A LOGISTICS COMPOSITE MODEL STUDY OF THE MANNING FOR THE NEW F-111A AVIONICS INTERMEDIATE SHOP

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LSSR 76-83

DEPARTMENT OF THE AIR FORCE
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Wright-Patterson Air Force Base, Ohio

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER LSSR 76-83	2. GOVT ACCESSION NO. A134975	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A LOGISTICS COMPOSITE MODEL STUDY OF THE MANNING FOR THE NEW F-111A AVIONICS INTERMEDIATE SHOP		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Michael L. Derenzo, GS-12 Gary A. Thies, Squadron Leader, RAAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Systems and Logistics Air Force Institute of Technology WPAFB OH		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Communication AFIT/LSH, WPAFB OH 45433		12. REPORT DATE September 1983
		13. NUMBER OF PAGES 141
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Approved for public release: IAW AFR 190-17.

Lynn E. Wolaver

LYNN E. WOLAVER
Dean for Research and Professional Development
Air Force Institute of Technology (ATC)
Wright-Patterson AFB OH 45433

15 SEP 1983

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Logistics Composite Model
Simulation
Manpower Requirements
Test Facilities
Manhours

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Thesis Chairman: Clinton F. Gatewood, Captain, USAF

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Effective manpower planning is essential to the continued success of the USAF. Tactical Air Command (TAC) is currently involved in the acquisition of automated test facilities to be employed in the maintenance of F-111A avionics equipment. The Logistics Composite Model (LCOM) was used to simulate the effect of the new test stations on manpower in the following AFSCs: 326X3, 326X4, 326X5. A TAC supplied LCOM model of the existing repair facility was modified to reflect the new test equipment. Then both the old and the modified model were run under the same flying and maintenance scenarios. A comparison of the results showed that the new test equipment will achieve superior performance to the existing facility with a significant reduction in manpower. Actual percentage improvements, assumptions made, and suggestions for further research are presented.

LSSR 76-83

A LOGISTICS COMPOSITE MODEL STUDY OF THE MANNING FOR THE NEW F-111A AVIONICS INTERMEDIATE SHOP

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirement for the

Degree of Master of Science in Logistics Management

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September 1983

Approved for public release;
distribution unlimited

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MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

Date: 28 September 1983

Clinton A. Hatewael

COMMITTEE CHAIRMAN

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READER

ACKNOWLEDGEMENTS

We wish to express our gratitude to our faculty advisor, Captain Clint Gatewood, and our reader, Major John Folkeson, for their assistance in the preparation of this thesis. In addition, the authors are deeply indebted to Mr. Richard A. Cronk and his associates for their technical advice on the operation of LCOM and the Network Plot Subsystem.

Finally, we thank our wives, Anne and Kerrie, for their understanding and support throughout this effort.

TABLE OF CONTENTS

CHAPTER	Page

CHAPTER Page

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

BACKGROUND AND PROBLEM STATEMENT

Introduction

Current techniques for estimating the technical manpower required to support new systems rely heavily on predictions of equipment reliability and maintainability. Despite efforts by acquisition personnel to validate the data by referencing it to past experiences with similar equipment, the accuracy of these estimates cannot be verified until the equipment ultimately enters service.

Problem Statement

In December 1982, the Air Force contracted (12) with Westinghouse for current technology automatic test equipment (ATE) to replace the present Central Processor and Controller (CENPAC) test equipment used for intermediate level maintenance of the F-111A avionic's line replaceable units (LRUs). Tactical Air Command (TAC) has begun analyzing (10) the overall impact of the new ATE on the mission effectiveness of the F-111A. TAC's study will concentrate on identifying any support resource which might adversely impact the aircraft's mission effectiveness. TAC intends to utilize the Logistics Composite Model (LCOM) simulation package to perform its study and (6) has requested a research effort to "quantify the impact of the new F-111 Avionics Intermediate Shop (AIS) test stations on the maintenance manpower requirements (AFSCs 326X3, 326X4, 326X5) in TAC." Additionally, TAC recommended that such research also use LCOM so that any networks developed could be included in the larger TAC study.

TAC (5) believes that the new AIS will achieve significant manpower reductions in AFSCs 326X3, 326X4, and 326X5. Our research focused on quantifying the manpower requirements for these three AFSCs. However, the necessary calculations required accurate data on test station reliability and maintainability, unit under test (UUT) repair times, repair methodology, and priority rules for processing UUTs. When we froze data for this study on 1 July 1983, the acquisition project remained in its infancy with the Critical Design Review Meeting (CDRM) yet to be convened. As a result, the only data available was purely speculative. Therefore, we decided to concentrate our initial efforts on developing a model which would allow calculation of the manpower requirements once more accurate data became available. Once the model was developed, we then used existing data to perform some rudimentary comparisons between the existing manpower requirements and those calculated by our model.

The use of LCOM appeared attractive because TAC could employ our networks in future studies and because a simulation model could be readily updated with more accurate data as it became available. However, before committing ourselves to this approach, we performed a literature review on the use of simulation and LCOM for assessing manpower requirements.

Definition of Terms

Appendix A contains a glossary of definitions for the terminology employed throughout this research.

Simulation

Description. Shannon (14:2) defines simulation as

> . . . the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system.

While simulation techniques may vary from pen and paper analysis, through throwing dice and analog modeling, to sophisticated digital computer models, all references to simulation in this research will be restricted to digital computer simulation.

Advantages/Disadvantages. Simulation involves the modeling of a real system and is normally applied when direct experimentation with the real system is impractical or impossible. Some of the many reasons (14:11) why direct experimentation may prove difficult include disrupting an organization's operations, the "Hawthorne Effect" of people modifying their behavior under observation, difficulty in maintaining the same operating conditions for all replications of an experiment, problems in obtaining a large enough sample population, and inability to explore alternatives. Often a critical reason is that the real system has yet to be implemented. Simulation provides a method of overcoming these limitations.

However, simulation has several disadvantages which necessitate extreme care in implementing its application to real world problems. Restraints on both the researcher's and the computer's resources dictate that no simulation model will include every factor from the real world. In particular, many real world factors are not even recognized by the researcher. Since the simulation is simplified, the basic assumptions for the model are critical to the ultimate utility of the simulation program. Shannon (14:13-14) warns that one of the greatest disadvantages of a simulation is that people tend to accept such results as realistic because they are run on a computer and the results are nicely documented and expressed in numerical quantities to an apparent accuracy of many decimal places. Using a simulation model to make inferences on the system under study requires rigorous validation of the underlying assumptions and resultant model, as well as sensitivity analyses of the parameters included in the model.

The concept of sensitivity analysis is important in simulation modeling. Shannon (14:32) describes sensitivity analysis as follows:

> Sensitivity analysis usually consists in systematically varying the values of the parameters over some range of interest and observing the effect on the response of the model. In almost any simulation model, many of the set variables are based upon highly questionable data. . . .If the answer changes greatly with slight variations in the values of some of the parameters, this may provide the motivation and justification for expenditure of more time and money to obtain more accurate estimates.

Manpower Applications. One methodology for performing a manpower requirements study is to identify the total workload by the skills necessary to complete the work and divide this workload by the average work a qualified worker can achieve. The difficulty of assessing the total workload or the capabilities of a worker determines the actual technique employed. Such techniques can include (17,18) work measurement, comparison to similar tasks, and regression analysis. However, if a system has not yet been introduced, techniques involving direct measurement are not possible. Techniques to estimate manpower requirements for new projects must rely on estimates of the total workload based on contractor projections and past experience. Once the estimates are made, they must be integrated to arrive at final manpower estimates. One method is to use estimated means and simply solve the manpower calculations manually. This technique is time-consuming, and sensitivity analysis of the estimates is difficult. Simulation appears to offer a sound technique for modeling the projected system in its operating environment and making the necessary measurements on the simulated performance of the system in lieu of actual system performance. Additionally, simulation allows the model parameters to be varied to facilitate sensitivity analysis.

Rand studies (1, 7) performed during the late sixties/early seventies used simulation techniques to predict Air Force maintenance manpower requirements and concluded that the method was extremely useful. The Air Force (17:6.2) formally approves simulation as a valid tool for determining work center manpower requirements. Studies by the Air Force Human Resources Laboratory (AFHRL) in 1974 (16) recognized that simulation could be used to evaluate the maintenance manning of new weapon systems. Therefore, we considered simulation a valid methodology for this research. Our next step was to decide whether the LCOM simulation software was appropriate to the task, or whether a new simulation model required development. We still preferred LCOM because any networks developed in our study could assist the more extensive TAC study.

Logistics Composite Model Simulation Software

History. A joint research effort between the Air Force Logistics Command (AFLC) and the Rand Corporation in 1966 resulted in the development of the Logistics Composite Model (LCOM) simulation software (3:2.1). Their research was concerned with the efficient use of computers to determine the optimal mix of the support resources necessary to achieve a particular operational performance. In 1971, TAC (4:1.1) pioneered the use of LCOM as "a tool that provided a significant aid in the development of Air Force aircraft maintenance manpower standards." LCOM has also been used in the weapons acquisition process to evaluate resource trade-offs, both early in the program and during the test and evaluation phase (4:1.1).

Since 1966, the LCOM software has undergone a continuing capability enhancement. In late 1981, LCOM became a standard Air Force automated data processing system (ADPS) and was assigned the number ADPS-14 (4:1.2). The current approved configuration is LCOM Software Release, Version 4.1.

Features. Dengler (3:2.2) summarizes the capabilities of the LCOM software as

> . . . a very powerful, flexible, and highly sophisticated tool. The modeling process can simulate virtually any operational environment a technician cares to define. Questions pertaining to requirements for spare parts, support equipment, facilities and human resources can all be addressed using LCOM simulation. For example, if a technician wishes to determine the maximum number of sorties that could effectively be flown using a prescribed set of resources, the simulation could be repeated, each time increasing the number of sorties until resources can no longer support additional sorties. Conversely, a sortie rate can be established and other parameters can be adjusted to obtain optimum resource utilization. Because of this flexibility, LCOM simulation can be used to answer a wide range of operational, logistics, and maintenance questions.

Appendix B contains a brief description of the LCOM system.

Model Validity. As discussed in the review of simulation, a model should be validated before confidence can be placed in any of the results obtained from the model. Drake (4:1.3) points out that the LCOM model has been confirmed by both "numerous historical" and "many statistical" validations. These validations confirm that the LCOM software can simulate an operating squadron with reasonable accuracy provided the individual model developed by the programmer is valid. This meant that we could rely on the language's ability to model an F-111A squadron, provided we specified the parameters correctly.

ATE Applicability. LCOM was basically designed to simulate the flying and maintenance activities at a single base. The operation and maintenance of avionic ATE form only a small part of the overall wing activities necessary to sustain a particular operational level. Accordingly, use of the LCOM model to make predictions about the manpower requirements for ATE had to be questioned. An Aeronautical Systems Division (ASD) study (9) used LCOM to evaluate the capability of the F-15 AIS to support surge requirements. It concluded (9:17-22) that the LCOM model could be used to make predictions of test equipment performance. Furthermore, the study records several problems which were encountered and the methods employed to resolve them. The Air Force (18:9.1) approves the use of LCOM for determining manpower requirements and devotes a full volume of Air Force Regulation 25-5 (19) to detailing the requirements and procedures for using LCOM. For these reasons, we considered the LCOM simulation package most appropriate for quantifying the impact of new ATE on avionics manpower requirements. Furthermore, the same model would also facilitate study of other factors, such as repair flows, test equipment quantities, and spares requirements.

<u>LCOM Data Base</u>. The LCOM data base (4:4.1) comprises operational, maintenance, and supply data pertinent to the operation of a particular weapon system. The operational data (4:4.1) includes the flying scenario and "user defined requirements" which will determine whether a sortie proceeds or is cancelled. The maintenance data (4:4.1-4.2) is in the form of maintenance networks and includes all scheduled and unscheduled activities required on both aircraft and non-aircraft resources. The supply data (4:4.2) includes "supply, demand, and resupply processes at the various levels of part indentures, i.e., assembly, subassembly, module." TAC provided a data base developed from F-111A operations for the period July 1982 to December 1982 inclusive. Pennartz (10) confirmed that all the networks described in this data base represent current networks used by TAC for any LCOM evaluation of the F-111A. Accordingly, we decided that the existing F-111A models could be modified to reflect the new AIS with relatively few changes to the existing data base. We identified the necessary changes as:

a. modifying the LRU failure networks to reflect the new test stations and any repair sequence changes,

b. removing the existing CENPAC scheduled and unscheduled maintenance networks, and

c. replacing the old networks with networks describing the new AIS maintenance requirements.

These changes are more fully discussed in Chapter 2.

Air Force Skill Levels

TAC (6) suggested that the study be confined to AFSCs 326X3, 326X4, and 326X5. These codes equate to the following skills (20):

a. AFSC 326X3 - Integrated Avionics Electronic Warfare Equipment and Component Specialist or Technician.

b. AFSC 326X4 - Integrated Avionics Computerized Test Station and Component Specialist or Technician.

c. AFSC 326X5 - Integrated Avionics Manual Test Station and Component Specialist or Technician.

