

There is likely to be a heterogeneous population of user in respect to automation experience. Some users may be experienced with automation, though not necessarily from their job in the manpower estimation domain. Other users may have little or no automation experience. The design imperative of ease of use for Product 5 is on target for the potential users. There will be a need to accommodate the transitions of users as they become increasingly familiar with the use of the aid.

The process of manpower estimation is characterized as a time-consuming and difficult process. In some cases, users may have a large amount of data upon which to develop an estimate. In other cases, users may have sparse data available to them for developing an estimate. It is likely that users will be quite receptive to an aid that reduces the time consuming nature of their task.

Whether or not the target user group for Product 5 can be characterized as homogeneous or heterogeneous is not known at this point. However, it is apparent that there is no formal training for the manpower estimation process. There are publications from TRADOC, Soldier Support Center, as well as local expertise and possibly locally developed guidelines that provide the basis for on-the-job training. Attempts should be made early in Phase 3 of this effort to determine the range of domain knowledge represented in the potential user group of Product 5.

Bring the User into the Design Process. In an attempt to maximize the potential user acceptance of Product 5, users need to be brought into the design and development process. The beginning of Phase 3 of this effort is an optimum time to bring the user into the process. At such a time our design and development process will be a sufficient point of maturity to

provide users with the design of the aid for their comment. Importantly, bringing the user in at that point will still enable user modifications to become incorporated into the actual aid.

The suggested vehicle for bringing the users into the process is a user interest group. Currently, each school has a standing MANPRINT committee. While these committees do not necessarily contain those individuals who are likely to be the users of Product 5, the DCD members of such committees are likely in a position to identify the potential users. In addition, there are undoubtedly members on MANPRINT committees who would be interested to learn about Product 5 as potential users of Product 5 output.

The user interest group would have multiple objectives. One objective is to explain to users the purpose and proposed operation of the aid. The second objective is to elicit from potential users an evaluation of the proposed aid and suggested remedies to shortfalls in the design or improvements that may be made. The following topics should be addressed by design developers at a user interest group meeting:

- The objective and purpose of Product 5
- Potential benefits of using Product 5
- How Product 5 works including data entry requirements
- Product 5 interface operation
- How to judge the performance of Product 5
- How Product 5 adapts to various skill and experience levels

Next, data should be elicited from the potential users on the following issues:

- User concerns related to transitioning from their current method of manpower estimation to the use of Product 5.
- User concerns about the learning requirements associated with Product 5.
- Whether Product 5 will allow the users to perform the estimation process in a manner acceptable to them.
- The quality of job performance and whether or not Product 5 is viewed as an asset.
- Potential problems with the use of Product 5 as designed.
- Suggested improvements of Product 5.

There are a variety of ways that opinions could be elicited during a user interest group session. A questionnaire could be given to participants to insure that input is obtained from all interested members. The use of a questionnaire would be advantageous in that brief demographic questions could be included to differentiate comments of potential "hands-on" users from users of the Product 5 output. The questionnaire method for eliciting opinions has the advantage of developing a written record of concerns and the type of user raising the concerns.

Participants in the user interest group should be made aware of the impact they have on Product 5 design and development. Some sort of follow-up, such as a memo to the interest group, is advised to inform the users of actions taken on their concerns. In this way, bringing the users into the design and development process also means providing them with feedback to keep them in the loop.

Members of the user interest group should include users from each TRADOC school if possible. Accomplishing this objective might necessitate meeting with subsets of the group at different times and locations. The alternative of comprising an interest group from one to two schools could have the disadvantage of a lack of generalizability of the findings. While there are likely similarities in the manpower estimation process across the schools there may be some differences due to the type of systems or equipment of concern at each school.

Cost and Benefits of User Interest Groups. Bringing users into the design and development process has costs associated with it. As evidenced by the tentative agenda for a user interest group, advanced preparation of materials is necessary for the design developer team. Given the objective of eliciting input from all TRADOC schools, multiple user interest groups meeting would be a possible requirement. On the user side, there is a cost in the time for attendance. The actual duration of a user interest group meeting can be reduced by the preparation of "read ahead" packages. A "read ahead" package could contain: Product 5 description, possibly storyboards to show interaction, design developer concerns for which user opinion is needed, meeting objectives and agenda. The use of a "read ahead" package offers the attendees the opportunity to be prepared for the conference and frequently increases the quality of a conference while reducing the time required.

The benefits of a user interest group directly impact the potential user acceptance of Product 5. Allowing users to evaluate the design prior to implementation offers the benefit of identifying potential problems while the problems may be readily corrected. Membership in user interest group gives the user the opportunity to become part of the aid development team. By becoming part of the team the user has an investment in the ultimate successful implementation of the automated aid into his or her work environment.

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APPENDIX A

SUMMARY OF R:BASE INTERFACE

Overview

The selection of the R:BASE data base management system (DBMS) for Product 5 directly constrains the nature of the Product 5 man-machine interface (MMI). This appendix identifies the specific MMI features of applications built using the R:BASE DBMS. These MMI features include the nature of menus and forms, as well as the keystrokes (and their sequences) used in manipulating menus and forms.

The Application Development Tools of R:BASE

R:BASE provides several application development tools through which users interactively define menus, associate objects to menu options, and define forms.

APPLICATION EXPRESS is used to define menus and to associate one of the following with each menu option (except "Exit"): 1) a form, 2) a lower level menu, 3) a "non-form-based" data base query/update statement in the R:BASE query language, 4) a report definition, or 5) an executable module written in a foreign (non R:BASE) language (e.g., "C"). APPLICATION EXPRESS is also used to define the structure of all data base tables which form the basis for the application.

FORMS EXPRESS is used to define forms, and is invoked by APPLICATION EXPRESS when the developer conveys the intention to associate a form with a menu option.

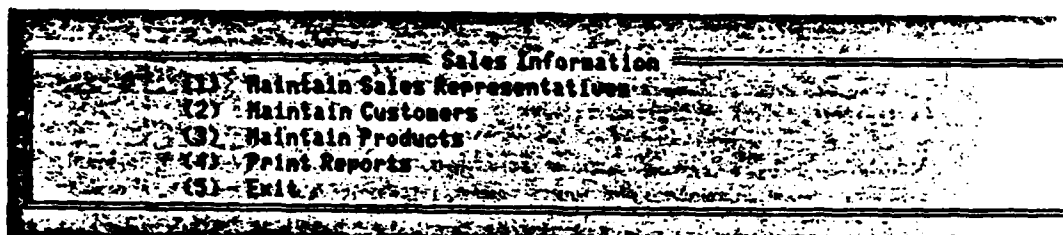
These are robust development tools. An additional tool, REPORTS EXPRESS is used to interactively define reports. All these tools generate "programs" in the R:BASE command language, which may be customized (e.g., through the insertion of additional statements in the R:BASE command language). A last step is required to compile the R:BASE command application definition into an executable representation.

Menus

R:BASE provides the mechanisms for defining two flavors of menus, vertically and horizontally-arranged menu options. Figure A-1 provides a sample of each. The last option in all menus should be "Exit." The selection of exit returns the user to the parent menu for all menu levels except the highest menu, and escapes the Product 5 application altogether at the main menu. R:BASE also enables the developer to optionally establish "[ESC]" with this menu "Exit" function.

For R:BASE menus with vertical options, the user selects an option by using the cursor direction keys (e.g., "down arrow") or typing the option

R:BASE Vertical Menu



R:BASE Horizontal Menu



Figure A-1. R:BASE Vertical Menu and R:BASE Horizontal Menu.

number (immediate left of option), followed by a "[RETURN]." The developer can also define function keys to be associated with menu options.

Note that menus have a menu title that is displayed on the menu above options (in the sample vertically-arranged options menu, "Sales Information").

During menu definition, the developer can define help text to be associated with a menu, which is available to the user at run-time through the selection of "[F10]." For Product 5, this mechanism should be used to describe in a few sentences the purpose of each menu option. R:BASE enables this help text to be up to 5 pages in length, but Product 5 should constrain it to a single page.

R:BASE Forms

R:BASE forms have the following characteristics:

1. Form fields require explicit user entry to add/modify. The notion of highlighting items for selection is not supported.
2. Forms can map to at most 5 data base tables.
3. Components (see Figure A-2):
 - a. Form title.
 - b. Operations menu at top of form (R:BASE terms these "menu options"). Generally, users first complete form fields with data, and then select an operation from the top of the form (e.g., the equivalent of "insert," "update," etc.).
 - c. Prompts for data entry (e.g., "Salesman:").
 - d. Form fields (for data entry/display/modification) that are associated with either table fields or with variables.
 - e. Status line which displays information about the completion status of data entry insertions/updates and field validation.
4. R:BASE supports the facility for expressing master-detail relationships on forms, such that fields from many instances of the detail record are displayed ("Transaction Detail" in Figure A-2) with a single instance of the master record to which they relate ("Transaction" in Figure A-2). This mechanism provides the remaining two components of R:BASE forms, below.
 - a. "Tiers" which map to single instances of the detail record.
 - b. "Regions" which are composed of the tiers and the detail record header line. There is a constraint of one region/form.

Line 1: Title
Line 2: Operations
Line

Text

Field

Region

Tiers

Last Line: Status

Region

Enter Transaction Date		S	E	DATE		S	E
Enter Transaction Number		S	E	Salesman		S	E
Enter Customer Number		S	E			S	E
Name		S				E	
Address		S				E	
City, State, Zip		S		E	S	E	
Phone		S		E			

Detail#	Model	Product Name	Qty	Price	Extended Price
S E	S E S		E S E S		E S E
S E	S E S		E S E S		E S E
S E	S E S		E S E S		E S E
S E	S E S		E S E S		E S E

Figure A-2. Text, Fields, Regions, and Tier On a Form.

5. R:BASE forms are driven by either of two run-time components of R:BASE, ENTER and EDIT, which are associated with the form at form definition. ENTER is used when the primary purpose is to enter new rows of data (though it is also possible to edit rows using ENTER); EDIT is used when the primary purpose is to edit existing data (though it is also possible to enter new rows using EDIT).
6. There is a different set of menu operations associated with ENTER and EDIT (see Figure A-3 and A-4), that are displayed at the top of the form.
7. During form definition, FORMS EXPRESS prompts for 1) general form characteristics, 2) table characteristics, and 3) field characteristics. Although forms fields can map to as many as 5 tables, the first table specified is treated as the main table that the form is meant to serve. R:BASE defines default characteristics for fields based on the source of the field's value, so that form fields that map to data base fields in other than the main table are assumed for display only. These default field characteristics can be modified. Further, expressions that reflect table lookups to fill form fields in other than the main table must be defined explicitly when the form is used with either ENTER or EDIT; table lookups must also be defined for entries in the main table when the form is used with ENTER.
8. A number of function keys are defined that enable the user to move the cursor throughout a form and to otherwise manipulate data on a form. These function keys and their corresponding actions are identified in Figure A-5.

Product 5 Forms

R:BASE effectively differentiates between the user actions of initially entering data and then modifying it (after it has been written to the data base). As previously mentioned, there are different menu operations associated with both (Figures A-3 and A-4). Although ENTER can be used to modify data, ENTER operations do not include the capability to move backward and forward through instances of the main table the form is meant to serve (see "+" note at bottom of Figure A-5). Although EDIT can be used to enter new data, this is accomplished by "writing over" an existing instance of the target table on the form (followed by the "Add New" EDIT operation). The definition of "lookups" for a form also differ depending upon whether the form is used to enter or modify existing data.

Consequently, Product 5 should have different menu options and form definitions that correspond to the actions of initially creating new data, and subsequent modification of that data. Modification can also include the random insertion of new instances of some target table.