Research Objective

Our overall objective for this research study was to assess the manpower required to operate and maintain the AIS test stations currently being procured in support of the F-111 avionics. Because of the subjectivity of much of the available data, we also wanted to apply some degree of sensitivity analysis to highlight those parameters which might prove most critical to the quantity of manpower required. However, the unavailability of even subjective data on several aspects of the project, including UUT test times, ATE test and repair times, and ATE scheduled maintenance and calibration requirements, precluded us from even attempting to quantify the manpower requirements accurately. Therefore, we limited the scope of this effort to performing an analysis of the existing LCOM data base for any problems which might impact our model and to producing a baseline model for the new AIS which could be expanded and refined as more data became available.

Research Questions

We posed the following research questions to guide us towards the stated objective:

a. Does the existing model have any idiosyncrasies which might be incompatible with either the version of LCOM we intend to use or the new model assumptions?

b. What changes must be made to the current F-111A LCOM data base to reflect the maintenance networks for the new AIS test equipment?

c. Is the modified model logically valid?

d. What are the baseline manhours, by AFSC, indicated by our model?

e. How do the new baseline manpower levels compare to those determined by the existing data base?

CHAPTER 2

METHODOLOGY

Introduction

As explained in Chapter 1, we used an F-111A LCOM data base supplied by TAC as the primary tool for our study. This data base consists of a fully validated model of F-111A operations based on the aircraft configuration and maintenance organization at Mountain Home AFB during the period July to December 1982. With the exception of the AIS facility, we assumed that all other facets of maintenance and operations would be unaffected by the introduction of the new ATE. Accordingly, we constrained our efforts to modifying the existing data base to reflect the new AIS test equipment and to performing a simple comparison between the manpower required for the existing and new AISs.

We considered the following tasks essential to meeting the overall research objectives posed in Chapter 1:

a. Identify any peculiarities with the existing model which might confound our study.

b. Identify and remove the existing CENPAC networks.

c. Develop and incorporate new networks to reflect both the new ATE and any other items of hardware necessary to interface the UUT to the ATE. These networks determine both the availability of the ATE to test an LRU and the repair and maintenance of the ATE.

d. Modify the existing LRU maintenance networks, within the AIS environment, to reflect the new ATE. Of prime concern was the identification of any changes to testing time or LRU reliability as a result of more thorough testing.

e. Run the LCOM simulation using the modified data base to establish a manpower requirements baseline.

f. Perform a series of simulations to determine the sensitivity of the manpower requirements to variations in the failure data for both the ATE and the LRUs.

LCOM Networks

An understanding of the LCOM network, and how the LCOM simulation uses it, is essential before the methodology of this research can be outlined. The following definitions describe the various components of an LCOM network. Figure 1 is a graphical representation of a basic LCOM network and will be used to illustrate the definitions.

```
     Task 1                Task 2                 Task 3
(A)-------------(B)----------------(C)---------
     D              : E(Ø.6)   AFSC           D
                    :          Resource
                    :          Duration
                    :
                    :  Task 4                 Task 5
                    :-----------------(D)---------
                      E(Ø.4)                  D
```

Figure 1. Basic LCOM Network

Network. A network (4:4.6) is a logical and chronological flow of actions. A graphical network is a diagram of these actions as detailed in Figure 1.

Node. Nodes (4:4.6) mark the beginning and end of a task and as such are action or event connectors. In Figure 1, the nodes are enclosed in parentheses and labeled A, B, C, and D. A node at the ending point of a network (no further actions following the node) does not require labelling. A common node is one which forms the beginning point for more than one task, as with node B in Figure 1.

Segment. A segment includes that portion (4:4.6) of a network which follows a node (e.g., from node A to node B) where some action takes place. Segment is a general term used to include several functions that could take place on this portion of the network.

Task. A task is an action (4:4.7) that usually requires time and resources, such as Tasks 1 through 5 in

Figure 1. Tasks can be specified with zero resources or time. A task is one of the functions that can be accomplished on a particular segment, and is specified on a graphical network by name, associated resources, manpower requirements, and duration as shown for task 2 in Figure 1. Task names are usually assigned with the first letter describing the type of task and the remaining alpha-numerics representing the item's work unit code (WUC).

<u>Path</u>. A path is a sequence (4:4.7) of tasks starting at any task and ending with a task which has no following task. In Figure 1, tasks 1, 2, and 3 constitute one path, while tasks 1, 4, and 5 form another.

<u>Branch</u>. A branch includes the path or paths (4:4.7) that logic may take starting with one of the tasks which begin at a common node. Branching occurs at node B of Figure 1 since both tasks 2 and 4 emanate from it.

<u>Resource</u>. A resource is an item (4:4.7) that is required to accomplish a task or that is being processed through a task. Resources are normally listed against each task, as shown in Figure 1 for task 2.

Networks can be designed in sections, thereby reducing the complexity and size of the network input data. Separate sections which are used in more than one place in the total network need only be defined once and then can be "called" from several locations within the network as required. Sections can also be used to constrain commencement of a task until another set of multiple tasks has been completed. This is achieved since, once a section is called, all actions within the section must be completed prior to continuing processing of the network from which the call was made. The flow of resources (transactions) through the networks is controlled by the use of selection modes which are defined in the input data. These selection modes act like gating mechanisms which control the opening, closing, and skipping of the various network sections. Selection modes are designated by a single alpha character and are graphically depicted, as shown in Figure 1, by the appropriate letter code entered at the lower left-hand side of a segment. These modes can be divided into four basic categories:

a. Those that function independently (C, D, and R).

b. Those that are probabilistic in nature (A, E, and G).

c. Those used to control mission timing (S).

d. Those that deal with specific model features (F, H, I, J, K, L, T, and U).

Full descriptions on the application of each mode are detailed in the LCOM User's Guide (4:4.8-4.12).

Specification of LCOM Data

The various graphical networks must be coded for input to the LCOM simulation model. A series of LCOM forms has been created to facilitate such coding. The following forms are of primary importance to this study:

a. The Form 11 is used to define a task network, including beginning and end nodes, task name, selection mode, and selection parameters.

b. The Form 12 is used to define task parameters, such as task name, type, priority, and duration, as well as resources necessary to complete the task.

c. The Form 13 is used to define all resources and clocks. Resource name, type, authorized quantity, and substitutes are specified on this form, as well as clock name and failure rate (in terms of mean, variance, and distribution type).

d. The Form 14 defines which tasks will decrement which clocks. Task name, clock name, decrement mode (sortie operating time or constant decrement), and the amount of decrement are specified on this form.

e. The Form 16 defines manpower authorizations for each shift and the number of shifts which will be worked each day.

f. The Form 17 defines the various missions (and configurations) which the aircraft will fly and specifies the network entry nodes for each specific mission type and major activity.

Thirteen different data input form types are required for complete specification of an LCOM model. Detailed descriptions of all LCOM input data forms are contained in the LCOM User's Guide (4:8.1-8.37).

Basic Methodology To Meet Research Objectives

An ideal methodology for quantifying the new AIS manpower requirements is best summarized by the flow chart depicted in Figure 2.

Validate Old Model

The first step in our methodology was to analyze the TAC-supplied data base to ensure that it contained no idiosyncrasies which would reflect in our new model. Ideally, this process would involve careful study of all existing documentation to ascertain what assumptions were made during model development, to ensure that the coding of the model was consistent with these assumptions, and to check that the assumptions were consistent with the new AIS. However, we were unable to locate any such

```
*************
* VALIDATE  *
* AND RUN   ***
* ORIGINAL  * *
* DATA BASE * *
************* *
              *
       ***************
       * OBTAIN DATA *
       * ON NEW AIS  ***
       *************** *
                       *
                ***************
                * MODIFY DATA *
                * BASE TO     *
                * REFLECT NEW ***
                * DATA BASE   * *
                *************** *
                                *
                         ***************
                         * DE-BUG AND  *
                         * VALIDATE    *
                         * MODIFIED    ***
                         * MODEL       * *
                         *************** *
                                         *
                                  ***************
                                  * PERFORM     *
                                  * SENSITIVITY *
                                  * ANALYSES ON ***
                                  * MANPOWER    * *
                                  * REQUIREMENTS* *
                                  *************** *
                                                  *
                                           ***************
                                           * COMPARE AND *
                                           * SUMMARIZE   *
                                           * RESULTS.    *
                                           * DRAW        *
                                           * CONCLUSIONS.*
                                           ***************
```

<u>Figure 2. Basic Research Methodology</u>

documentation for the data base. However, LCOM is substantially a self-documenting language, and we were able to decode the model logic flow and resource requirements. We achieved this by careful study of the listings and network diagrams produced using the Network Plot Subsystem held by Aeronautical Systems Division, Engineering Equipment Support Analysis Branch, LCOM Team (ASD/ENESA(LCOM)). This package automatically draws the networks from the Form 11 codes. Unfortunately, the documentation does not outline the exact purpose for the development of the model or any of the assumptions made by the programmer. Therefore, the reasons for the model performing certain tasks in various sequences were not readily apparent to us. Accordingly, we were restricted in our analysis of the existing model. We finally resorted to performing the following checks:

a. Check the sortie-generation networks to ascertain the types of flying missions modeled. This information was extracted from the Forms 11 and 17.

b. Analyze the logic of the existing LRU failure networks (since we anticipated retaining them relatively unchanged) to ensure they were compatible with the new AIS. We achieved this by extracting the Form 11s for all LRUs which would utilize the new AIS and using ASD's plot routine to draw the networks.

c. Analyze the old test station networks. This was achieved in a similar manner to the LRU failure network analysis, bearing in mind that these networks were destined to be removed from the new model.

d. Analyze the amount of resources of each type available in the model. This was done by examining the Form 13s.

e. Check the shift policies and number of personnel available for each shi[illegible]se were available from the Form 16s.

f. Run the old d[illegible]sure that the coding was compatible with the [illegible] 4.1 available to us.

g. Obtain a manpower requirements estimate of the existing facility for eventual comparison with our new model. Several minor changes were necessary to ensure that similar shift, resource, and flying policies were applied to both models.

<u>New AIS Data Collection</u>

The data required to model the new AIS can be divided into two groups; aircraft LRU data and ATE data. The data required for the aircraft LRUs consists of:

a. identification of the LRUs which are tested by the ATE and the hardware necessary to test each LRU type.

b. specification of the failure rate distributions for each LRU type.

c. specification of the test and repair time distributions for each LRU type.

d. repair sequences for each LRU type.

The ATE data required comprises:

a. identification of the AIS test equipment, tester replaceable units (TRUs), and interface hardware.

b. specification of the individual TRU and interface hardware failure rate distributions.

c. specification of the individual TRU and interface hardware repair time distributions.

d. identification of the number of men, and their associated AFSCs, necessary to operate and maintain each test station.

e. identification of AIS scheduled maintenance policies down to the TRU level, including calibration and confidence testing, and the amount of time, manpower, and support equipment necessary to perform scheduled maintenance.

f. identification of any existing test equipment which is to be retained in the new AIS.

Applicable LRUs. Identifying the LRUs which would be tested by the new AIS was a two-part procedure. First, the contract (12) provides a list of all LRUs to be tested by the new AIS. All F-111A LRUs were extracted from this list and compared to the existing data base to determine whether they were modeled. Any LRU not modeled was subjected to further research to determine why it had not been included. Configuration differences or extremely low failure rates appeared to be the prime reasons for exclusion. Second, the existing data base was checked for any LRUs currently tested by the existing test stations but not listed in the contract for the new AIS. Several such LRUs were discovered, and we decided to include them in the model, since they represented current aircraft configuration (second half of 1982) and would, we assumed, have to be tested on the new AIS if the current test equipment is phased out.

<u>LRU/ATE Cross Reference</u>. Once we compiled the list of LRUs to be modeled, the next step in our methodology was to determine which test station tested which LRU. San Antonio Air Logistics Center (SA-ALC) supplied a data package on the new AIS comprising all data presented at the Preliminary Design Review Meeting for the project. This data package included cross-references between LRU type and test station for the majority of LRUs to be modeled. Test station type for the remainder of the LRUs was assigned on the basis of similarity to those which were cross-referenced to a test station. Though we are confident that this

procedure was reasonably accurate, there is definitely potential for error and future work on the model should include a determination of the aircraft configuration at the time the new AIS enters service and a cross reference between all applicable LRUs and test station type. This data was not available at data cut-off.

New LRU Failure Rates. The new AIS has the potential of altering the failure rates for some aircraft LRUs by providing either better or worse fault isolation. Hopefully, the new AIS will provide better fault isolation than the existing support equipment. However, the contract (12:Doc.10,p.3) requires that the new test software be based on the existing test specifications. Accordingly, we anticipate no significant change in the aircraft LRU failure rates as a result of the new AIS. For this reason we decided that, where possible, the LRU failure rates and distributions detailed in the existing data base would be applicable to the new AIS. However, our model includes four additional LRUs which are specified in the contract (12) for the new AIS but which were not modeled on the TAC-supplied data base. We obtained failure data for these LRUs from a Common Data Extraction Program (CDEP) Listing of the F-111A squadrons based at Mountain Home AFB supplied by ASD/ENESA(LCOM). The CDEP is a special program used by LCOM modeler's to extract maintenance data from the USAF Maintenance Data Collection System and convert it to LCOM mean sorties between maintenance actions (MSBMAs) and maintenance action probabilities. MSBMA is defined with failure rate in Appendix A. Unfortunately, the CDEP listing covered the period January to December 1981 and so was not as recent as the data contained in the TAC data base for the other LRUs. We felt, however, that this data provided reasonable failure data for the four new LRUs enabling us to validate the logic of the networks which describe them. This data will have to be carefully monitored and validated as our baseline model is updated with the more reliable information which will become available as the AIS develops.

<u>LRU Test and Repair Times</u>. We were unable to obtain estimates of the test and repair times for the LRUs using the new test equipment. SA-ALC/MMP (2) informed us that the data would not be available before the Critical Design Review Meeting scheduled for late July 1983. Therefore, since the new programs will be based on the old test specifications, we assumed the worst possible repair times achieved by the new AIS would be no improvement over the existing repair times. We anticipate that the new AIS will probably offer some improvement on current test times through higher computer

speeds and quicker hookup of the UUT because of more efficient interface hardware. However, the time to rectify the LRU once the fault is diagnosed would not alter. Since the repair times in the model are a combination of both test and rectification time, as well as a function of the probability of the type repair action required, the improvement in overall test time is difficult to estimate. Additionally, the improvement will probably vary from LRU to LRU, depending on such factors as whether it is currently tested manually or automatically, how difficult it is to interface to the existing test station, and how long it takes to test using present procedures. If existing AIS data is used, the LRU repair times would require significant sensitivity analysis if an accurate estimate of manpower is to be extracted from our model. The data accuracy problem and sensitivity analysis requirements are discussed further in subsequent sections of the methodology.

Repair Sequences for Each LRU. Basically, the repair sequences are a factor of two issues. First, does the test station operator repair the fault on the station when it is discovered, or is the UUT transferred to another work bench, repaired and retested? Second, which test stations are capable of testing the LRU? Analysis of the current data base indicated that the current practice is for the station operator to repair the LRU as the fault is discovered. Discussions with Mountain Home AIS personnel (15) confirmed this to be the current practice and indicated that this practice would continue in the new AIS. Daniels (2) at SA-ALC also stated his belief that the test station operators would also repair the LRUs. Finally, the contract does not address this point specifically and test philosophy will have to be monitored as the AIS design firms. We decided that there was no evidence to suggest the testing philosophy will change. Therefore, we assumed that the test station operators would repair the UUTs as faults were diagnosed. This assumption allowed us to simplify the model and combine test and rectification times into the one task. The second aspect which affects the repair sequence modeled was the number of test stations capable of testing the particular UUT. We ascertained that roughly 5Ø percent of the LRUs could be tested on any of the test stations. We finally reduced the number of repair sequences down to two general types, each of which is fully described in Chapter 4.

AIS Configuration. A detailed configuration of the new AIS was essential to the development of the new model. As well as identifying the major test stations, we needed to know the configuration of these stations down to the TRU level. We also required details on any other support equipment or interface hardware which would be required to test an LRU. Interface hardware consists of any special adapters which may be necessary to connect an UUT to a test station for testing purposes. Finally, we had to identify any existing major support equipment which would be retained in the new AIS. We were able to compile reasonably accurate configuration details for the new equipment from the preliminary design review data package provided by SA-ALC. Identifying test equipment to be retained was not so easy. The inference we got from reading the contract and the SA-ALC data package was that the new facility would phase out all existing major test stations. However, during the comparison of LRUs specified in the contract and those modeled in the existing data base, we became aware that LRUs presently tested on the 3409 CENPAC test station were not listed in the contract. Mountain Home AIS staff (15) advised that they believed that three test stations were to be retained, namely the 3409, 6849, and 6850 test stations. A further check of the contract revealed that several LRUs currently tested on the 6849 and 6850 stations were designated for repair on the new AIS. Thus, we assumed that only the 3409 test station would be retained in the new facility, since this assumption most closely conforms to both the beliefs of current AIS staff and the contract.

TRU/Interface Hardware Failure Rates. The preliminary design review data package contained detailed contractor estimates for the AIS down to TRU level.

TRU/Interface Hardware Repair Times. SA-ALC personnel (2) advised that even contractor estimates of the repair times for individual TRUs were unavailable and would probably not be available before the CDRM. However, the maximum time to rectify any failure in the system was specified in the contract (12:Doc.1Ø,p.5). Additionally, the preliminary design review data contained contractor mean repair time predictions for each of the test stations which indicated that the limits set in the contract would be easily met. Accordingly, we decided to model the AIS to the test station level using the contract specification as the worst case. Subsequent to this decision, we managed to acquire a full breakdown of the contractor estimates for AIS maintainability to the TRU level. This data arrived too late for inclusion in our model, but it should provide the ideal starting data for expansion of the AIS section of our model to the TRU level.

AIS Scheduled Maintenance Requirements. As for the TRU repair time data, we were advised (2) that scheduled maintenance data would not be available before the CDRM. Scheduled maintenance includes any calibration checks which are specified for various TRUs to ensure they are in tolerance, plus any confidence check requirements which may be specified. While the new AIS is designed to minimize scheduled maintenance downtime, scheduled maintenance must be considered if the model is to be accurate. The contract does not provide any specific data which could be used to model AIS scheduled maintenance.

<u>Manpower Requirements</u>. The contract (12:Doc.1Ø,p.6) specifies:

> System design shall be oriented such that one technician can completely control and operate the test station. Also, the design shall be such that one technician can diagnose and repair the test stations without assistance. It is intended that the same technician will both operate and maintain a test station.

Since the test stations are automatic, we assumed that only the AFSC 326X4 would be required for the new AIS. The one caveat here was that some electronic countermeasures (ECM) equipment must be tested by AFSC 326X3, primarily for security reasons. In fact, the existing facility (15) segregates the ECM repair shop from the rest of the test stations. Also, the model considers only actual workers and does not account for any supervision requirements.

Flying Scenario. Originally, TAC (5) indicated that they would provide a peacetime flying scenario on which we could base our research. However, this scenario was unavailable up to the time of data cut-off and so we were forced to develop an extremely simple scenario which would enable us to run our new model and compare it to the existing model.

Modify Existing Data Base

Modification of the existing LCOM data base involved the following steps:

a. Identify the existing CENPAC networks.

b. Remove the existing CENPAC networks.

c. Identify the existing LRU repair networks, remove them from the data base, and develop the new repair networks.

d. Code and incorporate the new repair networks into the LCOM data base.

e. Develop the new AIS failure and repair networks.

f. Code and incorporate the new AIS networks into the LCOM data base.

The actual order in which we performed these tasks was critical to debugging the model and is discussed in the model debug and validation section of this chapter.

Identifying the existing CENPAC networks was relatively easy. As stated earlier, much of the data base is self-documenting. In fact, we felt that the only real omission in the data base documentation was an explanation of the assumptions used. The existing data base stored both the scheduled and unscheduled CENPAC maintenance networks (Form 11s) in self-contained blocks and identified the test stations by name in the comment columns. Thus, removing the CENPAC networks consisted of deleting the Form 11 networks from the data base using the U-Editor on the ASD Cyber Computer. The U-Editor was used in preference to the regular Editor on ASD/ENESA(LCOM) recommendation because it could cope more easily with the size of the data base. Once the Form 11 networks were removed, we performed an initialization run on the data base. The initialization run is basically a compilation run. Diagnostics are performed on the data base to highlight any logic errors, omitted data, or inconsistencies among data. If the data base passes the diagnostics, the data base is translated to a format compatible with the LCOM simulation language and stored as an "initialized file" ready for running. During the study, we found the diagnostics from the initialization run to be extremely powerful in detecting errors and very easy to use in finding the fault which caused the error. The resulting diagnostics from the initialization run flagged all resources (Form 13s), tasks (Form 12s), and failure clocks (Form 14s) which were no longer "called" by the Form 11 networks. Since only the CENPAC networks had been removed, the diagnostics flagged all other items which had to be removed from the model. The initialization runs were repeated until the only errors highlighted were the tasks which "called" the CENPAC networks from the LRU failure networks and those LRU repair tasks which required CENPAC test stations as a resource. These tasks were changed to reflect the new AIS during the LRU failure network modification phase of producing the new model.

The procedure employed for identifying the existing LRU failure and repair networks was a little more complicated. Once again the AIS section of the model was self-contained and the LRU type was annotated in the comments section. Basically, any repair task for an AIS type facility will be categorized by one of three types: a "K", "W", or "N" task. The "K" task describes a repair action of "tested serviceable" or no fault found, the "W" task a "tested and repaired" action, and the "N" task a "tested but requires depot level repair" action. We used the diagnostics from the previous initialization runs to identify those LRUs which were tested by the old CENPAC. The other feature of the LCOM tasks listed above is that the LRU WUC is included in the task name. Thus, once we identified the LRUs by WUC, we performed a careful edit of the Forms 11 file identifying the existing LRU failure and repair networks. After identifying them, the appropriate lines of code were edited out of the Form 11 file and the ASD/ENESA plot routines used to plot the existing networks. The graphical representations were then studied to determine the logic employed. The logic used was then analyzed for consistency with our assumptions for the new AIS. Once we were familiar with the current networks, we developed graphical networks to reflect the revised failure and repair sequences. New failure networks were developed for any additional LRUs which had to be modeled. The graphical networks were then coded on the appropriate input data forms. The coding process involved not only describing the repair sequences on the Form 11 networks, but also updating the Form 10, 12, 13, and 14 information to reflect revised manpower requirements, task names, repair times, failure clocks and other resources. Exponential distributions were used for the failure rates, since they were employed in the current data base for the LRUs modeled and had since been validated. Additionally, Shannon (14:359) states that the life of most electronic components is exponentially distributed. For similar reasons, we used lognormal distributions for the repair times.

The next step was to edit the new code into the existing data base. We performed this task using U-Editor. The editing involved not only the Form 11 networks, but also the Form 10, 12, 13, and 14 codes.

After the LRU networks were incorporated into the data base, the next step was to develop the new ATE networks. The ATE networks should model test equipment component failures and repair actions at the TRU/interface level of detail. However, as discussed in the data section, data on the scheduled and unscheduled maintenance of the AIS at the TRU level was unavailable. Accordingly, we were forced to limit our model of the AIS to the test station level of detail. We decided to use the maximums allowed by the contract for failure rate and repair time, and to produce a baseline model which would reflect AIS worst case performance. Again the basic approach was to graphically develop the model, code the appropriate forms, and edit the code into the data base.

Debug and Validate Model

To facilitate debugging, we performed the actual modification of the data base in the following sequence. First, since they involved no modification of existing networks, the new AIS networks were incorporated. These networks were relatively short and simple because the AIS was only modeled to test station level. At this stage, no CENPAC data had been removed from the model. Then, we modified the repair and failure networks (and associated resources, failure clocks, etc.) for just one LRU. Finally, we initialized the model to ensure that our method of modifying the model was feasible. Once any errors were removed, the final test was to run the model with the one LRU modified. This run proved that our changes were compatible with the LCOM language. Had we made any glaring conceptual errors and not tried to run the model until all LRUs were incorporated, we might have been faced with an extremely large task to correct the errors. Once we had confidence that our approach was feasible, we then removed the CENPAC networks and modified the remaining LRU failure and repair networks.

Debugging commenced in earnest with the completion of the code changes. Basically, the approach we took was to perform an initialization run, rectify all evident errors, and run another initialization. This process was repeated until the model was free from error and would run. This meant that we had eliminated all errors detectable by the diagnostic routines. However, errors which were undetectable by the diagnostics remained a possibility. We were afraid that mistakes such as typographical errors on node names might result in incorrect LRU repair sequences if the error was, itself, a valid node name for another network. We did notice that the diagnostics revealed several such errors and this served to increase our faith in them. However, as a final check, we isolated all our added networks from the Form 11 file and ran them through the ASD/ENESA (LCOM) Network Plot System. The resultant graphical plot of our networks was compared to our hand drawn design plots and any anomalies rectified. At this stage, we were confident that the model was coded as designed. The next step was to attempt a validation of the model.

Ideally, a model should be validated by comparison with historical data. Since we had no such data, we had to rely on comparison with the existing data base. Our philosophy was to model the new AIS to the maximum level of accuracy achievable using the limited data available. We decided to concentrate on a model which was logically consistent with the new AIS and which could be expanded to incorporate new data as it became available. As is already evident from our data discussions, the LRU repair times were retained from the existing data base on the assumption that the new AIS would perform no worse than the current facility. Hence, the old times represent worst case. Basically, our baseline model represents the difference between the old and the new AIS, assuming that the new AIS performs to the limits specified by the contract and does not improve test or repair times, or LRU reliability. If our model is logically consistent, the manpower requirements of both the old and the new should be of the same order of magnitude. Therefore, we decided to run both models under the same flying scenario and compare the results as a final check on logical validity. The results of this comparison are discussed in Chapter 5.