Table 7 Menu Options With the ENTER Command

Option	Purpose
Add	Adds the data on the form to the appropriate tables. Clears the screen for you to enter another row.
Duplicate	Adds the highlighted row as a new row to its table and leaves the values displayed in the fields for you to use again. If you have entered data on the form below the highlighted row, those rows are added to their tables and cleared from the screen. When you are entering repetitive information into a table, use this option to save time and keystrokes.
Edit Again	Returns you to the form so that you can edit your data. Does not add the data to the database. Applies only before the data is added to the database.
Discard	Removes the highlighted row from the screen. If the form serves more than one table and the row is not in the last table, a prompt asks if you want to discard only the highlighted row, or the highlighted row and any dependent rows further down the form.
Quit	Ends the session of form use. You can also leave the form by pressing [ESC].

For a list of function keys used in form processing, see table 6 under the EDIT command in this dictionary.

ENT is the shortest form of the command name.

Examples

ENTER transform FROM b:\transact\trans.dat

Uses the form *transform* to load data from the external file *trans.dat* residing on drive *b:* in directory *transact*.

ENTER transform FOR 1 ROW

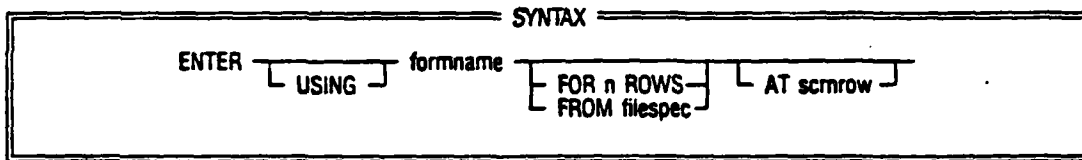
Displays the form *transform* and allows the user to enter one row of data to the first table served by *transform*. The user can enter as many rows of data in subsequent tables as are appropriate for the one row entered in the first table. This option is convenient in applications that require other actions to take place after loading each complete entry.

ENTER transform AT 5

Displays the form *transform* at screen row 5.

Figure A-3. The ENTER Option.

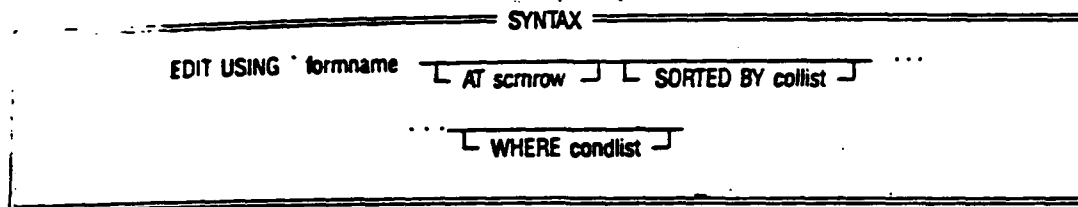
ENTER Using a Form



- Related Commands** EDIT USING, SET AUTOSKIP
- See Also** Chapter 3, *User's Manual*
- Purpose** The ENTER command is used to add data to tables using the specified form (see the FORMS command in this dictionary).
- Options** *USING*: This word is optional.
 AT scrmrow...: Draws the form on a specific row of the screen other than the first.
 FROM filespec: Indicates that the data is entered from an external ASCII file rather than from keyboard entry. It can only be used with a single-table form.
 FOR n ROWS...: Limits the number of rows entered to the integer number represented by *n*.
- Comments** This command displays a previously created form on the screen to be used for data entry. For instructions on how to set up a form, see the FORMS command in this dictionary.
 FileGateway is the recommended method for transferring fixed field ASCII files into R:BASE; however, you can transfer fixed field ASCII files into R:BASE using a form with the ENTER command and the *FROM filespec* option. If adding data from a fixed field ASCII data file with rows less than or equal to 80 characters, define a form that matches column entry locations to file locations. If the rows are greater than 80 characters, use FileGateway. To add data to a table via the keyboard, omit the file specification.
 When a form is created, the form designer determines which database actions are allowed on the specified tables and which menu options are displayed during form use. Table 7 shows all the menu options available with the ENTER command using a form.

Figure A-3 (Continued). The ENTER Option.

EDIT Using a Form



Related Commands	EDIT, ENTER, SET AUTOSKIP
See Also	Chapter 3, <i>User's Manual</i>
Purpose	The EDIT USING command is used to view, change or update data, or delete rows that are displayed in the specified form (see the FORMS command in this dictionary).
Options	<i>AT scrnrow...</i>: Draws the form on a specific row of the screen other than the first. <i>SORTED BY...</i>: Sorts the rows by the column(s) you specify in the column list. <i>WHERE...</i>: Limits the rows to be edited. In a form that serves more than one table, the WHERE clause applies to the first table in the form.
Comments	This command displays data on the screen using a previously created form (see the FORMS command in this dictionary for instructions on how to set up a form). When the form is created, the form designer determines which database actions are allowed on the specified tables and which menu options are displayed during form use. Table 5 shows all the menu options available with the EDIT command using a form.

Figure A-4. The EDIT Option.

Table 5 Menu Options With the EDIT Command

Option	Purpose
Edit	Moves you from the menu to the form so that the data displayed on the screen may be edited.
Save	Saves the changes that have been made on the displayed data, highlights the first table served by the form, and displays the data from the next row of that table. The rows that you changed are replaced in the table.
Add New	Makes a new copy of the highlighted row in its table and retains the original row without changes.
Delete	Deletes the highlighted row from its table and clears the row from the screen. Before this action takes place, a prompt asks you to confirm the command.
Reset	Resets the values in the highlighted row to their state before changes were made. Applies only to the highlighted row before changes have been saved to the database. After modifications have been stored, <i>Reset</i> can no longer be used to restore that row.
Previous	If changes have been made in the displayed data, asks for confirmation to save the changes to the database. Highlights the first table served by the form and displays the data from the previous row of that table.
Next	If changes have been made in the displayed data, asks for confirmation to save the changes to the database. Highlights the first table served by the form and displays the data from the next row of that table. The rows that you changed are replaced in the table.
Quit	Ends the session of form use. You can also leave the form by pressing [ESC].

Table 6 shows the function keys available when using a form.

Examples In each example, the form can be used to perform predefined database actions on the specified tables.

EDIT USING *transform* SORTED BY *custid*

Displays the form *transform* with the rows for the first specified table in customer id order.

EDIT USING *transform* WHERE *custid* = 100

Displays the form *transform* with only the rows for the first specified table in which the customer id number is equal to 100.

EDIT USING *transform* AT 5 WHERE *transid* EXISTS

Displays the form *transform* beginning at the fifth screen row, and displays all the rows from the first specified table that contain a value in the *transid* column.

Figure A-4 (Continued). The EDIT Option.

Table 6 Function Keys Used In Form Processing

Key	Purpose
[F2]	Erases the contents of the field from the screen.
[Shift-F2]	Starting with the cursor position, erases to the end of the field.
[F4]	Causes the last character typed to be repeated when you press the right or left arrow key. Press [F4] again to stop repeating the character.
[F5]	Resets the value of the current field to its original state (undoes edits).
[F7]†	Displays the previous row in the current table.
[F8]†	Displays the next row in the current table.
[F9]	Highlights the next table served by the form and moves you to the first field of that table.
[F10]	Displays help for the current field or page.
[Shift-F10]	Displays more function keys.
[Ins]	Inserts a space at the cursor.
[Del]	Deletes the character at the cursor.
[↑]	Moves to the previous line in a field with more than one line.
[↓]	Moves to the next line in a field with more than one line.
[Tab]	Moves to the next field in the current row. From the last field in a row, moves to the first field.
[Shift-Tab]	Move to the previous field in the current row. From the first field, go to the last field.
[ENTER]	Within a row, moves to the next field. From the last field in a row, moves to the next table. From the last field in a region that displays more than one row of data at a time, scrolls to the first field in the next row.
[PgUp]	Moves to the previous page in a multi-page form.
[PgDn]	Moves to the next page in a multi-page form.
[ESC]	From anywhere on the form, returns you to the menu. From the menu, returns you to the system from which you entered the form—the R> prompt or your application.

† When the form is used with the ENTER command, these keys apply only to rows entered in a region that displays multiple rows or rows displayed through master lookups.

EDI is the shortest form of the command name.

Figure A-5. Function Keys Used in Form Processing.

APPENDIX B

FORMING JOBS FROM CATEGORY 1 (OPERATOR) TASKS

The process for forming jobs from Category 1 tasks is drawn largely from the production scheduling and resource planning literature. Figure B-1 shows the process of creating these jobs. The steps are listed below.

1. Determine the technological sequence of tasks required to perform each function. (User may update original entered sequence.)
2. Develop a precedence network defining the task relationships to the required functions.
3. Determine the time required to perform each task under each set of environmental conditions. (Input earlier, user may update.)
4. Identify required response time for the job function and check task times against response time requirement. If one or more task times exceed the response time, the task(s) must be redesigned or the response time must be relaxed.
5. Identify constraints on assigning tasks to jobs due to proximity and simultaneity requirements.
6. Using automated resource allocation techniques, create work stations/jobs based on the precedence network and response time requirements.
7. Test the sensitivity of the number of work stations/jobs to the response time requirement.
8. List the possible job assignments and resulting response times.

Input to Step 1 is the task sequence entered by the user during data entry. Each task related to a given system function is selected by the user along with its immediate predecessor(s) (i.e., the task(s) that must be completed before it can begin). Note that all tasks related to a given function will fall in the same task group. The system design will drive the task sequence. The sequence will be determined by successively asking the question "What tasks must be completed before this task can begin?" The questioning process continues until all tasks related to a function have been placed in sequence (note that some tasks or series of tasks may be performed in parallel).

Step 2 formalizes the information collected in the first step by creating a network that reflects the aggregate set of precedence requirements associated with the successful accomplishment of a given function. The precedence network is important in that it identifies those tasks that must be performed in sequence and those that can (but not must) be done at the same time. This is done automatically.