Sensitivity Analyses

Table 1 lists the main variables in the model and comments on their accuracy.

VARIABLE TYPE	NUMBER OF VARIABLES	DATA SOURCE	COMMENTS ON VARIABLE ACCURACY
LRU FAILURE RATE	130	Existing TAC Data Base	Unchanged from original model. No major change in LRU reliability anticipated as a result of new AIS.
LRU TEST /REPAIR TIME	130	Existing TAC Data Base	No estimates available. Existing task times used on the basis that new AIS will be as fast as present facility. Anticipate some reduction in task times, but the potential for improvement will vary from LRU to LRU depending on current ease of hookup and testing.

Table 1. Variable Accuracy

AIS FAILURE RATES	4	Contract For New AIS	AIS modeled to test station level only. Contract specified minimum time between failure for AIS used on basis that new AIS will at least meet contract specifications. Data represents worse case and contractor predicts better performance.
AIS REPAIR TIME	4	Contract For New AIS	Using same rationale as above, repair times represent maximum down-time allowed in the contract for an AIS failure. Contractor estimates indicate that the new AIS will easily surpass contract limits.
AIS SCHEDULED MAINTENANCE			AIS scheduled maintenance requirements were unavailable and could not be modeled.

Table 1. Variable Accuracy

Table 1 shows three primary sources of error in our model. First, the LRU repair task times may vary significantly from those of the existing AIS. Second, the new AIS will probably outperform the contract specifications for reliability and maintainability, since contractor estimates show better than 100% improvement.

Finally, the lack of scheduled maintenance simulation may place a large limitation on the model. For the above reasons, significant sensitivity analyses would be warranted before accurate estimates of manpower requirements could even be attempted.

The LRU repair task times caused us the greatest concern. Since any improvements could vary substantially from LRU to LRU, across the board reductions for all task types would not be acceptable for sensitivity analyses. This meant that any meaningful sensitivity analyses on these LRUs would have to look at various combinations of improvements. This approach is impractical for two reasons. First, there are some 130 LRUs which are affected and, even if we were to look at only one level of improvement, say 20 percent, there are some 8385 ((130 x 129)/2) combinations of improvements which would have to be tested. Each would require a separate simulation run of at least 15 minutes CPU time. Also, only about 100 days of simulation could be run in this time. The number of combinations and probable levels could conceivably be reduced by careful study of current and proposed test methods. This research would be extremely time-consuming, and we suspect that if enough data were available on the new test methods to support it, contractor estimates of the repair times would also be available. Therefore, we decided to leave sensitivity analyses of LRU repair times for future research when more positive data is available.

Our baseline model uses the contract reliability and maintainability data to enable worst case performance to be simulated. Since available contractor data indicates the test stations will substantially exceed contract specifications for these two factors, we decided to perform a sensitivity run using the contractor's estimates. We reasoned these estimates should represent the most optimistic performance of the AIS and hence a rough range of probable manhour requirements could be established. Future development and refinement of the model would allow this range to be tightened as more data becomes available. We felt that the data limitations in other areas did not warrant a more stringent sensitivity analysis of the AIS reliability and maintainability performance. Our methodology establishes the likely limits of performance and allows calculation of a manpower range.

Finally, the lack of scheduled maintenance data further clouds the accuracy of any results our model may yield. The design philosophy is to reduce calibration and confidence testing down-time to a minimum. Consequently, we feel this will have minimum impact on test station manpower requirements. However, until firm data is available, the possibility does exist that the scheduled maintenance will significantly affect manpower requirements. Hence, the lack of simulation of the AIS scheduled maintenance is a major limitation of our model.

Summary of Assumptions

We were forced to make several assumptions in the development of our new model. While the majority of them were forced on us by data availability, one major assumption was that the data base supplied by TAC was accurate and validated. This meant that we did not have to analyze other sections of the data base, such as flight line maintenance and mission generation, in the same detail as the AIS networks. Many of the assumptions forced on us by lack of data have been mentioned in the text. However, they are summarized below

a. The TAC-supplied data base represents current aircraft configuration and any LRUs requiring existing AIS test stations for repair will be tested by the new AIS when it is commissioned.

b. The new AIS will not significantly affect the existing LRU failure rate.

c. The new AIS will achieve LRU repair times that are no worse than currently being attained.

d. The test station operators will also repair the UUTs on the station as faults are diagnosed.

e. The 3409 test station is the only major test equipment which will be retained from the old AIS.

f. The new AIS will at least conform to contract specifications.

g. AIS operations will not be interrupted by lack of test station spares or special support equipment.

h. Test fixtures and interface hardware comprise part of the test station. Therefore, the only resources necessary to repair an LRU are a qualified operator and a serviceable test station.

Summary of Limitations

The most serious limitation of this study is the lack of historical data available to validate the new model. Lack of data also prevented us from modeling the AIS to TRU level and including scheduled maintenance. Finally, existing repair task times had to be used in the repair networks. All of these factors combined to restrict our model to determination of the highest possible manpower requirements for the new AIS.

CHAPTER 3

ANALYSIS OF TAC DATA BASE

Introduction

Before we could commence development of our new model, we had to satisfy ourselves that the model supplied by TAC would operate on LCOM version 4.1 using the computer resources available to us. Once we had verified compatibility of TAC's model with these resources, the next step was to run the old model and prepare a manpower baseline with which to compare the results of the modified model. Modification of the existing model could then begin. This chapter outlines the limited analysis performed on the existing data base to ensure that it was compatible with LCOM 4.1 and the changes we proposed to incorporate in the new model.

Compatibility with LCOM Version 4.1

After consultation with ASD/ENESA (LCOM) staff, we decided that the most efficient resource available to us for running LCOM was the ASD AMDAHL 470/V7C IBM-compatible computer. However, for the convenience of interactive editing and because we were familiar with its capabilities, we decided to maintain the Forms Files on the ASD Cyber computer. The Forms Files are merely the program source codes which comprise the data base. The version of LCOM currently maintained on the AMDAHL computer is version 4.1. Therefore, before we could scope the size of the remodeling task, we had to ensure that the TAC data base was compatible with LCOM version 4.1. Therefore, our first task was to run the old data base. This involved routing the Forms File from the Cyber computer to the AMDAHL via a tieline and performing an initialization run. The job control language (JCL) to achieve this was extracted from the CDC/IBM User's Guide (8:72) and is enclosed at Appendix C.

Initialization Run. The first initialization run was suppressed because of an error in the Form 12s. The task PDEPØT was defined as a Type 4 task. A Type 4 task (4:4.13) "specifies the first task in a sequence of repair tasks when the part will actually begin depot processing." Aircraft, men, and equipment cannot process through a Type 4 task under LCOM version 4.1, although previous versions did allow equipment to process through this type of task. The PDEPØT task in the TAC model was used to model a supply delay of 23 days from when the repair network determined depot repair was required until a serviceable replacement was available from the depot supply network. As networked, the LRU passed through this task to keep it out of circulation until a replacement was generated. Thus, the TAC model attempted an illegal task and the Forms File would not initialize. We changed the task to a Type 5 task (4:4.13), which is used to specify a delay. This approach retains the delay time for depot repair, but the task is not recorded as a depot return and statistics for depot returns become distorted. Since this did not affect AIS manpower requirements, our approach was valid. However, any future studies using our model would have to take this into consideration if they intended to predict the percentage of depot tasks arising.

Flying Scenario

Once the model initialized, we then wanted to ensure that it would run. However, the running of any LCOM model requires a flying scenario. Since TAC failed to provide an approved peacetime flying schedule, we were forced to fabricate a simple flying program. Some draft data made available from TAC enabled us to hypothesize the following sortie parameters:

a. Overall sortie rate: 9.5 sorties per month per aircraft.

b. Mean sortie duration: 3.00 hours , normally distributed, with a variance of .25

The flying scenario we developed from this information is not meant to exactly represent an F-111A squadron operating in peacetime conditions. Rather, we aimed at generating a simple flying schedule which would exercise our AIS networks at a realistic sortie and flying hour rate. We did not attempt to model several mission types, weather alerts, aborts, or night operations since the TAC data base confined us to only one mission profile anyway. A mission is distinguished from a sortie by the external and internal configurations of the aircraft necessary to complete the specific mission type. All missions are sorties. An aircraft performing a test flight after maintenance would have a different configuration, and hence mission, to one flying a bombing mission, even though both would be classed as sorties. The second profile would require stores, such as bombs, to be loaded, and would probably require much more fuel. The various mission types to be simulated are specified on the Form 17s. The mission called "TEST" is the only mission specified in the TAC model. For any mission type to be flown, it must also be scheduled in the flying scenario. Since the flying networks were only designed to handle one mission type, we only had to specify one mission profile in our simplified scenario.

The final factor to be determined was how many aircraft to model. The TAC data base modeled only 24 aircraft. However, Mountain Home personnel (15) confirmed that the existing facility supported two squadrons of F-111As and one squadron of EF-111As. The flying scenario was set for two squadrons, since this is the number of squadrons of F-111As which the new facility would have to support. The TAC flying scenario draft data indicated a total primary aircraft allocation of 40 aircraft for Mountain Home. Using this data, plus the sortie rate, we determined that 6.3 sorties would be required daily per squadron, based on a 30-day month. We modeled a simple flying scenario which involved two aircraft (one per squadron) departing on the hour, every hour, from 0700 to 1300, thus flying 7 sorties a day per squadron. The Form 20s used to input this schedule are enclosed at Appendix D. Once the flying scenario was coded on the Form 20s, it was converted to the exogenous file on the AMDAHL. The exogenous file uses the Form 20 information to calculate the actual flying program for the number of days specified. It calculates the length of each sortie from the distribution data and then converts the Form 20s to a format compatible with the initialization file so that the two can be used to execute the simulation. The exogenous file can be likened to a compiled or object listing of the total flying program. The necessary JCL (8:70) for producing the exogenous file from the Form 20s on the AMDAHL is enclosed at Appendix C.

Shift Manning Policy

The shift manning policy apparent in the draft scenario data provided by TAC indicated that maintenance personnel would work two shifts, operating from 0500 to 2100 hours five days a week. Note that the shift policy does not take into account meal breaks, and so the second shift finishes at 2100 rather than 2400. A more detailed shift policy could be written to account for meal breaks. We considered our shift policy adequate since 16 hours of working time was modeled. However, we decided to work the shifts seven days a week. We did this because it was much simpler to write the flying program for seven days a week operations; hence, maintenance personnel were required to support the schedule. We reasoned that by modeling both flying and operations seven days a week, coding would be simplified. Then, by assuming no maintenance or flying over the weekend, the model represented only the working days. Thus, 200 days of model time equates to 280 days of calendar time.

Resources

Careful study of the Form 16s and Form 13s revealed that the TAC model was not constrained by either manpower or test stations. Therefore, the model would not show the impact of shortages of either resource on the aircraft mission effectiveness. Since the purpose of the model is to calculate the manpower requirements to support a certain level of mission effectiveness, manpower should not be constrained unless the manpower is automatically limited by the number of test stations. Unlike the new AIS, the old test stations required more than one operator for some tasks. Because we could not determine the number of men each test station required, we decided not to constrain manpower while running the old model. However, if there are only so many items of test equipment available, the model should be constrained to that number. Otherwise, the impact of these shortages on the flying program would not be evident. We established from Mountain Home (15) that the existing AIS comprised the following test stations:

Model	Quantity
3409	4
6849	4
6850	4
1803	4
6802	4
6803	4
6805	4
6815	4
6825	4
6846	4
6885	2
6891	4
6811	4
6830	4

However, as discussed before, these test stations support a squadron of EF-111As as well as the F-111As. This made it difficult to determine the relative allocation of the existing AIS test stations between F-111A and EF-111A equipment. We performed three runs of the existing model varying test station quantities to determine how much effect test station quantity had on manpower requirements. The first run constrained the test stations to the above quantities. The second run reduced the quantity of all but the 6885 station by one (i.e. three of all except 6885, two of the 6885). The third run reduced them all by one again, including the 6885 (i.e. two of all except the 6885, one of the 6885). The results, detailed in Chapter 5, allowed us to produce a range of manhours required which could be compared with the new AIS.

Model Runs

Once the above changes were made, we initialized and ran each version of the model using the JCL (8:73) enclosed at Appendix C. We discovered one final shortcoming with the TAC model when we ran the constrained models which involved the release of the aircraft to the serviceable pool once all failed LRUs had been removed and replaced. The old model failed to release the aircraft until after the test station failure networks were called. Thus, if the test stations were down for prolonged maintenance, the aircraft was removed from the serviceable pool, even though the necessary on-equipment repair actions may have been completed. This problem is illustrated in Chapter 4 during the discussion of the old repair networks for WUC 14HAD. We rectified this problem by releasing the aircraft at the JBLANK task, which forms the first task for each of the test station failure networks.

We have reserved the discussion of the results of these runs until Chapter 5 so that they can be directly compared with those from the new model runs.

CHAPTER 4

MODEL DEVELOPMENT, DEBUGGING, AND VALIDATION

Introduction

Modification of the TAC model involved the removal of the existing CENPAC networks, the development and incorporation of new AIS networks, and the modification of the existing LRU failure and repair networks to reflect the new AIS. Then the new model had to be debugged and validated. This chapter outlines the development process, details the changes made to the existing data base, and documents the results of the validation phase.

LCOM Model Description

Figure 3 describes the basic simulation process employed by our model. Missions are scheduled from the data contained in the exogenous file. An aircraft is drawn from the pool which contains all available serviceable aircraft. Prior to the sortie, the aircraft has munitions loaded and preflight tests performed by both maintenance personnel and aircrew. Any faults found at this stage are either rectified or another aircraft is selected. As a result of unscheduled maintenance on the aircraft, unserviceable LRUs are generated which require

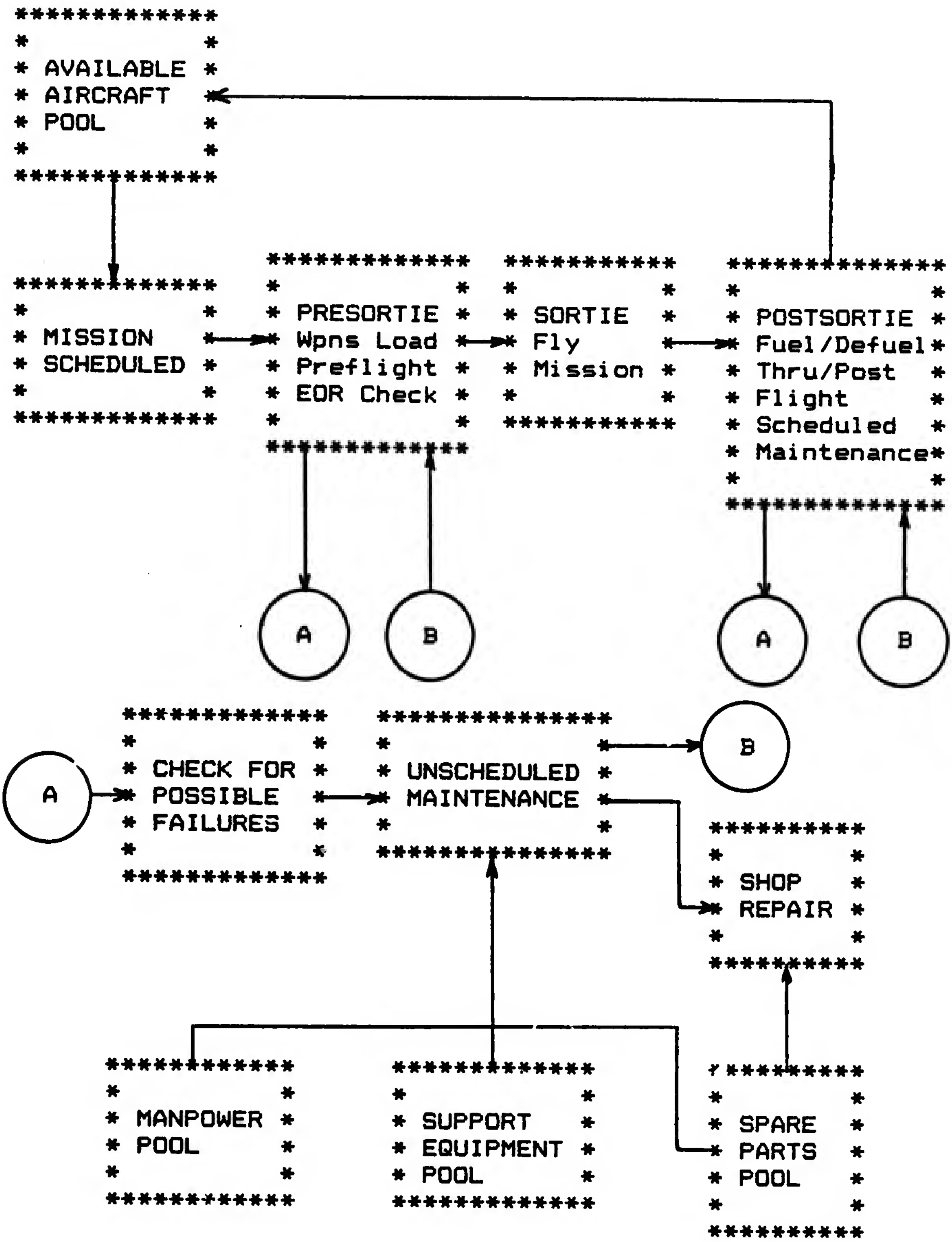


Figure 3. Simulation Process

shop repair. Shop repair is the process of rectifying the failed items in a workshop designated to repair it. If the aircraft is serviceable, the sortie is flown, and all aircraft and LRU failure clocks are decremented by the length of the flight. At the end of the sortie, the post sortie tasks are performed, including fueling, defueling, any scheduled maintenance, and rectification of all unscheduled failures. Again, these maintenance actions can generate items requiring shop repair. Once the aircraft is repaired, it is returned to the available aircraft pool.

The shop repair cycle commences with the input of an unserviceable item. The item is tested, repaired (or forwarded to a higher-level repair facility, such as a depot), and then returned to serviceable stock in the spare parts pool. Items are drawn from the spare parts pool to rectify the aircraft during the on-equipment unscheduled maintenance. Both aircraft and shop work derive the necessary manpower, support equipment, and component spares to effect repair from various resource pools. The shop repair tasks can normally be broken into the broad categories of airframe, engine, electrical, and avionics.

The TAC-supplied data base has all the necessary code to simulate F-111A operations in the format outlined in Figure 3. However, our model is specifically concerned with the shop repair portion of the model and the avionics shop in particular. Figure 4 provides a breakout of the shop repair section of the model reflecting the new AIS. The failed LRU is checked to determine which shop it should be routed to. Assuming it is avionic in nature, it is forwarded to the AIS. On arrival at the AIS, the LRU is sorted into the queue of work for the relevant test equipment required to repair it. Here the LRU is tested and repaired, provided that the test equipment is serviceable, qualified manpower is available, and any component spares are in stock. The LRUs normally follow one of three repair paths:

a. test, repair, and forward to serviceable pool.

b. test, no fault found, and forward to serviceable pool.

c. test, unrepairable at shop, forward to higher-level repair, normally a depot.

For our model, component spares are assumed available, since the object of the model is to determine manpower. Manpower is limited to one of the appropriate AFSCs for each test station. Test station availability is determined by modeling its unscheduled maintenance. This is done by checking each test station's failure clock at the end of each LRU repair action to determine whether a failure has occurred. If a test station failure does

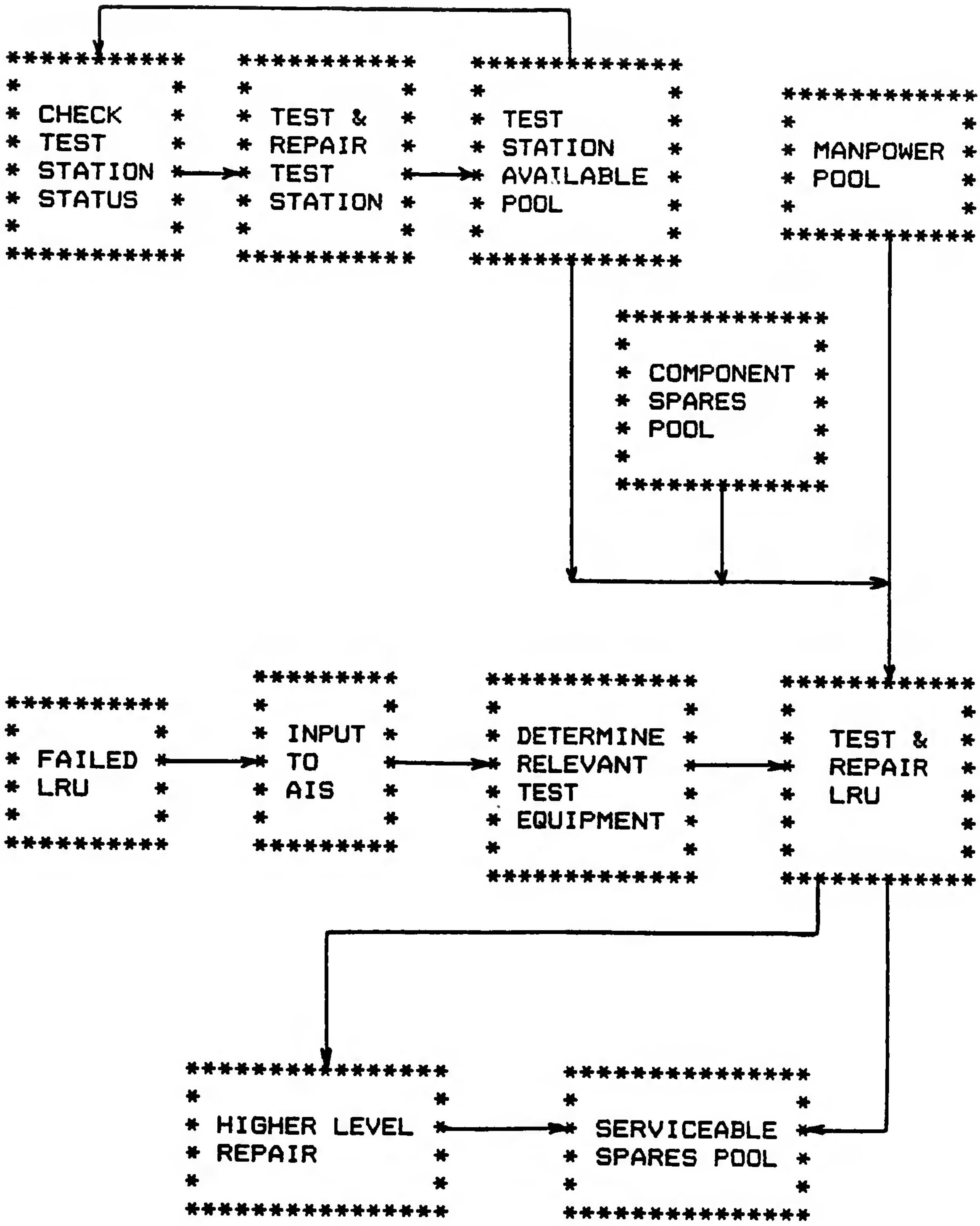


Figure 4. AIS Repair Process

occur, it is removed from the serviceable pool until it is repaired, and any repair action requiring that test station is placed in queue.

<u>AIS Unscheduled Maintenance</u>

The AIS, as we modeled it, was assumed to comprise two each of the following test stations: a Computer Test Station, a Video Test Station, a Radio Frequency (RF) Test Station, and an Electronic Countermeasures (ECM) Test Station. This information was extracted from the preliminary design data package. The contract specifies only the computer, video, and RF test stations. However, two RF test stations are being procured, one for general radio equipment and the other for ECM. As discussed before, the ECM section is physically separated from the rest of the test equipment, mainly for security reasons. Additionally, the ECM test station is manned by an AFSC 326X3, while the rest of the test stations are manned by an AFSC 326X4. For these reasons, we distinguish between the two stations.