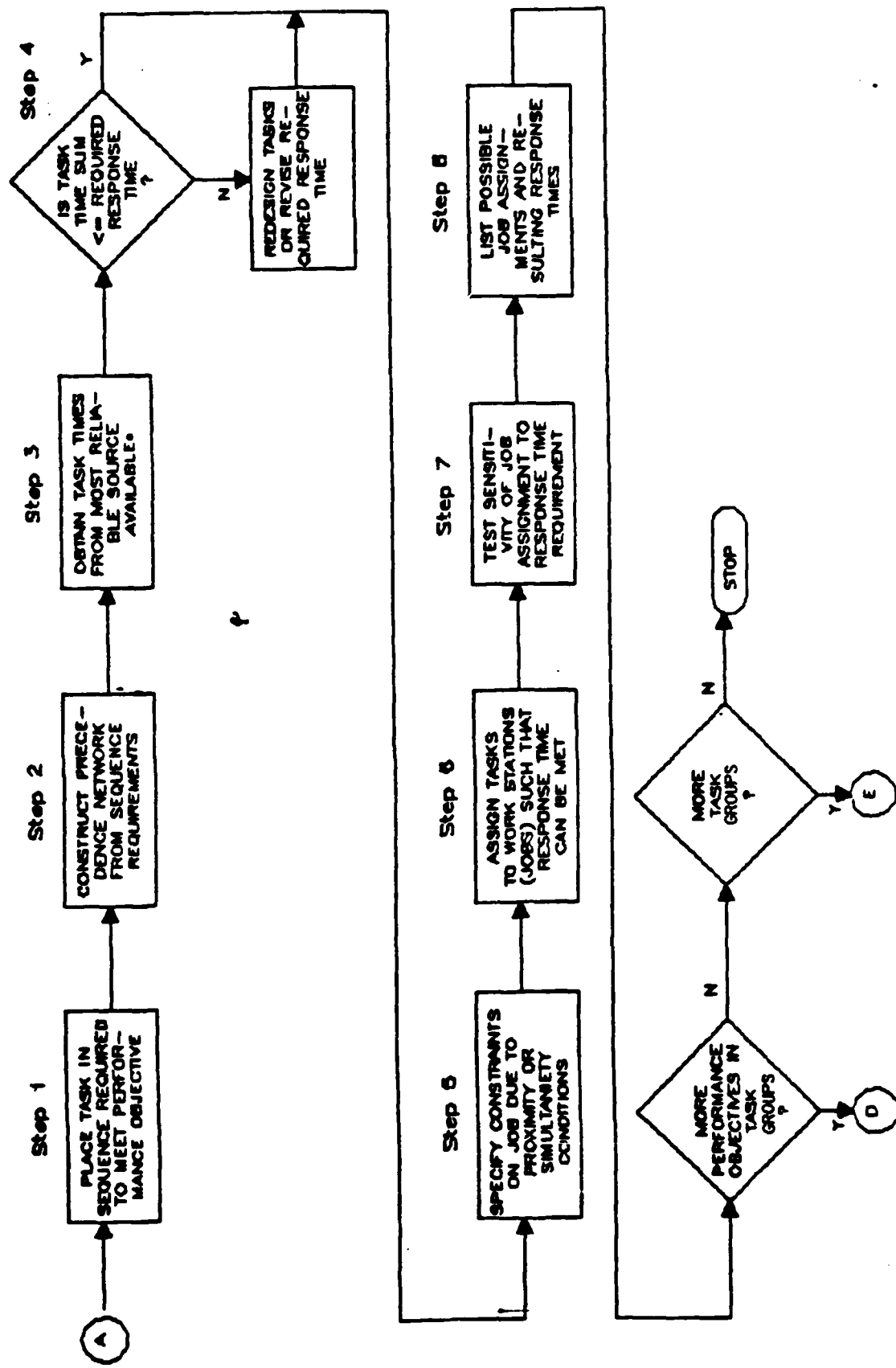


Figure B-1. Process for Converting Category 1 Tasks Into Jobs.

Step 3 assigns times to each of the tasks in the precedence network. The method that Product 5 will use to identify and assign task times was discussed earlier. An example of a precedence network (from Step 2) with task times (from Step 3) is shown in Figure B-2.

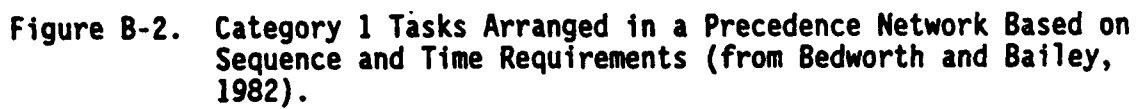
In Step 4, the response time requirement for the total job function is identified for the specific set of tasks required to accomplish the function. Note that the achievable response time for a function cannot be less than the greatest sum of all sets of required tasks that must be performed sequentially. If the sum of the task times for a required set of sequential tasks exceeds the required response time, then the response time cannot be achieved regardless of the crew size. In this case, either the response time must be relaxed or the system must be redesigned to reduce the time required to perform the tasks in the sequence.

Step 5 in the job forming process requires identification of any constraints that might affect the partitioning of tasks into jobs. These constraints will restrict the formation of jobs and may arise due spatial considerations (i.e., distance between working areas in which tasks are performed) or a requirement that two or more tasks occur simultaneously or in rapid succession. Tasks that cannot be combined into the same job will be tagged to ensure that they are not combined. Another form of constraint is one that requires a set of tasks to be performed by the same person. Constraints of this type may cause tasks from different job tasks to be combined in the same job. The user will be asked if simultaneity or proximity constrains job function. The system default will be "no" constraints.

Step 6 of the process is at the heart of the job forming process. The process makes use of a network analysis technique known as the critical path method (CPM) or critical path scheduling (CPS). In the case of Category 1 tasks, the objective is to determine the number of jobs required to meet the mission timeline requirements for completing all the tasks required to successfully accomplish the function.

Step 6 is an iterative process through which tasks are assigned to a given crew size such that the response time is minimized. If the minimum response time achievable with a given crew size is unacceptable (i.e., it fails to meet the system requirement), the crew size will be increased. This process will continue until the point where either the requirement is met or further increases in crew size do not decrease the response time. This process is repeated for each job task containing Category 1 tasks. In each case, the minimum number of jobs that can still meet the required response times is determined. The largest of these minimum requirements is the lower bound for jobs for the weapon system for Category 1 tasks. If any of the functions must be carried out simultaneously, the number of jobs must increase to permit all of the required tasks to be completed within the required time for all functions that must be completed together.

Several slightly different algorithms are available for implementing the resource allocation process described above. Lang (1977) provides a heuristic approach for allocating a single type of resource to tasks in a critical path network. An algorithm for allocating multiple resources was

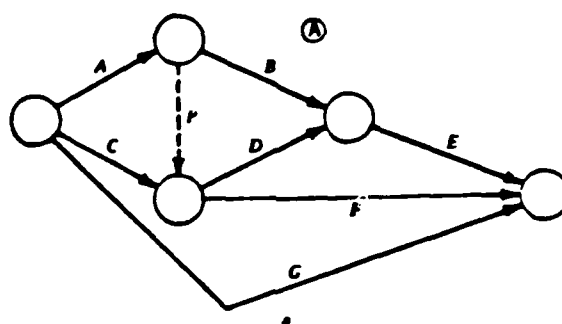


developed by Brooks (1963) and further extended by Bedworth (1973) and Bedworth and Bailey (1982). Bedworth and Bailey (1982) provided a computer coded algorithm that implements the Brook's algorithm.

Brook's (1963) algorithm (BAG) was selected for use in Product 5 for assigning Category 1 tasks to jobs. The computer coded algorithm is available for use in Product 5. The steps required to assign tasks (activities) to jobs (resources) are as follows. For convenience, Figure B-3 gives a network and tabular results of these steps based on three jobs.

- A. Develop the task network, identifying tasks and their required times.
- B. Determine the maximum time each task controls through the network on any one path. This is like calculating the critical-path time through the network assuming that the starting node for each task being analyzed is the network starting node. This activity control time will be designated ACTIM for convenience.
- C. Rank these times in decreasing ACTIM sequence, as in Figure B-3 (G, A, C, etc.). ACTIM for task A is found by summing the times for tasks A, D, and E, to obtain a total of 16. The rows titled TEARL, TSTART, TFIN, and TNOW are explained as follows:
 1. TEARL is the earliest possible time, because of precedence and time limitations, to schedule each task. The actual time will be equal to or later than TEARL. TEARL equals the latest TFIN time for all immediate predecessor tasks.
 2. TSTART is the actual start time of the task. If there were no job limitations, TSTART would always equal TEARL.
 3. TFIN is the completion time of each task. This equals the tasks TSTART added to the job-duration time.
 4. TNOW is the time at which job assignments are now being considered. Initially TNOW equals zero, but subsequently it equals the lowest TFIN time for all tasks currently being worked on.
- D. Sequence the tasks according to job constraints. TNOW is set at zero. The allowable tasks (ACT. ALLOW.) to be considered for scheduling at TNOW of zero are those tasks that would have a critical path method starting time of 0, namely tasks G, A, and C. These are placed in the ACT. ALLOW. row, sequenced in decreasing ACTIM order. In this example, G, A, and C all have the same ACTIM, and so a secondary rule is needed. For this example we will choose longest duration first, which dictates schedule G first. Another rule is needed for A and C, since both are five time-units long. Arbitrarily choose A before C. In the job-available column, the jobs initially available are placed--namely, three.

- STEP A: Develop Task Network
- STEP B: Determine Task Duration
- STEP C: Rank Tasks In Order of Network Durations (ACTIM)
- STEP D: Determine Job Resources Available (3)
- STEP E,F: Assign Tasks to Jobs, One Task at a Time in Network Order
- STEP G: Repeat Process Until Jobs are Formed



Activity	Duration	Resources Required
A	5	1
B	4	1
C	5	1
D	7	1
E	4	1
F	8	1
G	16	1
P	Pseudo	-

Activity		G	A	C	D	B	F	E	PROJECT COMPLETION TIME
ACTIVITY DATA	Duration	16	5	5	7	4	8	4	
	ACTIM (C)	16	16	16	11	8	8	4	
	Resources required	1	1	1	1	1	1	1	
	TEARL	0	0	0	5	5	5	12	
	TSTART	0	0	0	5	5	9	12	
	TFIN	16	5	5	12	9	17	16	
ALGORITHM ITERATION RESULTS	TNOW	0		(P) 5		9	12	(G)	
	Resources available	(D) 1	2	2	2	10	10		
	ACT ALLOW	(E) 1	2	2	2	1	1		
	Iteration No.	1	2	3	4				

Figure B-3. Brooks Algorithm Applied to Allocation of Category 1 Tasks to Multiple Jobs.

- E. Determine if the first task in ACT. ALLOW., G, can be assigned. It can, since three jobs are available and G requires only one. Also, no predecessor limitations prevent G from beginning. G is removed from the ACT. ALLOW. list and the number of jobs available is decreased by one to a value of two, since G required one job. TSTART for task G is set at the current TNOW and the TFIN is set a TSTART plus task G's duration time. Now it is necessary to determine if task G being completed will allow another task to be feasible at some future time. With G it is not, since G is itself an entire critical path. This same process is repeated for the remainder of ACT. ALLOW. tasks until the jobs available are depleted. In this case, all task G, A, and C could be assigned a TSTART of zero. From the network of Figure 11 it is seen that assigning task A allows task B to be scheduled a TEARL of five time-units later (task A's TFIN). Similarly, tasks D and F can be assigned a TEARL that is the latest of A's and C's TFIN times. Note that if task A had required too many resources to allow assignment at TNOW of zero, we would still see if task C could be assigned.
- F. TNOW is raised to the next TFIN time, which happens to be five, the completion times of both tasks A and C. The jobs available at TNOW of five is set to the number remaining after assigning resources at TNOW equal to zero (zero in this case), added to the number of jobs freed because of task completion at the new TNOW (two in this case). ACT. ALLOW. we now set at those not assigned at the previous TNOW (none in this case), added to those that have a TEARL equal to or less than TNOW (D, B, and F).
- G. Repeat this assignment process until all tasks have been scheduled. The latest TFIN gives the response time that can be achieved with the resources assigned--in this case, 17 time units. Three jobs have been scheduled.

Step 7 in the job forming process provides a means for investigating alternative numbers of jobs and assessing the effect of these alternatives on the ability of the system to meet performance requirements. For example, a slight relaxation in the performance requirement might result in a need for one less job. Conversely, by adding another job to a weapon system, system performance may increase dramatically. Systems designers and Army decision makers need to be aware of such swings in both requirements and performance in order to make rational design decision.

The product of this process will be a listing of the unique jobs that result from Category 1 tasks. With each job will be a listing of the specific tasks associated with the job. Also, for each function consisting of Category 1 tasks, a resource profile will be shown that indicates what each job is required to do, over what time period, and the proportion of the soldier's time that is spent doing the tasks assigned to the job.

FROM BEDWORTH AND BAILEY (1982).