The unscheduled maintenance networks for the four stations are extremely simple and are detailed at Figure 5. Figure 5 was produced directly from our Form 11 file using the ASD/ENESA (LCOM) Network Plot Subsystem. Therefore, we can use the network plot to check that the code has no mistakes. One of the unscheduled maintenance

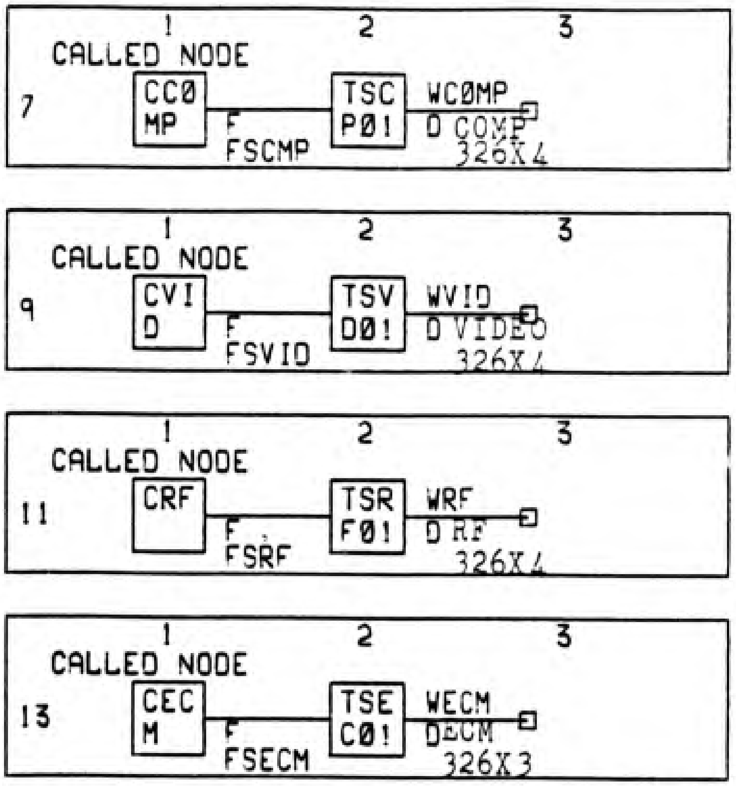


Figure 5. New AIS Unscheduled Maintenance Networks

networks is "called" at the end of any LRU repair task which requires a test station. For example, referring to Figure 5, consider that an LRU has just completed repair on a computer test station. The last task in the LRU network would be to "CALL" the computer unscheduled maintenance network commencing at node CCØMP. Task FSCMP would then be initiated. The selection mode at node CCØMP is an "F," which means that the computer station's failure clock FSCMP is checked to determine whether a failure has occurred. If no failure is indicated, the "F" mode returns the simulation back to the main networks. If a failure does occur, the simulation proceeds to node TSCPØ1, which has a "D" selection mode meaning that task WCØMP will be processed whenever node TSCPØ1 is reached. A "W" task is a bench check and repair task which is used to represent the amount of time necessary to repair the test station. To prevent the repaired LRU from being tied up during the test station repair process, the LRU is released by the "W" task. The computer test station (COMP on the network) is specified as a resource for the "W" task, as is one AFSC 326X4. Specifying COMP ensures that the computer cannot be used to test other LRUs while it is unserviceable. Similarly, specifying the AFSC ensures that manhours to repair the AIS are recorded. Our baseline model uses a constant repair time of two hours, which is the maximum allowed by the contract. The automatic plot does not print the resources required to perform a task, but we have added them to Figure 5 to facilitate reading of the network. If the plot routine is being used to validate a network's coding, care must be taken to cross-refer each task to the relevant Form 12 to ensure the correct resources and task time have also been specified.

LRU Failure and Repair Networks

The LRU failure networks may be divided into two basic groups, those that can be tested on the common core stations and those that can only be tested on one particular test station. Each of the test stations has a common core, and approximately 50 percent of the LRUs modeled can be tested on this part of the station. That means that these LRUs can be tested on any one of the four station types. Because of the isolation of the ECM shop, we decided not to model the ECM stations as common. Our rationale centers on two facts. First, the ECM test station is manned by an AFSC 326X3 who should work ideally only on ECM equipment. Secondly, since the principal reason for separating the ECM shop is security, we reasoned that the extra traffic created by testing non-ECM common core LRUs would be undesirable. However, to offset the additional workload placed on the other three types of test stations, we routed all ECM common core LRUs directly to the ECM facility. We felt that this approach would allow the ECM shop to remain relatively orderly and prevent it from being cluttered with non-ECM LRUs. If the test station usage and mission accomplishment figures indicate that this policy will not work, our model will have to be altered to reflect a policy where common core LRUs can be tested on any one of the four test station types.

The first step in modeling the LRU networks was to identify which LRUs were to be modeled. As explained in Chapter 2, the contract specified 91 LRUs which were testable on the new AIS. Additionally, the TAC model included some 49 LRUs which were not covered specifically in the contract. Assuming that the TAC model represented current aircraft configuration and that these LRUs would have to be tested on the new AIS when the old equipment is phased out, we decided to retain the additional LRUs in our model. Finally, some 20 LRUs specified in the contract were not modeled in the existing TAC data base. We checked these LRUs against the CDEP data held by ASD/ENESA (LCOM) and found that with four exceptions, all the LRUs had either MSBMAs greater than 2000 sorties per failure or nil failures recorded against them. We decided not to model those LRUs with a MSBMA greater than 2000, based on a previous study (11:80) which suggested that LRUs whose MTSBAs exceed this rate need not be modeled. However, we still had some reservations that the reason for the low failure rates may be that the items are presently in the process of being incorporated into the fleet but will be aircraft fit by the time the new AIS is commissioned. A check of the names of the LRUs concerned indicated most were high reliability items such as control boxes, relay assemblies, and electrical equipment racks. Several others had similar names to equipment found in the TAC model indicating a different model system from that specified in the contract. Most of the equipment falling into this category was ECM-related. Discussions with Mountain Home staff (2) indicated that several modification programs were in progress for F-111A ECM equipment and that the TAC data base was probably the more accurate source for current configuration. Therefore, we feel relatively confident with the configuration we modeled. However, aircraft configuration at the time of AIS acceptance needs to be accurately assessed and our model amended accordingly. Appendix E lists the configuration modeled by WUC and cross-refers each to the data source used for its selection.

Our final task before commencing modeling was to determine which test station was required for each LRU. The SA-ALC preliminary design data package included a cross-reference between the LRUs specified in the contract and the test stations capable of repairing them. For the LRUs we added, we simply compared their description to those for which the test stations were known and assigned test stations on the basis of similarity of equipment. We felt this approach was fairly accurate since one of the authors has had experience with F-111C avionic's LRUs and their testing. However, these assignments do need confirmation once the configuration to be tested by the new AIS can be determined. Appendix E also contains a cross-reference between the LRUs modeled, the test stations assigned, and whether the assignment was verified on the data package or estimated.

Once the configuration to be modeled was chosen and the test station assignments were made, the task of developing the networks was straight-forward, though extremely time-consuming. The first step was to analyze an existing LRU failure and repair network, since our intention was to modify these to the requirements of the new AIS. Figure 6, the original network for the WUC 14HAD LRU, was produced from the TAC data base using the ASD/ENESA (LCOM) plot routine. Node 1Ø9 is called at both the presortie and postsortie checks. Since no task is specified for the segment between nodes 1Ø9 and A4HØØ, the simulation proceeds to node A4HØØ. This node incorporates an "F" selection mode. The failure clock F14H** is checked for a failure. If no failure has occurred, the simulation returns to the main network. If a failure has occurred, the simulation passes to node IA4HØ1. The failure clock covers all LRUs whose WUC begins with 14H. The "E" selection mode at node IA4HØ1 determines which LRU type fails. This selection mode indicates mutually exclusive probabilistic branching. Several segments emanate from node IA4HØ1 to repair

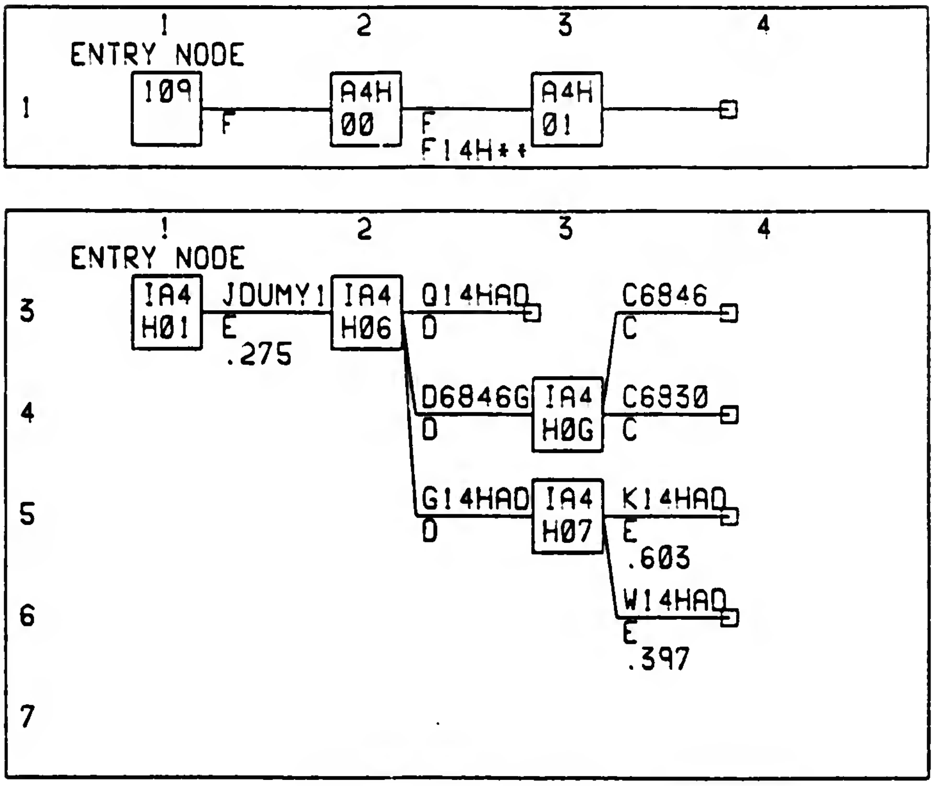


Figure 6. Old Repair Networks for WUC 14HAD

networks for the various 14H group of LRUs. Each segment has a chance of being selected with the probability of a 14HAD failure being Ø.275. If the segment from IA4HØ1 to IA4HØ6 is selected, a failure of WUC 14HAD has been discovered on the aircraft. The task JDUMY1 is a zero-time task used to provide a path to the 14HAD repair network. Node IA4HØ6 has a "D" selection mode at each of the three segments emanating from it. This means that all three tasks will be performed. The Q14HAD task is a "draw a replacement item from stock" task and represents the time taken to obtain a replacement component from stock. The G14HAD task generates an LRU type 14HAD for processing through the repair network and releases the aircraft back to the main networks. The LRU repair networks for 14HAD consist of two segments emanating from node IA4H07. Both tasks have an "E" selection mode, which means that one or the other will be selected based on the probabilities listed at each branch. The K14HAD task indicates that the item is bench checked serviceable. The W14HAD task indicates that the item is bench checked and repaired. Since both networks end at this point, the LRU is returned to the serviceable spares pool once the task is completed. The task D6846G emanating from node IA4H06 is a decrement task which decreases the failure clocks for both the 6830 and 6846 test stations by a set amount. Once the failure clocks are decremented, the unscheduled networks for both stations are called up via the C6846 and C6830 tasks. The D6846G task illustrates the problem discussed in Chapter 3 where the aircraft was not released until after completion of both C6846 and C6830. At node IA4H06, the aircraft is still processing through the repair networks. While task G14HAD releases the aircraft from the test and repair networks, TAC did not release it from the test station failure networks at D6846G. Therefore, the aircraft was tied up by these networks. Since we could not release the aircraft on a D type task, we released the aircraft at the first task of each of the failure networks. We did not like the fact that the test station decrement and unscheduled maintenance networks were in parallel with the LRU repair networks. This indicated that, if the test station was backlogged, the test station could be decremented for a failure and repaired while the LRU meant to trigger the failure remained in queue awaiting repair. The anomaly of this type of network was highlighted by Melaragno (9:80). His suggested remedy was to place the decrement and call to repair after the LRU had processed across the station. We decided to incorporate this feature in our model. Incidentally, this approach also made it unnecessary to release the aircraft at our test station failure networks (to avoid the problem of tying aircraft up during test station maintenance), since they now follow the G14HAD task. The TAC data base also decremented the test station failure clocks by the number of LRUs processed rather than test time. We decided that calculation of the test station failure clock would be complicated with the new AIS because of the amount of variability of workload created by the common feature. Hence, we decided to set the test station failure clocks to the

MTBMA of the test station and decrement the failure clock by the mean length of the actual repair task.

As mentioned before, we found that the networks could be divided into two basic types, based on whether they were testable on the common core or required a specific test station type. The network for the LRU requiring an individual test station formed the basic building block for the network to model a common core LRU. Therefore, we decided to illustrate our LRU failure networks using an LRU which could be tested on the common core. Fortunately, WUC 14HAD is one such LRU, thus allowing comparison between the old and the new networks for this item. Figure 7 details the new network for this LRU extracted directly from our model and printed using the ASD/ENESA (LCOM) plot routine.