RESALL PROGRAM

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IEEE461-LIBRARY(1).RESALL

1	C		A	5
2	C		A	10
3	C		A	15
4	C		A	20
5	C		A	25
6	C	THE RESALL PROGRAM	A	30
7	C		A	35
8	C	(RESOURCE ALLOCATION)	A	40
9	C		A	45
10	C	FOR FURTHER INFORMATION CONTACT	A	50
11	C	DAVID D. BEDWORTH	A	55
12	C	INDUSTRIAL ENGINEERING DEPARTMENT	A	60
13	C	ARIZONA STATE UNIVERSITY	A	65
14	C	TENPE, ARIZONA 85281	A	70
15	C		A	75
16	C		A	80
17	C		A	85
18	C		A	90
19	C		A	95
20	C	RESALL USES A HEURISTIC APPROACH TO ASSIGNING SCARCE	A	100
21	C	RESOURCES ON A CRITICAL PATH (CPM) TYPE PROJECT.	A	105
22	C	1. ASSIGNMENT OPTION: DETERMINES THE SHORTEST SCHEDULE	A	110
23	C	UNDER LIMITED MULTIPLE-RESOURCE CONSTRAINTS. A	A	115
24	C	MODIFICATION OF THE BROOKS ALGORITHM IS UTILIZED -	A	120
25	C	SEE PRODUCTION SYSTEMS CONTROL BY BEDWORTH AND BAILEY -	A	125
26	C	JOHN WILEY AND SONS - NEW YORK.	A	130
27	C		A	135
28	C	2. BALANCE OPTION: GIVEN A REQUIRED TIME SCHEDULE, THE	A	140
29	C	PROGRAM WILL DETERMINE THE MINIMUM AMOUNT OF A SINGLE	A	145
30	C	SCARCE RESOURCE TO ALLOW THE TIME SCHEDULE TO BE	A	150
31	C	MAINTAINED. AN ITERATIVE APPROACH USING OPTION ALLOCATION	A	155
32	C	IS UTILIZED.	A	160
33	C		A	165
34	C	RESALL ALLOWS FOR BOTH NORMAL AND OVERTIME OPERATION AND	A	170
35	C	COSTING FOR AN ASSIGNMENT RUN ONLY. ONLY A NORMAL RUN IS	A	175
36	C	ALLOWED FOR A BALANCING PROBLEM.	A	180
37	C		A	185
38	C	RESALL WILL COMPUTE BASIC CPM DATA IF DESIRED BUT WILL NOT	A	190
39	C	PERFORM A CRASHING COST OPTIMIZATION.	A	195
40	C		A	200
41	C		A	205
42	C		A	210
43	C		A	215
44	C		A	220
45	C		A	225

46	C	INPUT REQUIREMENTS, USING CARD FORMATS, ARE AS FOLLOWS:	A 230
47	C	CARD J REPRESENTS TYPE J. THERE SHOULD BE MORE THAN 1 CARD OF	A 235
48	C	TYPES J AND 8 FOR THIS PROGRAM.	240
49	C	(ALL INTEGER-FORMAT DATA IS RIGHT JUSTIFIED IN FIELD)	245
50	C	CARD 1, COLS 1 - 78: FORMAT 20A4, USER TITLE INFORMATION.	250
51	C	CARD 2, COLS 1 - 10: TOTAL NUMBER OF ACTIVITIES IN THE	255
52	C	PROJECT, BETWEEN 3 AND 100 INCLUSIVE,	260
53	C	FORMAT F10.0.	265
54	C	COLS 11- 20: TOTAL NUMBER OF RESOURCE TYPES,	270
55	C	BETWEEN 1 AND 20 INCLUSIVE, F10.0.	275
56	C	COLS 21- 30: CRITICAL PATH TIME FROM CPM PROGRAM	280
57	C	RUN. IF 0. IS INPUT, CPM DATA WILL	285
58	C	BE COMPUTED.	290
59	C	COLS 31- 40: FIXED (INDIRECT) COST PER TIME PERIOD,	295
60	C	F10.0. THIS MAY BE 0. FOR NO COSTING.	300
61	C	COLS 41- 50: STARTING TIME FOR NORMAL SCHEDULE	305
62	C	(USUALLY 0.), F10.0.	310
63	C	COLS 51- 60: STARTING TIME FOR OVERTIME SCHEDULE	315
64	C	(USUALLY 0.), F10.0.	320
65	C	COL 61: IF 0, INHIBITS DETAILED PRINTING FOR	325
66	C	EACH ITERATION. IF 1, GIVES DETAILED	330
67	C	PRINTING.	335
68	C	COL 62: IF 0, INHIBITS PRINTING OF FINAL	340
69	C	RESOURCE PROFILES OVER TIME. IF 1,	345
70	C	ALLOWS RESOURCE PROFILE PRINTING.	350
71	C	COLS 63- 67: IF 0, THIS IS ASSIGNMENT OPTION. IF	355
72	C	1., BALANCE - F5.0.	360
73	C	COLS 68- 77: TIME REQUIRED FOR PROJECT BALANCE	365
74	C	RUN - F10.0.	370
75	C		375
76	C	CARD 3+, COLS. 1-32, FORMAT 8A4, DESCRIPTION OF RESOURCE	380
77	C	- ONE CARD NEEDED FOR EACH RESOURCE - PUT IN SAME	385
78	C	SEQUENCE AS GIVEN ON TIME AND COST CARDS	390
79	C		395
80	C	CARD 4, NORMAL RESOURCE QUANTITIES, 2014 FORMAT. RESOURCE	400
81	C	1 IN COLS 1-4; RESOURCE 2 IN COLS 5-8 ETC. LEAVE	405
82	C	NON-USED RIGHT-JUSTIFIED RESOURCE	410
83	C	COLUMNS BLANK.	415
84	C		420
85	C	CARD 5, OVERTIME RESOURCE QUANTITIES - SAME PROCESS AS	425
86	C	FOR CARD 4 - FORMAT IS 2014.	430
87	C		435
88	C	CARD 6, NORMAL RESOURCE COSTS, 2014 - SAME PROCESS AS	440
89	C	FOR CARD 1. THESE ARE DIRECT COSTS.	445
90	C		450
91	C	CARD 7, OVERTIME RESOURCE COSTS, 2014 - SAME PROCESS AS	455
92	C	FOR CARD 4. THESE ARE DIRECT COSTS.	460
93	C		465
94	C	CARD 8+, ACTIVITY CARDS - ONE PER ACTIVITY:	470
95	C	COLS 1 - 3: TAIL NODE NUMBER, I3.	475
96	C	COLS 4 - 6: HEAD NODE NUMBER, I3.	480
97	C	COLS 7 - 9: EARLIEST START TIME FOR ACTIVITY	485
98	C	- NOT NEEDED IF CRITICAL PATH	488
99	C	FOUND IN THIS RUN. (I3)	A 495
100	C	COLS 10- 12: DURATION TIME FOR ACTIVITY, I3.	A 500
101	C	COLS 13- 15: TOTAL FLOAT FOR ACTIVITY, I3. NOT	A 505
102	C	NEEDED IF CRITICAL PATH FOUND IN	A 510
103	C	THIS RUN.	A 515
104	C	COLS 16- 18: FREE FLOAT FOR ACTIVITY, I3. NOT	A 520
105	C	NEEDED IF CRITICAL PATH FOUND IN	A 525
106	C	THIS RUN.	A 530
107	C	COLS 19- 78: RESOURCE QUANTITIES NEEDED FOR THIS	A 535
108	C	ACTIVITY, 2013. RESOURCE 1 IN COLS	A 540
109	C	19-21, RESOURCE 2 IN COLS 22-24,	A 545
110	C	ETC. UNUSED RIGHT-JUSTIFIED	A 550
111	C	RESOURCES LEAVE BLANK.	A 555

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112 C A 360
113 C ANOTHER SETUP MAY FOLLOW. TWO BLANK CARDS SIGNIFY LAST A 365
114 C SETUP A 370
115 C AN EXAMPLE OF DECK SET-UP FOLLOWS WHERE USER DOES NOT A 375
116 C FURNISH DATA FROM CPH RUN. TWO SCARCE RESOURCES ANALYZED: A 380
117 C A 385
118 C A 390
119 C RESALL ASSIGNMENT RUN - TEST. A 395
120 C 5. 2. 0. 0. 0. 0.00 0. A 400
121 C RESOURCE 1 A 405
122 C RESOURCE 2 A 410
123 C 3 4 A 415
124 C 2 2 A 420
125 C 25 30 A 425
126 C 40 60 A 430
127 C 1 2 0 5 0 0 2 3 A 435
128 C 2 4 0 7 0 0 1 1 A 440
129 C 1 3 0 3 0 0 3 2 A 445
130 C 3 4 0 10 0 0 2 0 A 450
131 C A 455
132 C A 460
133 C..... A 465
134 C..... A 470
135 C..... A 475
136 C A 480
137 C RESALL WAS COMPILED IN ASCII-FORTRAN ON A UNIVAC - 1110. A 485
138 C A 490
139 C..... A 495
140 C..... A 500
141 C..... A 505
142 C..... A 510
143 C BOUNDS ON RESALL PROBLEMS INCLUDE: A 515
144 C 1. A MINIMUM OF 3 PROJECT ACTIVITIES AND A MAXIMUM OF 100. A 520
145 C 2. A MINIMUM OF 1 RESOURCE AND A MAXIMUM OF 20. A 525
146 C 3. ONLY 1 RESOURCE ALLOWED FOR A BALANCE RUN. A 530
147 C 4. NO OVERTIME CONDITIONS ALLOWED FOR A BALANCE RUN. A 535
148 C..... A 540
149 C..... A 545
150 C..... A 550
151 C..... A 555
152 C A 560
153 C RESALL WAS ORIGINALLY DEVELOPED BY RICHARD MASON, WORKING A 565
154 C WITH DAVID DEBWORTH, FOR PART OF THE MS RESEARCH PAPER A 570
155 C TITLED AN ADAPTATION OF THE BROOKS ALGORITHM FOR SCHEDULING A 575
156 C PROJECTS UNDER MULTIPLE RESOURCE CONSTRAINTS - INDUSTRIAL A 580
157 C ENGINEERING DEPARTMENT, ARIZONA STATE UNIVERSITY, TEMPE:1970 A 585
158 C SUBSEQUENT CHANGES AND ADDITIONS WERE MADE BY DAVID DEBWORTH A 590
159 C A 595
160 C..... A 600
161 C..... A 605
162 C..... A 610
163 C..... A 615
164 C CHARACTER*4 TITLE(13), RTIT(20,30) A 620
165 C DIMENSION ESX(100), TENP(100), NRPL(100), POOL(22), USED(22), SP(2 A 625
166 C 12), IPBOL(22), IUSED(22), ISP(22), IT(100), IN(100), IASST(100), K A 630
167 C 2RES(20), NRES(20), KCSTN(20), LINE(110), MRCEN(200,20), KCSTO(20) A 635
168 C 3, MRCED(200,20), IASFT(100), ITENP(100) A 640
169 C COMMON T(100), N(100), DUR(100), ES(100), TF(100), FF(100), CPTD, A 645
170 C ISHORN, NACT, KEXIT, ASST(100), ASFT(100), RN(100,20), NRES A 650
171 C INTEGER OVERT, BLANK, RES(20), ORES(20), CSTN(20), CSTO(20), T, N, A 655
172 C 1 ES, DUR, TF, FF, RN A 660
173 C DATA NORN/1NM/, OVERT/1ND/, BLANK/1N / A 665
174 C A 670
175 C.....READ PROJECT HEADER - REQUIRED A 675
176 C A 680
177 C 5 READ 10,TITLE A 685

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178	10 FORMAT (13A6)	A 890
179	C	A 895
180	C*****READ PARAMETER CARD--TOTAL NUMBER OF ACTIVITIES, TOTAL	A 900
181	C*****TYPES OF RESOURCES, CRITICAL PATH TERMINATION DATE,	A 905
182	C*****FIXED COST RATE, START TIME OF NORMAL SCHEDULE, AND	A 910
183	C*****START TIME OF OVERTIME SCHEDULE.	A 915
184	C	A 920
185	READ 15,TACT,TRES,CPTD,FX,SMON,SOVER,IPPD,IRSH,BALNC,TREQ	A 925
186	15 FORMAT (AF10.0,2I1,FS.0,F10.0)	A 930
187	IF (TACT.EB.0.) CALL EXIT	A 935
188	NACT=TACT	A 940
189	NRES=TRES	A 945
190	OUT=0.	A 950
191	IVERTP=0	A 955
192	KEKIT=1	A 960
193	C	A 965
194	C*****READ RESOURCE HEADERS - ONE REQUIRED/RESOURCE	A 970
195	C	A 975
196	DO 20 I=1,NRES	A 980
197	READ 25,(RTIT(I,J),J=1,5)	A 985
198	20 CONTINUE	A 990
199	25 FORMAT (3A6)	A 995
200	C	A 1000
201	C*****READ NORMAL AND OVERTIME RESOURCE QUANTITY CARDS,	A 1005
202	C	A 1010
203	READ 30,(RES(I),I=1,20)	A 1015
204	READ 30,(ORES(J),J=1,20)	A 1020
205	30 FORMAT (20I4)	A 1025
206	C	A 1030
207	C*****READ NORMAL AND OVERTIME RESOURCE COST CARDS.	A 1035
208	C	A 1040
209	READ 30,(CSTN(J),J=1,20)	A 1045
210	READ 30,(CSTO(K),K=1,20)	A 1050
211	DO 35 I=1,20	A 1055
212	KRES(I)=RES(I)	A 1060
213	KORES(I)=ORES(I)	A 1065
214	KCSTN(I)=CSTN(I)	A 1070
215	KCSTO(I)=CSTO(I)	A 1075
216	35 CONTINUE	A 1080
217	C	A 1085
218	C*****INITIALIZE PERIOD RESOURCE VALUES.	A 1090
219	C	A 1095
220	DO 40 I=1,200	A 1100
221	DO 40 J=1,NRES	A 1105
222	NRCEH(I,J)=0	A 1110
223	40 NRCEH(I,J)=0	A 1115
224	C	A 1120
225	C*****READ ACTIVITY CARDS--TAIL, HEAD, EARLIEST START TIME,	A 1125
226	C*****DURATION, TOTAL FLOAT, FREE FLOAT--ALL DETERMINED BY	A 1130
227	C*****A PREVIOUS CPM ANALYSIS,	A 1135
228	C	A 1140
229	DO 45 I=1,NACT	A 1045
230	45 READ 50,T(I),N(I),ES(I),DUR(I),IF(I),FF(I),(RN(I,J),J=1,NRES)	A 1150
231	50 FORMAT (26I3)	A 1155
232	C	A 1160
233	C*****PRINT INPUT INFORMATION	A 1165
234	C	A 1170
235	INFLAG=1	A 1175
236	IF (CPTD.NE.0.) GO TO 55	A 1180
237	INFLAG=0	A 1185
238	CALL CRITIC	A 1190
239	55 PRINT 60	A 1195
240	60 FORMAT (1M1,2X,67NTHIS IS THE BEDFORTH-NASON ADAPTATION OF BROOKS	A 1200
241	1RESOURCE ALGORITHM.,///,2X,29NTHE DATA INPUT IS AS FOLLOWS:,,//)	A 1205
242	PRINT 65,TITLE	A 1210
243	65 FORMAT (///,2X,14NPROJECT TITLE:,13A6,///)	A 1215

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244      IF (INFLAG.EQ.0) GO TO 75      A 1220
245      PRINT 70                        A 1225
246      70 FORMAT (//,4X,30NCRITICAL PATH AND FLOATS INPUT BY USER,///)      A 1230
247      GO TO 85                        A 1235
248      75 PRINT 80                      A 1240
249      80 FORMAT (//,4X,42NCRITICAL PATH AND FLOATS NOT INPUT BY USER,///)      A 1245
250      85 PRINT 90,1ACT                A 1250
251      90 FORMAT (//,4X,21NNUMBER OF ACTIVITIES:,F14.0)      A 1255
252      PRINT 95,TRES                  A 1260
253      95 FORMAT (//,4X,25NNUMBER OF RESOURCE TYPES:,F10.0)      A 1265
254      PRINT 100,CPTD                 A 1270
255      100 FORMAT (//,4X,19NCRITICAL PATH TIME:,F16.0)      A 1275
256      PRINT 105,FX                   A 1280
257      105 FORMAT (//,4X,25NFIXED COST PER TIME UNIT:,F10.0)      A 1285
258      PRINT 110,SNORN                A 1290
259      110 FORMAT (//,4X,24NSTART TIME (NORMAL SCHED):,F9.0)      A 1295
260      PRINT 115,SOVER                A 1300
261      115 FORMAT (//,4X,24NSTART TIME (OVERTIME SCH):,F9.0)      A 1305
262      IF (BALNC.GT.0.) GO TO 125      A 1310
263      PRINT 120                      A 1315
264      120 FORMAT (//,4X,24NTHIS IS AN ALLOCATION RUN.)      A 1320
265      GO TO 135                      A 1325
266      125 PRINT 130,TRES              A 1330
267      130 FORMAT (//,4X,43NTHIS IS A BALANCING RUN. TIME REQUESTED IS:,F5.0)      A 1335
268      PRINT 140                      A 1340
269      140 FORMAT (//,4X,35NRESOURCE INFORMATION IS AS FOLLOWS:,/)      A 1345
270      PRINT 145                      A 1350
271      145 FORMAT (//,4X,8NRESOURCE,35X,8NQUANTITY,19X,4NCOST)      A 1355
272      PRINT 150                      A 1360
273      150 FORMAT (2X,13NNUMBER TITLE,30X,15NNORMAL OVERTIME,9X,15NNORMAL OV      A 1365
274      IERTIME,/)                      A 1370
275      DO 155 I=1,NRES                A 1375
276      155 PRINT 160,I,(RTIT(I,J),J=1,5),RES(I),ORES(I),CSTN(I),CSTO(I)      A 1380
277      160 FORMAT (4X,I3,3X,5A6,3X,I5,3X,I5,10X,I5,4X,I5)      A 1385
278      PRINT 165                      A 1390
279      PRINT 165                      A 1395
280      165 FORMAT (//,3X,21NACTIVITY INFORMATION:,/)      A 1400
281      PRINT 170                      A 1405
282      170 FORMAT (//,1X,14NIDENTIFICATION,1X,6NHEARLY,5X,5NTOTAL,2X,4NFREE,20      A 1410
283      1X,10NRESOURCES REQUIRED)      A 1415
284      PRINT 175                      A 1420
285      175 FORMAT (4X,9NTAIL-HEAD,3X,5NSTART,1X,4NTIME,1X,5NFLOAT,1X,84NFLOAT      A 1425
286      1 R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 R13 R14 R15 R16      A 1430
287      2X17 R18 R19 R20,/)      A 1435
288      DO 180 I=1,NACT                A 1440
289      180 PRINT 185,T(I),N(I),ES(I),DUR(I),TF(I),FF(I),IRN(I,J),J=1,NRES)      A 1445
290      185 FORMAT (4X,I3,2X,I3,4X,I3,3X,I3,3X,I3,3X,I3,1X,9I4,1X,11I4)      A 1450
291      IF (NACT.LT.3) GO TO 960      A 1455
292      C                                A 1460
293      C*****TEST FOR RESTRICTIONS ON RESOURCE BALANCING      A 1465
294      C                                A 1470
295      IF (BALNC.EQ.0.) GO TO 195      A 1475
296      IF (NRES.GT.1) GO TO 940      A 1480
297      IF (CPTD.GT.TRES) GO TO 950      A 1485
298      C                                A 1490
299      C*****DETERMINE STARTING RESOURCE LEVEL - MAXIMUM FOR ANY ACTIVITY      A 1495
300      C                                A 1500
301      MAXR=0                          A 1505
302      DO 190 I=1,NACT                A 1510
303      IF (RN(I,1).GT.MAXR) MAXR=RN(I,1)      A 1515
304      190 CONTINUE                  A 1520
305      RES(I)=MAXR                    A 1525
306      NCSTO(I)=0                     A 1530
307      ORES(I)=0                      A 1535
308      NORES(I)=0                     A 1540
309      KRES(I)=RES(I)                 A 1545
310      JRES=NRES(I)                  A 1550

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311	C	A 1355
312	C=====TEST FOR PROJECT FEASIBILITY. DETERMINE IF THE RESOURCE	A 1360
313	C=====REQUIREMENTS FOR ANY ACTIVITY EXCEED THOSE AVAILABLE.	A 1365
314	C	A 1370
315	195 DO 200 N=1,NRES	A 1375
316	200 POOL(N)=RES(N)+ORES(N)	A 1380
317	DO 205 I=1,MACT	A 1385
318	DO 205 J=1,NRES	A 1390
319	IF (POOL(J)-RM(I,J)) 775,205,205	A 1395
320	205 CONTINUE	A 1400
321	C	A 1405
322	C=====COMPUTE MAXIMUM REMAINING PATH LENGTHS.	A 1410
323	C	A 1415
324	DO 210 I=1,MACT	A 1420
325	SUM=ES(I)+TF(I)	A 1425
326	210 MRPL(I)=CPTD-SUM	A 1430
327	C	A 1435
328	C=====ARRANGE ACTIVITY DATA IN ORDER OF LONGEST REMAINING PATH	A 1440
329	C=====LENGTH, BREAK TIES BY RANKING THE ACTIVITY WITH THE	A 1445
330	C=====LONGEST DURATION FIRST.	A 1450
331	C	A 1455
332	215 KRUB=0	A 1460
333	ML1=MACT-1	A 1465
334	DO 240 I=1,ML1	A 1470
335	IP1=I+1	A 1475
336	DO 235 J=IP1,MACT	A 1480
337	IF (MRPL(I)-MRPL(J)) 225,220,235	A 1485
338	220 IF (BUR(I).GE.BUR(J)) GO TO 235	A 1490
339	KRUB=1	A 1495
340	225 DO 230 L=1,NRES	A 1500
341	TENP(L)=RM(I,L)	A 1505
342	RM(I,L)=RM(J,L)	A 1510
343	230 RM(J,L)=TENP(L)	A 1515
344	SORT=MRPL(I)	A 1520
345	MRPL(I)=MRPL(J)	A 1525
346	MRPL(J)=SORT	A 1530
347	SORT=T(I)	A 1535
348	T(I)=T(J)	A 1540
349	T(J)=SORT	A 1545
350	SORT=N(I)	A 1550
351	N(I)=N(J)	A 1555
352	N(J)=SORT	A 1560
353	SORT=ES(I)	A 1565
354	ES(I)=ES(J)	A 1570
355	ES(J)=SORT	A 1575
356	SORT=DUR(I)	A 1580
357	DUR(I)=DUR(J)	A 1585
358	DUR(J)=SORT	A 1590
359	SORT=FF(I)	A 1595
360	FF(I)=FF(J)	A 1600
361	FF(J)=SORT	A 1605
362	SORT=TF(I)	A 1610
363	TF(I)=TF(J)	A 1615
364	TF(J)=SORT	A 1620
365	235 CONTINUE	A 1625
366	240 CONTINUE	A 1630
367	IF (KRUB) 245,245,215	A 1635
368	C	A 1640
369	C=====INITIALIZE TEMPORARY STORAGE LOCATIONS.	A 1645
370	C	A 1650
371	245 PTIME=SHORN	A 1655
372	IF (OUT.GT.0.0) PTIME=SOVER	A 1660
373	CORR=0.0	A 1665
374	TIME=0.	A 1670
375	OUT=0.	A 1675
376	IACT=0.	A 1680
377	PSFT=0.	A 1685