The failure network remains the same as for the old model until node IA4H06. At this node, the Q14HAD and G14HAD tasks remain unchanged. However, the test station decrements are no longer present at this point. As stated before, the repair network for a single test station forms the basic building block for a common core LRU. Therefore, we will look at the repair network for the computer station, assuming it is the one that has been selected. The selection process would have routed the LRU to node IA4H10. Again, "E" selection modes are used to determine whether the repair will bench check

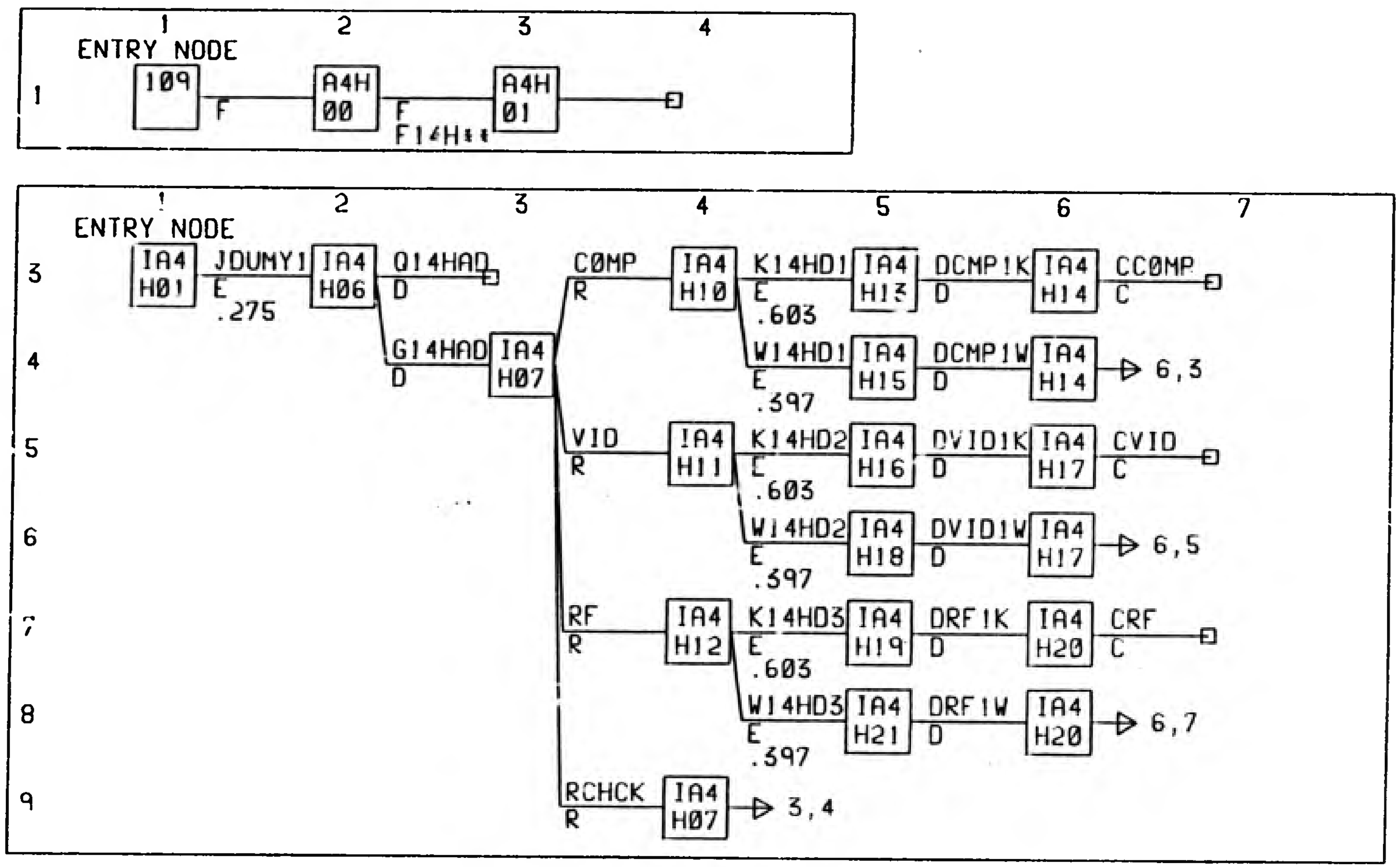


Figure 7. Revised Network for WUC 14HAD

serviceable (task K14HD1) or will require repair (task W14HD1). However, on completion of the relevant repair task, the test station is decremented by the mean length of the task (task DCMP1K or DCMP1W). Then the LRU is routed to node IA4H14, where the computer unscheduled network described previously is called by task CCØMP. As can be seen, the parallel networks for the video and RF test stations are similar.

The only part left to explain is the selection process. When an LRU arrives at node IA4HØ7, it is faced with one of four paths, each controlled by an "R" selection mode. The "R" selection mode checks each branch, starting from the top and working to the bottom, and selects the first path having the necessary resources to perform the task. The tasks CØMP, VID, and RF are zero-time tasks which require one AFSC 326X4 and a relevant test station. If all resources are busy on other tasks, the "R" selection mode would normally place the LRU in queue for the top test station, namely the computer. To alleviate this problem, we modeled the fourth branch with task RCHCK. This task requires no resources, so it will always be selected if all test stations are busy. Task RCHCK incorporates a one hour delay in routing the LRU back to node IA4HØ7, where the cycle can begin again, continuing until a test station is free. We favored this approach because the computer test station would not become backlogged with common core LRUs while others are free. Our model still causes the top test stations to be favored for common core LRUs, but only if they are free. We could not devise a purely random assignment pattern based on which test station was free. Another alternative considered was to select the test station by means of "E" selection modes at node IA4H07, each set at one third. However, while this would balance the number of common core LRUs fed to each test station type, if the test station were not free, the LRU would remain in queue for that station even if another were free. We feel that the use of the "R" mode was the best that could be achieved using the LCOM language. Should one station appear more heavily loaded than any of the others, rearranging the order of the "R" selection tasks could be experimented with to achieve a more even workload.

Modification of the Existing Model

Our first step in the modification of the existing data base was to add the unscheduled networks for the new test stations without removing any existing code. Then we modified the existing failure and repair networks from those of Figure 6 to those of Figure 7. This involved not just the Form 11s, but also the Form 12s, 13s, 10s, and 14s. The Form 12s were updated to specify the additional "K" and "W" tasks for the LRU, the additional decrement tasks for the test stations, and the "R" selection mode tasks. The Form 13s and 10s were updated to reflect the new test stations as resources. The Form 10s were also updated to reflect the various failure clock decrements for each LRU repair task. At this stage, we initialized the model to ensure that our logic and coding methodology were consistent with LCOM. Since none of the original model had changed except for the failure and repair networks for LRU 14HAD, we reasoned that any errors flagged would be as a result of our new code. We managed to initialize and run this model after rectifying a few minor discrepancies. Once we had achieved a run, we were confident that our approach was feasible and we could commence modification in earnest.

The next step was removal of the old test station networks. This was achieved as described in the methodology chapter and was performed without difficulty, though the exercise itself was extremely time-consuming.

Incorporating the new networks was achieved interactively using the U-Editor and was even more time-consuming than the removal of the old test station networks. Basically, the process involved repeating the procedures discussed for LRU 14HAD 130 times, once for each LRU modeled.

Several other miscellaneous changes were also considered to the model for the new AIS. For example, the two-shift policy described in Chapter 3 was retained. Ideally, we would have liked to constrain manpower for the AIS to one man per test station. However, some 280 WUCs were discovered in the TAC model which required one of the AFSCs 326X3, 326X4, or 326X5 as a resource while not requiring a test station. Appendix F contains a list of these UUTs. Two explanations are possible. First, the task did not require a test station. In this instance, we believe that a different AFSC should have been used to perform the task. Second, these UUTs generate so little test station usage that they do not significantly impact the test station failure mechanisms. Since the model was designed for manpower calculations, the programmer decided it was unnecessary to include the test station as a resource. Without a list of the programmer's assumptions, we were unable to determine the reason for not including the test stations. In either event, this factor would not affect the manpower requirements in the TAC model since manpower was unconstrained. However, if the test station is required, test station utilization statistics would be distorted. We decided not to require test stations as a resource for these UUTs in case the reason for not including them is that other test equipment is required. Additionally, leaving the resources unchanged meant that the models were still able to be compared. However, we recommend that this issue be clarified and the test stations be added as resources if required. If, in fact, the test station operators are performing the work and they require no test station, perhaps consideration should be given to using a different AFSC.

Logical Validation

We followed the methodology detailed in Chapter 2 for debugging our model. We found that the diagnostics of the initialization process were extremely powerful and were able to detect several typographical errors and omissions. Once we succeeded in initializing the model, the next step was to extract the LRU and AIS networks from the Form 11s file and produce a plot of the networks using the ASD/ENESA (LCOM) plot routine. The first step of our validation was to compare these networks with our original designs and to verify that the logic was consistent with our assumptions. The plot routines are scaled to print the networks on 30 inch wide paper. The plot of our networks was some 13 feet long. We were unable to cut-up and photo-reduce these plots so that they could be included in our thesis without destroying much of the cross-referencing which makes them so invaluable. Also, the photo-reduced plots were difficult to read because of their size. Therefore, we decided not to include the plots, but to forward them to our sponsors at TAC in the 30 inch format. Copies for other interested parties could be produced from our Form 11s as required.

Once we were satisfied that the networks were logically valid, the next step was to double check all of the repair task times, the clock decrements, and failure clocks to ensure no errors had been made in transcription. These checks completed our validation of the model. Ideally, the model should have been run against historical data to fully validate it. However, such data was unavailable and we had to rely on comparison with the TAC data base. The results of these comparisons are discussed in Chapter 5.

CHAPTER 5

RESULTS OF BOTH MODEL RUNS

Introduction

As discussed in Chapter 2, the major thrust of our research was to produce a running model of the new AIS. Part of our validation methodology also required running of the TAC-supplied model. Finally, we wanted to ascertain whether, using the limited data available to us, the new AIS offered some potential for reducing manpower.

Basic Run Parameters

Both the old and the new models were run using the same flying and maintenance scenarios. Spare parts and manpower levels in both models were unconstrained so that they would not impact the flying schedule and, hence, the workload and manpower calculations for the AIS. We ensured that these factors were unconstrained by setting the number of spare LRUs available to 100 and the number of each AFSC to 200. These values correspond to the levels set in the TAC model. Test stations, however, were restricted to the number physically available. We did this to determine whether sufficient test stations were available to support the flying program. In the case of the old model, it was difficult to determine how many test stations could be devoted to F-111A operations, since they are used to support EF-111A operations as well.

We performed three runs of the old model, the first using the total number of test stations available and the others progressively reducing these numbers. For the new AIS, the contract distinguishes between the number of test stations being procured to support the F-111A and EF-111A workloads. We used these figures in our model. We caution that the results obtained will only allow comparison between the two AISs, since data availability has limited the degree of detail we could incorporate into our model. The results of the comparison between the two models will reflect any manpower savings which can be expected in the new AIS as a result of improved maintainability and reliability, the one operator policy, and a reduced number of test stations. Since no change of failure rates or test times has been modeled, further reductions in the manpower could be expected if the new AIS results in a general reduction of either or both of these parameters. Additionally, our range of test station failure and repair rates is between the worst case where contract specifications are just met and the optimistic case of the test equipment achieving the contractor's initial estimates of performance. More realistic data on these times will enable the range to be reduced. On the other hand, our model was unable to incorporate any test station scheduled maintenance requirements. This factor would tend to make the manpower required for the new AIS marginally lower than when these requirements are included. We believe the changes will not be significant, since the contract specifies minimal downtimes for scheduled maintenance.

Stabilization of Simulation

The ideal methodology (3:6.1) for running an LCOM simulation would be to first determine the warm-up period, or the time the model requires to reach steady-state. Once steady-state is reached, the run time should be determined to ensure the output statistics clearly measure long-term effects of all input variables. The LCOM Training Guide (3:6.1-6.6) discusses techniques for determining these conditions. The implementation of this methodology requires numerous simulation runs using different starting seed values each run. Since data limitations have restricted our model to a rough approximation of the manpower required for the new AIS, we could not justify the amount of computer time necessary to establish the warm-up and run times exactly.

However, the Training Guide also points out (3:6.5) that "stabilization for most aircraft studies should be reached within a 15 to 30 day interval," while "somewhere near 2000 sorties must be flown before an adequate run time is achieved." Rather than perform several runs, we decided to use these approximations and add a significant safety factor. We used a warm-up period of 50 days, which represents a safety factor approaching 100 percent. Since our flying schedule generates 14 sorties per day, it would take 143 days to fly 2000 sorties. Therefore, we used a run length of 200 days after stabilization was reached, for a total simulation run of 250 days. Statistics are collected only for the last 200 days. A run length of 200 days represents about a 35 percent safety factor. We stress that this approach was only taken because our data did not warrant a more thorough approach. Future studies, using more accurate data, would have to determine these run times more precisely.

Old Model Run Results.

Table 2 details the results for the TAC model modified to reflect the two-shift policy and constrained test station resources. Analysis of these statistics revealed some interesting results. Even with the full

Number of 6885 Test Stations	2	2	1
Number of Remaining Test Stations	4	3	2
326X3 Manhours	20308	15370	10836
326X4 Manhours	18190	15188	9897
326X5 Manhours	6495	6276	4597
Test Station Backlog (Hours)	20310	24081	22170
Total Manhours Including Backlog	65303	60915	47500
Sortie Accomplish-Rate (Percent)	97.46	87.46	60.54

Table 2. Old Model Run Results (200 Days Operations)

number of test stations, the existing AIS cannot sustain the flying scenario without a significant AIS backlog. As we reduced the number of test stations, the backlog built up to such proportions that, even with 100 spare of each LRU, the sortie accomplishment rate began to fall. A check of the performance statistics showed that WUCs 73ABO and 76KKO exceeded the 100 items backlog and so constrained the model. We reasoned that the total manhours required for the AIS to support the flying scenario comprised the individual totals worked by each relevant AFSC plus the amount of hours of work in backlog. Unfortunately, the breakdown of the backlog into AFSCs was not readily discernible. While this data could be extracted manually from the shop repair statistics, we felt that our data accuracy did not warrant the effort since the results contained in Table 2 are sufficient for a rudimentary comparison with the performance of the new model.