378	SUPP=0.	A 1890
379	OVER=0.	A 1895
380	TOT=0.	A 1900
381	COST=0.	A 1905
382	CHORN=0.	A 1910
383	TFIX=0.	A 1915
384	TITLE=0.	A 1920
385	THORN=0.	A 1925
386	TOVER=0.	A 1930
387	TOTAL=0.	A 1935
388	OUNT=4	A 1940
389	DO 250 J=1,22	A 1945
390	250 SP(J)=0.	A 1950
391	DO 255 I=1,NACT	A 1955
392	ESX(I)=ES(I)	A 1960
393	ASFT(I)=0.	A 1965
394	TEMP(I)=0.	A 1970
395	255 USED(I)=0.	A 1975
396	C	A 1980
397	C=====COMPUTE THE COST OF NORMAL AND OVERTIME RESOURCES.	A 1985
398	C=====PRINT APPROPRIATE OUTPUT TITLES.	A 1990
399	C	A 1995
400	DO 260 N=1,NRES	A 2000
401	CH=CSTN(N)+RES(N)	A 2005
402	CO=CSTO(N)+ORES(N)	A 2010
403	OUT=OUT+CO	A 2015
404	260 COST=COST+CH	A 2020
405	PRINT 265	A 2025
406	265 FORMAT (1H1)	A 2030
407	IF (BALNC.OT.0.) GO TO 270	A 2035
408	IF (IPPD.NE.1) GO TO 345	A 2040
409	PRINT 275	A 2045
410	GO TO 290	A 2050
411	270 PRINT 280	A 2055
412	PRINT 285	A 2060
413	275 FORMAT (/,54X,25HTHIS IS AN ALLOCATION RUN)	A 2065
414	280 FORMAT (/,54X,23HTHIS IS A BALANCING RUN)	A 2070
415	285 FORMAT (///,4X,91HOVERTIME RESOURCES ARE OF NO BENEFIT IN A BALANC	A 2075
416	ING RUN. IF AN OVERTIME QUANTITY WAS INPUT,/,4X,60HBY THE USER IT	A 2080
417	2 WILL BE SET TO ZERO BY THIS PROGRAM BEFORE BALANCING.,//)	A 2085
418	290 IF (OUT) 305,305,295	A 2090
419	295 PRINT 300	A 2095
420	300 FORMAT (59X,17HOVERTIME SCHEDULE,/))	A 2100
421	GO TO 325	A 2105
422	305 PRINT 310	A 2110
423	310 FORMAT (60X,15HNORMAL SCHEDULE,/))	A 2115
424	IF (BALNC.EO.0.) GO TO 325	A 2120
425	PRINT 315,JRES	A 2125
426	315 FORMAT (/,10X,27HSTARTING RESOURCE LEVEL IS ,13,6H UNITS)	A 2130
427	KREQ=TREQ	A 2135
428	PRINT 320,KREQ	A 2140
429	320 FORMAT (/,10X,26HMAXIMUM TIME REQUESTED IS ,14,11H TIME UNITS)	A 2145
430	GO TO 340	A 2150
431	325 PRINT 330	A 2155
432	330 FORMAT (46X,35HPERIOD RESOURCES CONSUMED AND COSTS,ON SUMMARY,/))	A 2160
433	PRINT 335	A 2165
434	335 FORMAT (7X,8HACTIVITY,30X,15HRESOURCE VALUES)	A 2170
435	PRINT 340	A 2175
436	340 FORMAT (2X,11HPERIOD SLIP,2X,110HR1 R2 R3 R4 R5 R6 R7 R8 R	A 2180
437	19 R10 R11 R12 R13 R14 R15 R16 R17 R18 R19 R20 FIXED IDLE N	A 2185
438	20R1AL OVER TOTAL)	A 2190
439	345 DO 350 J=1,20	A 2195
440	350 IPOL(J)=POOL(J)	A 2200
441	IF (IPPD.NE.1) GO TO 340	A 2205
442	PRINT 355,(IPOL(J),J=1,20)	A 2210
443	355 FORMAT (2X,11HQUANTITY: (,2014,1H),//)	A 2215

444	C	A 2220
445	C=====COMPUTE FIXED COSTS, AND IDLE, NORMAL, AND OVERTIME	A 2225
446	C=====RESOURCE COSTS, AND SUM TO FIND THE TOTAL COST FOR A	A 2230
447	C=====GIVEN TIME PERIOD.	A 2235
448	C	A 2240
449	340 DO 345 L=1,1000	A 2245
450	IF (IAC7) 455,455,345	A 2250
451	345 DO 380 I=1,NRES	A 2255
452	USED(I)=RES(I)+ORES(I)-POOL(I)	A 2260
453	OT=USED(I)-RES(I)	A 2265
454	IF (OT) 375,380,370	A 2270
455	370 CBT=CSTO(I)+OT	A 2275
456	OVER=OVER+CBT	A 2280
457	GO TO 380	A 2285
458	375 UU=RES(I)-USED(I)	A 2290
459	SP(1)=CBT(I)+UU	A 2295
460	SUPP=SUPP+SP(1)	A 2300
461	380 CONTINUE	A 2305
462	CNORM=CST-SUPP	A 2310
463	IF (NACT-IAC7) 385,385,390	A 2315
464	385 IF (PSFT-TIME) 570,390,390	A 2320
465	390 TOT=FIX+SUPP+CNORM+OVER	A 2325
466	IF (BALNC.GT.0.) GO TO 400	A 2330
467	IF (IPPD.NE.1) GO TO 400	A 2335
468	IF (NDUNT-20) 400,400,395	A 2340
469	C	A 2345
470	C=====PRINT FOR THE CURRENT TIME PERIOD THE RESOURCES CONSUMED	A 2350
471	C=====AND COST SUMMARY INFORMATION.	A 2355
472	C	A 2360
473	395 PRINT 500	A 2365
474	PRINT 245	A 2370
475	PRINT 340	A 2375
476	KOUNT=0	A 2380
477	400 DO 415 J=1,NRES	A 2385
478	IUSED(J)=USED(J)	A 2390
479	IF (OUT) 405,405,410	A 2395
480	405 NRCE(L,J)=IUSED(J)	A 2400
481	GO TO 415	A 2405
482	410 NRCE(L,J)=IUSED(J)	A 2410
483	415 CONTINUE	A 2415
484	ITIME=PTIME	A 2420
485	JTIME=L	A 2425
486	IF (BALNC.GT.0.) GO TO 430	A 2430
487	IF (IPPD.NE.1) GO TO 430	A 2435
488	PRINT 420,ITIME,(IUSED(J),J=1,NRES)	A 2440
489	420 FORMAT (/,'IN',I3,'H *****',20I4)	A 2445
490	PRINT 425,FIX,SUPP,CNORM,OVER,TOT	A 2450
491	425 FORMAT (7I1,26MCOSTS FOR THIS PERIOD ARE:,5F7.0,/,)	A 2455
492	KOUNT=KOUNT+2	A 2460
493	430 TFIX=TFIX+FIX	A 2465
494	TIDLE=TIDLE+SUPP	A 2470
495	TNORM=TNORM+CNORM	A 2475
496	TOVER=TOVER+OVER	A 2480
497	TOTAL=TOTAL+TOT	A 2485
498	SUPP=0.	A 2490
499	CNORM=0.	A 2495
500	OVER=0.	A 2500
501	TOT=0.	A 2505
502	C	A 2510
503	C=====DETERMINE IF ANY ACTIVITIES END AT THE END OF THE	A 2515
504	C=====CURRENT TIME PERIOD. IF SO, PLACE THEIR RESOURCES BACK	A 2520
505	C=====INTO THE POOL.	A 2525
506	C	A 2530
507	DO 450 I=1,NACT	A 2535
508	ETIME=ASFT(I)-CORR	A 2540
509	IF (TIME-ETIME) 450,455,450	A 2545

310	435 IF (ABST(I)) 450,450,440	A 2330
311	440 DO 445 J=1,NRES	A 2335
312	POOL(J)=POOL(J)+RN(I,J)	A 2340
313	445 CONTINUE	A 2345
314	450 CONTINUE	A 2350
315	C	A 2355
316	C*****DETERMINE IF ANY ACTIVITIES ARE SCHEDULED TO START AT	A 2360
317	C*****THE END OF THE CURRENT TIME PERIOD. IF SO, DETERMINE	A 2365
318	C*****THE ORDER IN WHICH RESOURCES ARE TO BE ALLOCATED.	A 2370
319	C*****PRIORITY IS GIVEN TO THE ACTIVITY WITH THE LONGEST	A 2375
320	C*****REMAINING PATH LENGTH. IF THERE ARE INSUFFICIENT	A 2380
321	C*****RESOURCES, SLIP THE ACTIVITY ONE TIME UNIT FOR	A 2385
322	C*****CONSIDERATION IN THE NEXT TIME PERIOD.	A 2390
323	C	A 2395
324	455 DO 535 I=1,MACT	A 2400
325	SHORT=0.	A 2405
326	IF (TIME-ESX(I)) 535,460,460	A 2410
327	460 DO 470 J=1,NRES	A 2415
328	POOL(J)=POOL(J)-RN(I,J)	A 2420
329	IF (POOL(J)) 465,470,470	A 2425
330	465 SHORT=SHORT+POOL(J)	A 2430
331	470 CONTINUE	A 2435
332	IF (SHORT) 475,520,520	A 2440
333	475 DO 480 N=1,NRES	A 2445
334	SP(N)=POOL(N)	A 2450
335	480 POOL(N)=POOL(N)+RN(I,N)	A 2455
336	ESX(I)=ESX(I)+1.	A 2460
337	DO 490 NN=1,NRES	A 2465
338	IF (SP(NN)) 490,490,485	A 2470
339	485 SP(NN)=0.	A 2475
340	490 CONTINUE	A 2480
341	IF (BALNC.BT.0.) GO TO 505	A 2485
342	IF (IPPD.NE.1) GO TO 545	A 2490
343	IF (COUNT-20) 505,505,495	A 2495
344	495 PRINT 500	A 2500
345	500 FORMAT (3X,24HFOR THE ABOVE INFORMATION,/,3X,10H1. ***** FOR A	A 2505
346	ACTIVITY SLIP MEANS THAT THE FOLLOWING RESOURCES WERE CONSUMED DURI	A 2510
347	2HSTHAT TIME PERIOD.,/,3X,10H2. WHERE ACTIVITY IS LISTED UNDER ACT	A 2515
348	IVITY SLIP, IT MEANS THAT ACTIVITY COULD NOT BE SCHEDULED IN THAT	A 2520
349	4TIME,/,3X,9HPERIOD BECAUSE OF A RESOURCE SHORTAGE. THE RESOURCE C	A 2525
350	5AN BE IDENTIFIED BY A NEGATIVE QUANTITY.)	A 2530
351	PRINT 245	A 2535
352	PRINT 340	A 2540
353	COUNT=0	A 2545
354	C	A 2550
355	C*****PRINT THE ELIGIBLE ACTIVITY THAT HAS BEEN SLIPPED DUE TO	A 2555
356	C*****A LACK OF RESOURCES AND IDENTIFY THE RESOURCE SHORTAGES,	A 2560
357	C	A 2565
358	505 TYPE=PTIME+1.	A 2570
359	ITIME=TYPE	A 2575
360	IT(I)=T(I)	A 2580
361	IN(I)=N(I)	A 2585
362	DO 510 J=1,NRES	A 2590
363	510 ISP(J)=SP(J)	A 2595
364	IF (BALNC.BT.0.) GO TO 530	A 2600
365	IF (IPPD.NE.1) GO TO 530	A 2605
366	PRINT 515,ITIME,IT(I),IN(I),(ISP(NN),NN=1,NRES)	A 2610
367	515 FORMAT (/,1X,13,1X,13,2H -,13,2014)	A 2615
368	COUNT=COUNT+1	A 2620
369	GO TO 530	A 2625
370	C	A 2630
371	C*****SCHEDULE THE ACTIVITY, AND THEN REMOVE IT FROM FUTURE	A 2635
372	C*****CONSIDERATION. COUNT ACTIVITIES SCHEDULED. COMPUTE	A 2640
373	C*****CURRENT LATEST PROJECT SCHEDULED FINISH TIME.	A 2645
374	C	A 2650
375	520 ABST(I)=PTIME	A 2655

376	ASFT(I)=PTIME+DUR(I)	A 2880
377	ES(I)=ES(I)+9999.	A 2885
378	ESX(I)=ES(I)	A 2890
379	IACT=IACT+1	A 2895
380	IF (ASFT(I)-PSFT) 530,530,525	A 2900
381	525 PSFT=ASFT(I)	A 2905
382	530 TEMP(I)=ASFT(I)	A 2910
383	535 CONTINUE	A 2915
384	C	A 2920
385	C===== TEST ACTIVITIES TO SEE IF SLIPPAGE CAN BE ABSORBED WITH	A 2925
386	C=====FREE FLOAT, IF NOT, COMPUTE ACTIVITY DELAY, AND THEN	A 2930
387	C=====ADJUST ACCORDINGLY THE EARLIEST START TIME OF THE	A 2935
388	C=====ACTIVITY AND THE EARLIEST START TIMES OF ANY IMMEDIATE	A 2940
389	C=====DEPENDENT ACTIVITIES.	A 2945
390	C	A 2950
391	DO 540 I=1,NACT	A 2955
392	IF (ES(I)-ESX(I)) 540,540,540	A 2960
393	540 DIFF=ESX(I)-ES(I)	A 2965
394	IF (FF(I)-DIFF) 545,540,540	A 2970
395	545 BLAY=DIFF-FF(I)	A 2975
396	HEAD=H(I)	A 2980
397	DO 555 K=1,NACT	A 2985
398	IF (T(K)-HEAD) 555,550,555	A 2990
399	550 ESX(K)=ES(K)+BLAY	A 2995
400	555 CONTINUE	A 3000
401	560 CONTINUE	A 3005
402	TIME=TIME+1.	A 3010
403	IF (IACT.GT.0) PTIME=PTIME+1.	A 3015
404	IF (IACT.GT.0) CORR=PTIME-TIME	A 3020
405	565 CONTINUE	A 3025
406	IF (BALNC.GT.0.) GO TO 605	A 3030
407	IF (IPPD.NE.1) GO TO 575	A 3035
408	IF (ROUNT.GT.0) PRINT 500	A 3040
409	IF (ROUNT-20) 590,590,575	A 3045
410	570 IF (BALNC.GT.0.) GO TO 580	A 3050
411	IF (IPPD.NE.1) GO TO 575	A 3055
412	IF (ROUNT.GT.0) PRINT 500	A 3060
413	IF (ROUNT-16) 590,590,575	A 3065
414	575 PRINT 265	A 3070
415	GO TO 590	A 3075
416	580 PRINT 505,KRES(1)	A 3080
417	585 FORMAT (/,10X,39HRESOURCE FOR THIS ITERATION WAS SET AT ,13,7H UNI	A 3085
418	ITS.)	A 3090
419	590 IF (OUT) 620,620,595	A 3095
420	595 PRINT 600	A 3100
421	600 FORMAT (////)	A 3105
422	PRINT 300	A 3110
423	GO TO 630	A 3115
424	605 PRINT 265	A 3120
425	PRINT 610,TITLE	A 3125
426	610 FORMAT (13A6,//)	A 3130
427	PRINT 615,KRES(1)	A 3135
428	615 FORMAT (/,10X,39HRESOURCE FOR THIS ITERATION WAS SET AT ,13,7H UNI	A 3140
429	ITS.)	A 3145
430	GO TO 635	A 3150
431	620 PRINT 625	A 3155
432	625 FORMAT (////)	A 3160
433	PRINT 310	A 3165
434	630 PRINT 635	A 3170
435	635 FORMAT (//,50X,19HTOTAL PROJECT COSTS,//)	A 3175
436	PRINT 640	A 3180
437	640 FORMAT (35X,5NFIXED,11X,4NIDLE,9X,6NNORMAL,7X,8NOVERTIME,10X,5NTOT	A 3185
438	1AL,//)	A 3190
439	PRINT 645,TFIX,TIDLE,TNORM,TOVER,TOTAL	A 3195
440	645 FORMAT (25X,5F15.0)	A 3200
441	PRINT 650	A 3205

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642      450 FORMAT (//,35X,44NA DETAILED SCHEDULE FOR THIS RUN IS GIVEN ON THE A 3210
643      1 NEXT OUTPUT PAGE.) A 3205
644      C A 3220
645      C=====PRINT PROJECT ACTIVITY SCHEDULE, WHICH CONSISTS OF A A 3225
646      C=====LISTING OF THE REVISED ACTIVITY START AND FINISH TIMES, A 3230
647      C A 3235
648      655 PRINT 265 A 3240
649      KKK=13 A 3245
650      IF (OUT) 670,670,660 A 3250
651      660 PRINT 665 A 3255
652      665 FORMAT (//,20X,17HOVERTIME SCHEDULE,/) A 3260
653      660 TO 660 A 3265
654      670 PRINT 675 A 3270
655      675 FORMAT (//,29X,15HNORMAL SCHEDULE,/) A 3275
656      680 PRINT 685 A 3280
657      685 FORMAT (//,24X,26H PROJECT ACTIVITY SCHEDULE,/) A 3285
658      ICPTB=CP7B A 3290
659      PRINT 690,ICPTB A 3295
660      690 FORMAT (19X,30HCRITICAL PATH TERMINATION DATE,IS,///) A 3300
661      PRINT 695 A 3305
662      695 FORMAT (14X,30HTHESE ARE THE REVISED START AND FINISH,6H TIMES,/) A 3310
663      PRINT 700 A 3315
664      700 FORMAT (/,21X,32H ACTIVITY START FINISH) A 3320
665      PRINT 705 A 3325
666      705 FORMAT (20X,10HTAIL HEAD,8X,15H(END OF PERIOD),/) A 3330
667      C A 3335
668      C=====USE CRITIC SUBROUTINE TO REORDER ACTIVITIES A 3340
669      C=====PRIOR TO PRINTING THE FINAL SCHEDULE. A 3345
670      C A 3350
671      NEXIT=0 A 3355
672      CALL CRITIC A 3360
673      DO 720 I=1,NACT A 3365
674      KKK=KKK+1 A 3370
675      IF (KKK=53) 715,715,710 A 3375
676      710 PRINT 265 A 3380
677      PRINT 700 A 3385
678      PRINT 705 A 3390
679      KKK=0 A 3395
680      715 J(I)=7(I) A 3400
681      IN(I)=N(I) A 3405
682      IASST(I)=ASST(I) A 3410
683      IASFT(I)=ASFT(I) A 3415
684      720 PRINT 725,IT(I),IN(I),IASST(I),IASFT(I) A 3420
685      725 FORMAT (20X,13,3H - ,13,7X,13,9X,13) A 3425
686      DO 735 I=1,NL1 A 3430
687      IP1=I+1 A 3435
688      DO 735 J=IP1,NACT A 3440
689      IF (TEMP(I)-TEMP(J)) 730,735,735 A 3445
690      730 SORT=TEMP(I) A 3450
691      TEMP(I)=TEMP(J) A 3455
692      TEMP(J)=SORT A 3460
693      735 CONTINUE A 3465
694      ITEMP(I)=TEMP(I) A 3470
695      IF (OUT.GT.0.) IVERTP=ITEMP(I) A 3475
696      PRINT 740,ITEMP(I) A 3480
697      740 FORMAT (//,15X,27HMINIMUM PROJECT DURATION = ,13,11H TIME UNITS) A 3485
698      IF (BALNC.GT.0.) 60 TO 790 A 3490
699      C A 3495
700      C=====TEST TO DETERMINE IF THE SCHEDULE JUST PRINTED WAS AN A 3500
701      C=====OVERTIME SCHEDULE. IF SO, ZERO THE OVERTIME RESOURCE A 3505
702      C=====AND COST ARRAYS, AND THEN REPEAT THE PROGRAM TO COMPUTE A 3510
703      C=====THE NORMAL SCHEDULE. A 3515
704      C A 3520
705      745 IF (OUT) 785,785,750 A 3525
706      750 IF (BALNC.EQ.0.) 60 TO 755 A 3530
707      KORESL=KRES(1) A 3535

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708	KRES(1)=JRES-ORES(1)	A 3540
709	JRES=KRES(1)	A 3545
710	795 DO 760 K0=1,NRES	A 3550
711	ORES(K0)=0.	A 3555
712	760 CSTQ(K0)=0.	A 3560
713	765 DO 770 N0=1,MACT	A 3565
714	770 ES(N0)=ES(N0)-0.	A 3570
715	GO TO 195	A 3575
716	775 PRINT 780	A 3580
717	780 FORMAT (///,10X,90MPROJECT COULD NOT BE COMPLETED AS RESOURCES REQ	A 3585
718	UIRED EXCEEDED AVAILABLE RESOURCES ON THE NEXT RUN.)	A 3590
719	GO TO 5	A 3595
720	785 IF (BALNC.ST.0.) GO TO 795	A 3600
721	GO TO 810	A 3605
722	790 IF (ITEMP(1).ST.TREQ) GO TO 805	A 3610
723	GO TO 745	A 3615
724	795 KNRSL=KRES(1)	A 3620
725	PRINT 800	A 3625
726	800 FORMAT (///,50X,17MBALANCE COMPLETE.)	A 3630
727	GO TO 810	A 3635
728	805 RES(1)=KRES(1)+1.0	A 3640
729	KRES(1)=RES(1)	A 3645
730	GO TO 765	A 3650
731	C	A 3655
732	C*****PRINT RESOURCE UTILIZATION PROFILES	A 3660
733	C	A 3665
734	810 K=1	A 3670
735	IF (IRSN.NE.1) GO TO 5	A 3675
736	KTIME=JTIME	A 3680
737	JTIME=JTIME-1	A 3685
738	815 PRINT 820,K	A 3690
739	820 FORMAT (1H1,50X,15HRESOURCE NUMBER,1X,12,1X,7HSUMMARY,//)	A 3695
740	PRINT 825,(RTIT(K,J),J=1,5)	A 3700
741	825 FORMAT (20X,16HRESOURCE ITEM IS,1X,5A6)	A 3705
742	IF (BALNC.ST.0.) GO TO 830	A 3710
743	KTOT=KRES(K)+KORES(K)	A 3715
744	GO TO 835	A 3720
745	830 KTOT=0	A 3725
746	KRES(1)=KNRSL	A 3730
747	835 PRINT 840,KRES(K),KTOT	A 3735
748	840 FORMAT (20X,23HNORMAL QUANTITY IS, ,13,20X,21HOVERTIME QUANTITY	A 3740
749	1 IS,13,23H. (NORMAL AND OVERTIME))	A 3745
750	PRINT 845,KCSTN(K),KCSTO(K)	A 3750
751	845 FORMAT (20X,23HNORMAL COST/PERIOD IS, ,13,20X,21HOVERTIME COST/PER	A 3755
752	IODS,13,//)	A 3760
753	PRINT 850	A 3765
754	850 FORMAT (52X,23HUTILIZATION INFORMATION,//)	A 3770
755	PRINT 855	A 3775
756	855 FORMAT (20X,15HNORMAL SCHEDULE,25X,17HOVERTIME SCHEDULE)	A 3780
757	PRINT 860	A 3785
758	860 FORMAT (14X,8HQUANTITY,6X,19HPERCENT UTILIZATION,9X,8HQUANTITY,6X,	A 3790
759	119HPERCENT UTILIZATION)	A 3795
760	PRINT 865	A 3800
761	865 FORMAT (5X,4HTIME,7X,4HUSED,7X,22H0 1 2 3 4 5 6 7 8 9 10,9X,4HUSED	A 3805
762	1,7X,22H0 1 2 3 4 5 6 7 8 9 10,//)	A 3810
763	DO 870 N=1,110	A 3815
764	870 LINE(N)=BLANK	A 3820
765	DO 930 L=2,KTIME	A 3825
766	IPT=((((NRCE(L,K))+21.)/(KRES(K)))+20.	A 3830
767	JPT=((((NRCE(L,K))+21.)/(KRES(K)+KORES(K)))+70.	A 3835
768	DO 875 N=28,IPT	A 3840
769	875 LINE(N)=NORN	A 3845
770	KFLAG=0	A 3850
771	DO 890 N=70,JPT	A 3855
772	IF (L-IVERTP-1) 880,890,885	A 3860
773	880 LINE(N)=OVERT	A 3865

774	GO TO 890	A 3870
775	885 KFLAG=1	A 3875
776	890 CONTINUE	A 3880
777	LT=L-1	A 3885
778	IF (KFLAG) 895,895,905	A 3890
779	895 PRINT 900,LT,MRCEN(L,K),(LINE(I),I=20,49),MRCEN(L,N),(LINE(I),I=70	A 3895
780	1,91)	A 3900
781	900 FORMAT (3X,13,8X,13,8X,22A1,8X,13,9X,22A1)	A 3905
782	GO TO 915	A 3910
783	905 PRINT 910,LT,MRCEN(L,K),(LINE(I),I=20,49),(LINE(I),I=70,91)	A 3915
784	910 FORMAT (3X,13,8X,13,8X,22A1,20X,22A1)	A 3920
785	915 DO 920 N=20,1PT	A 3925
786	920 LINE(N)=BLANK	A 3930
787	DO 925 N=70,1PT	A 3935
788	925 LINE(N)=BLANK	A 3940
789	930 CONTINUE	A 3945
790	PRINT 935	A 3950
791	935 FORMAT (//,30X,39NPARTIAL OVERTIME UTILIZATION ASSUMES NORMAL QUAN	A 3955
792	TITIES USED,/,30X,72WFULLY BEFORE OVERTIME FOR COSTING. FOR EXAMPL	A 3960
793	2E, IF THE OVERTIME QUANTITY,/,30X,60H(NORMAL AND OVERTIME) IS 2 AM	A 3965
794	3D ONLY 1 UNIT IS USED, THEN THE,/,30X,53HUTILIZATION COST IS NORMA	A 3970
795	4L AND THE IDLE COST IS ZERO.)	A 3975
796	K=K+1	A 3980
797	IF (MRES.GE.K) GO TO 815	A 3985
798	GO TO 5	A 3990
799	940 PRINT 945	A 3995
800	945 FORMAT (1M0,2X,73MNO BALANCE AS NUMBER OF RESOURCE TYPES IS GREATE	A 4000
801	1R THAN 1 - RUN TERMINATED)	A 4005
802	GO TO 5	A 4010
803	950 PRINT 955	A 4015
804	955 FORMAT (1M0,2X,72MNO BALANCE AS TIME REQUIRED IS LESS THAN CRITICA	A 4020
805	1L PATH TERMINATION DATE)	A 4025
806	GO TO 5	A 4030
807	960 PRINT 965	A 4035
808	965 FORMAT (1M0,2X,70MA RUN CANNOT BE MADE AS THE NUMBER OF ACTIVITIES	A 4040
809	1 IS LESS THAN A MINIMUM THREE.)	A 4045
810	GO TO 5	A 4050
811	END	A 4055
812	SUBROUTINE CRITIC	5
813	DIMENSION EF(100), LS(100), LF(100)	10
814	COMMON T(100), H(100), DUR(100), ES(100), TF(100), FF(100), CPTD,	15
815	ISHORN, TACT, KEXIT, ASST(100), ASFT(100), RN(100,20), MRES	20
816	INTEGER TACT, T, H, TF, FF, ES, DUR, RN	25
817	REAL LS, LF	30
818	C *** CPM SUBROUTINE TO FIND OUT CRITICAL PATH	35
819	C	40
820	C *** TACT=TOTAL NUMBER OF ACTIVITIES.	45
821	C *** SHORN=START TIME FOR PROJECT.	50
822	C *** T(I)=TAIL NODE NUMBER FOR ACTIVITY I.	55
823	C *** H(I)=HEAD NODE NUMBER;H(I)>T(I).	60
824	C *** DUR(I)=DURATION TIME OF ACTIVITY I.	65
825	C *** CPTD=CRITICAL PATH TIME	70
826	C *** ES(I)=EARLIEST START TIME FOR ACTIVITY I.	75
827	C *** EF(I)=EARLIEST FINISH TIME FOR I.	80
828	C *** LS(I)=LATEST START TIME FOR I.	85
829	C *** LF(I)=LATEST FINISH TIME FOR I.	90
830	C *** TF(I)=TOTAL FLOAT FOR ACTIVITY I.	95
831	C *** FF(I)=FREE FLOAT FOR I.	100
832	C *** ASST(I)=SCHEDULE START FOR ACTIVITY I.	105
833	C *** ASFT(I)=SCHEDULE FINISH FOR ACTIVITY I.	110
834	C	115
835	C	120
836	C *** CHECK THE INPUT DATA	125
837	C	130
838	TACT=MACT	135
839	DO 5 I=1,TACT	140
840	IF (H(I).LE.T(I)) GO TO 125	145

841	5 CONTINUE	130
842	C	135
843	C *** PRIMARY SORTING ON TAIL NODES.	140
844	C	145
845	IX=TACT-1	170
846	DO 25 N=1, NX	175
847	NX=N+1	180
848	10 IF (T(N).LE.T(NX)) GO TO 20	185
849	DO 15 L=1, NRES	190
850	ITEMP=RN(NX, L)	195
851	RN(NX, L)=RN(N, L)	200
852	15 RN(N, L)=ITEMP	205
853	JT=T(NX)	210
854	JA=N(NX)	215
855	JB=DUR(NX)	220
856	AC=ASST(NX)	225
857	AD=ASFT(NX)	230
858	T(NX)=T(N)	235
859	N(NX)=N(N)	240
860	DUR(NX)=DUR(N)	245
861	ASST(NX)=ASST(N)	250
862	ASFT(NX)=ASFT(N)	255
863	T(N)=JT	260
864	N(N)=JA	265
865	DUR(N)=JB	270
866	ASST(N)=AC	275
867	ASFT(N)=AD	280
868	20 NX=NX+1	285
869	IF (NX.GT.TACT) GO TO 25	290
870	GO TO 10	295
871	25 CONTINUE	300
872	C	305
873	C *** SECONDARY SORTING ON HEAD NODE.	310
874	C	315
875	KX=TACT-1	320
876	DO 30 K=1, KX	325
877	KR=K+1	330
878	30 IF (T(K).GE.T(KR)) GO TO 30	335
879	IF (N(K).GT.N(KR)) GO TO 35	340
880	DO 45	345
881	35 JX=N(K)	350
882	JY=DUR(K)	355
883	AX=ASST(K)	360
884	AY=ASFT(K)	365
885	N(K)=N(KR)	370
886	DUR(K)=DUR(KR)	375
887	ASST(K)=ASST(KR)	380
888	ASFT(K)=ASFT(KR)	385
889	N(KR)=JX	390
890	DUR(KR)=JY	395
891	ASST(KR)=AX	400
892	ASFT(KR)=AY	405
893	DO 40 L=1, NRES	410
894	ITEMP=RN(K, L)	415
895	RN(K, L)=RN(KR, L)	420
896	40 RN(KR, L)=ITEMP	425
897	45 KR=KR+1	430
898	IF (KR-TACT) 30,30,30	435
899	30 CONTINUE	440
900	C	445
901	C *** CRITICAL PATH CALCULATIONS: FORWARD PASS.	450
902	C	455
903	ES(1)=SMOON	460
904	EF(1)=ES(1)+DUR(1)	465
905	N=1	470
906	NX=N+1	475
907	35 IF (T(NX).GE.T(N)) GO TO 40	480
908	ES(NX)=ES(1)	485

909	EF(NX)=ES(NX)+DUR(NX)	490
910	NX=NX+1	495
911	GO TO 55	500
912	60 CONTINUE	505
913	DO 75 N=NX,TACT	510
914	XD=0.0	515
915	RA=Y(N)	520
916	DO 70 I=1,TACT	525
917	IF (N(I).NE.RA) GO TO 70	530
918	IF (EF(I).LT.XD) GO TO 45	535
919	XD=EF(I)	540
920	45 ES(N)=XD	545
921	70 CONTINUE	550
922	EF(N)=ES(N)+DUR(N)	555
923	75 CONTINUE	560
924	C *** CRITICAL PATH LENGTH	565
925	C	570
926	KA=N(TACT)	575
927	RD=0.0	580
928	DO 85 N=1,TACT	585
929	IF (N(N).NE.KA) GO TO 85	590
930	IF (EF(N).LT.RD) GO TO 80	595
931	RD=EF(N)	600
932	80 CPTD=RD	605
933	85 CONTINUE	610
934	C	615
935	C *** FINDING OUT TOTAL FLOAT, FREE FLOAT BY BACKWARD PASS.	620
936	C	625
937	LF(TACT)=CPTD	630
938	LS(TACT)=CPTD-DUR(TACT)	635
939	NT=TACT-1	640
940	NX=TACT	645
941	DO 100 N=1,NT	650
942	NX=NX-1	655
943	IF (N(NX).NE.N(TACT)) GO TO 90	660
944	LF(NX)=CPTD	665
945	LS(NX)=CPTD-DUR(NX)	670
946	GO TO 100	675
947	90 XL=9999999.	680
948	NR=NX+1	685
949	DO 95 K=NR,TACT	690
950	IF (T(K).NE.N(NX)) GO TO 95	695
951	IF (LS(K).GT.XL) GO TO 95	700
952	XL=LS(K)	705
953	95 CONTINUE	710
954	LF(NX)=XL	715
955	LS(NX)=LF(NX)-DUR(NX)	720
956	100 CONTINUE	725
957	C	730
958	C *** FINAL CALCULATIONS	735
959	C	740
960	DO 120 J=1,TACT	745
961	TF(J)=LF(J)-EF(J)	750
962	JN=N(J)	755
963	DO 105 K=J,TACT	760
964	IF (JN.EQ.N(TACT)) GO TO 110	765
965	IF (T(K).NE.JN) GO TO 105	770
966	ESX=ES(K)	775
967	GO TO 115	780
968	105 CONTINUE	785
969	110 ESX=CPTD	790
970	115 EF(J)=ESX-EF(J)	795
971	120 CONTINUE	800
972	RETURN	805
973	125 WRITE (4,130) T(I),N(I),I	810
974	130 FORMAT (10X,40HERROR: HEAD NODE EQUAL OR GREATER THAN TAIL NODE,10	815
975	IN T(I) IS ,12,13H AND N(I) IS ,12,10H WITH I = ,12,/)	820
976	CALL EXIT	825
977	END	830