The fact that even the maximum test station configuration could not sustain the flying scenario without significant backlog suggests that one of the following assumptions may have been in error as described:

a. The flying rate used in our model may be much higher than that achieved in practice. We have applied a very simple flying program based on relatively long sortie lengths which were not validated by TAC.

b. The two-shift policy may not be

appropriate to the flying schedule assumed.

Since the major purpose of this research was to build a working model of the new AIS and to compare the old AIS with it under similar operating conditions, we could not justify the expense of additional runs under varied flying scenarios and shift policies. These runs should be performed only after the model has been updated with more accurate data. Until a scheduled maintenance policy and realistic test and repair times are available, we feel that the level of absolute accuracy required cannot be achieved. Furthermore, we consider that it is more advantageous to compare the two AISs under a scenario that taxes them, thus making the relative superiorities of each more apparent.

One final point which became obvious when we ran the old model was the high workload for AFSC 326X3. Since this AFSC is concerned only with ECM equipment, it became apparent that the ECM workload is approximately half the total workload of the existing AIS.

New Model Run Results

Table 3 details the results for the new model runs. Initially, we made two runs, the first of which we called our worst case model. The test station failure and repair rates for this model reflect the lower limits of performance acceptable by the contract. The second

Model	Worst Case	Optimis-tic	Worst + No ECM Common
326X3 Manhours	11330	11164	11309
326X4 Manhours	21104	21866	21508
326X5 Manhours	476	473	506
Test Station Backlog (Hours)	7808	4920	5908
Total Manhours Including Backlog	40718	38423	39231
Sortie Achievement Rate (Percent)	99.45	99.82	99.61
Test Station Utilization:			
Computer	74.62	77.22	75.13
Video	54.56	56.96	55.76
RF	57.25	57.42	57.64
ECM	100.00	100.00	100.00

Table 3. New Model Run Results (200 Days Operations)

run, called our optimistic model, reflects the contractor's estimates for test station failure and repair times.

The combined manhour/backlog figures indicate that the new AIS should offer a significant reduction of manpower. The implication from these figures is that the existing CENPAC equipment consumes a considerable amount of its manpower in rectifying test equipment failures. We draw this conclusion from the fact that the major difference between our model of the new AIS and the old CENPAC equipment is the improved reliability of the new AIS combined with the flexibility of test station assignment for the common LRUs. Both models use the same test and repair times. We caution that schedule maintenance has yet to be included for the new AIS. However, it is inconceivable that this workload will make some 20,000 manhours of difference.

Our model also revealed that the new AIS would be incapable of supporting the flying scenario, based on our assumptions for test station assignment or loading. However, all of the backlog was restricted to the ECM test stations. A review of the utilization rates for the remaining test stations revealed substantial idle time available for each. Therefore, we reasoned that under different test station loading assumptions, the new AIS should be capable of supporting our scenario. We postulated two possible loading policies which would reduce the workload of the ECM stations:

a. One approach would be to remove all the common ECM equipment from the ECM test stations and test it on the remaining test stations. Combined with this approach, any piece of ECM equipment not restricted for security reasons should be assigned to the RF stations rather than the ECM ones. We partially tested this policy by performing a run of our model with the common ECM LRUs tested by the other stations. This run was performed using the contract data for AIS reliability and maintainability. The change involved only five LRUs, but it reduced the backlog by almost 2000 hours. We are confident that testing of some of the other LRUs on the RF station would have enabled the flying scenario to be achieved without backlog. However, we were unsure of which equipment to segregate from the main shop for security reasons and were hesitant to experiment with the model any further.

b. Should it remain desirable for all ECM equipment to remain segregated, the other option we would suggest is to dedicate a third RF station to the ECM area. This approach would reduce the number of RF stations to one. However, from the test station loading figures, one RF test station should be capable of performing the non-ECM workload, probably with a greater percentage of the common equipment being shared by the computer and video test stations. Additionally, the ECM shop would probably have excess capability which could be used for RF equipment in the event of a protracted RF test station failure. This alternative is only viable if the ECM and the RF stations remain the same test station type. While we only distinguished between the two for geographical siting reasons, we remind the reader that Mountain Home staff believed that they might become distinct stations. On the basis of the indications of our preliminary runs, we recommend that this should be avoided to retain the maximum amount of flexibility possible in the new AIS. We were unable to run our model under the second scenario because time limitations prevented us from modifying the necessary parameters. However, we feel that the advantages discussed are intuitively correct.

The results obtained from the limited runs of our new model are summarized as follows:

a. First, under the shift conditions and flying scenario assumed, the new AIS offers a significant reduction of manpower.

b. Second, the new AIS appears to offer a significant performance improvement as witnessed by the much lower backlog figures for the new model.

c. Finally, careful attention to test station loading combined with retaining the same configuration for both RF and ECM test stations will allow the performance of the new AIS, as compared to the old AIS, to be increased even further.

While we feel our model has sufficient accuracy to predict relative performance of the new AIS, too many factors remain unresolved to allow the relative advantages to be quantified absolutely with any degree of confidence. Specifically, scheduled maintenance of the test equipment and accurate test and repair times are essential for accurate quantification. However, even at the level modeled, our model certainly demonstrates that the new AIS will be superior to the existing facility. Further refinement of our model should allow these advantages to be accurately predicted prior to the new AIS entering service.

CHAPTER 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Our research focused on the development of an LCOM model which would allow manpower studies to be performed for the new F-111A AIS. We achieved this by modifying a TAC-supplied model of existing F-111A operations to reflect the new facility. Once we developed our model, we performed some rudimentary comparisons between the old and the new AIS. Specifically, we considered manpower requirements and performance of the two AISs under the same flying and maintenance scenarios.

Our new model represents the worst case operation of the new AIS. We assumed that the new AIS will at least meet contract specifications and that the LRU test and repair times will, at worst be comparable to the existing AIS. However, our model does not go below the test station level of detail and does not include test station scheduled maintenance. Lack of specific data precluded inclusion of these features.

We compared the performance of the new and the old AIS by running both models under the same flying schedule and comparing the manhours required, the amount of work backlogged, and mission accomplishment rate achieved. As detailed in Chapter 5, the new AIS required significantly fewer manhours for a much higher level of performance. In fact, even if all assets were specifically devoted to the F-111A, the old AIS was unable to sustain the flying scenario assumed. We stress that the results of the old model runs may not represent observed performance at Mountain Home because of the extremely simplified flying scenario and shift policy we used.

By contrast, we feel we were able to demonstrate that the new model is capable of supporting the same flying scenario with approximately a 35 percent reduction in manpower provided the test station loading was revised for the ECM equipment. Our analysis also revealed the desirability of retaining a common configuration for the RF and ECM test stations. Both models assume no spares or manpower shortages. However, since TAC assured us that their model was validated, we assume that if more realistic operations and maintenance data were used, the results would be realistic. In any event, by running the two models under the same conditions, we were able to make an assessment of the comparative performances of each.

Conclusions

Our analysis of the new AIS indicates that it will be significantly superior to the existing AIS both in terms of manpower requirements and mission capability.

Recommendations

First, we believe that our model should be expanded to incorporate both scheduled and unscheduled test station maintenance. Once this is accomplished, TAC would have a basic model for analyzing not only the manpower requirements for the new AIS, but also the impact of the new AIS on mission achievement. We stress that our model has not been fully validated as yet and that a validation program is essential once historical data becomes available. One possibility for further model development and validation may be through the AFIT Thesis Program. Much of the TRU data necessary to expand the unscheduled maintenance networks is now available and more accurate data on scheduled maintenance requirements and test times should be available within the time frame of a follow-on thesis.

Our second recommendation is that SA-ALC carefully evaluate the optimum repair flows to maximize AIS effectiveness. Though we used unvalidated flying and maintenance scenarios, we did demonstrate the susceptability of the new AIS's performance to test station loading or repair flows. Specifically, a definite policy on the repair of the ECM equipment must be developed to ensure that this equipment does not restrict the overall effectiveness of the new AIS. Coupled to this aspect is our strong recommendation that the configuration of the RF and ECM test stations should remain common to provide maximum flexibility for the AIS. We expressed reservations about the aircraft configuration we modeled and obviously this aspect requires clarification before meaningful estimates of the manpower required for the new AIS can be made. Again, we feel that a refined version of our model offers the appropriate tool for determining the most efficient utilization policy and resultant manpower requirements for the new AIS.

APPENDICES

__Reliability__. Reliability measures an item's inherent nature to remain in an operational state. Reliability (13:576) is commonly defined as "the probability that a system, subsystem, component, or part will perform a required function, under specified conditions without a failure, for a specified period of time." Reliability is normally expressed in terms of the mean time between failure. The definition of failure rate expands this concept.

__Maintainability__. Maintainability (13:406) describes "a characteristic of design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time when the maintenance is performed using prescribed procedures and resources. System maintainability may also be expressed in such terms as mean time to repair, maintenance manhours per flying hour, or mean down time."

__Mission Effectiveness__. Mission effectiveness attempts to measure how well a particular organization performs in achieving its established goals or mission. For aircraft, it is most usually expressed as the ratio of the number of sorties flown to the number of sorties scheduled.

__Sortie__. The term sortie (13:634) describes "the flight of a single aircraft from takeoff until landing."

Support Resource. A support resource is any item required to accomplish a task. Support resources are commonly referred to as support items, which are defined as (13:673) "items subordinate to, or associated with, an end item (i.e., spares, repair parts, tools, test equipment, support equipment, and sundry materials) and required to operate, service, repair, or overhaul an item."

Support Equipment. Support equipment (13:673) is a subset of support resources and specifically refers to "equipment such as special purpose vehicles, power units, maintenance stands, test equipment, special tools, and test benches used to facilitate or support maintenance actions, detect or diagnose malfunctions, or monitor the operational status of systems, subsystems, or equipments."

Automatic Test Equipment. Automatic test equipment (ATE) is (13:80) a generic term for "electronic devices capable of automatically or semi-automatically generating and independently furnishing programmed stimuli, measuring selected parameters of an electronic, mechanical, or electromechanical item being tested, and making a comparison to accept or reject the measured values according to predetermined limits." Normally, ATE operates by the use of pre-programmed test software.

<u>Line Replaceable Unit</u>. A line replaceable unit (LRU) is the most basic component of any aircraft system which can be removed and replaced to rectify an aircraft unserviceability. An LRU is self contained and is identified as a repairable item. An avionic's LRU is often referred to as a "black box."

<u>Avionics Intermediate Shop</u>. An Avionics Intermediate Shop (AIS) is a facility where off-equipment maintenance is performed on avionic LRUs. The level of maintenance is normally too complicated for, or requires special support equipment not available to, the on-equipment maintenance component. Part of the AIS workload is to determine what items are beyond its capability and thus require forwarding to a depot for repair.

<u>Unit Under Test</u>. Unit under test (UUT) is a generic term used to designate any item being tested by a piece of ATE.

<u>Air Force Speciality Code</u>. The Air Force Speciality Code (AFSC) is a five digit designator used by the Air Force to identify an airman's specific area of expertise. Specific examples are shown in the section on manpower skill levels near the end of Chapter 1.

Logistic's Composite Model. The Logistic's Composite Model (LCOM) simulation package is a computer model of an operational squadron. It simulates both the operational and support functions of that squadron to the level of detail considered necessary for a particular problem. We discuss the history of the LCOM software in Chapter 1 while Appendix B details its capabilities.

LCOM Network. An LCOM network is a logical and chronological flow of actions (4:4.6). The network translates a sequence of tasks or events required to complete the processing of a particular item or activity into a format decodable by the simulation software.

Work Unit Code. A work unit code (WUC) is a standardized (3:3.18) designation for the individual parts that comprise a weapon system. WUCs were originally designed for the Air Force Maintenance Data Collection System. Each part is assigned a five digit alpha-numeric code. The first two digits define the major system of equipment, the third digit defines the particular sub-system, the fourth digit defines the component, and the fifth digit identifies the specific part within the component.

Failure Rate. Failure rate, a measure of the reliability of an item, is normally expressed in terms of the time between successive failures. However, the time measured depends on the units used to specify failure rate. The two most common methods of specifying failure rates in LCOM (3:3.14) are Mean Sorties Between Maintenance Actions (MSBMA) and Mean Time Between Maintenance Action (MTBMA). The MSBMA reflects the average number of sorties expected before the component fails. The MTBMA reflects the average number of operational hours expected to occur between failures. For aircraft components, the operational hours are equated to flying hours. For test equipment, the operational hours are equated to testing hours. Both MSBMA and MTBMA are usually specified in terms of mean, variance, and population distribution. The TAC-supplied data base uses MSBMA for expressing LRU failure rates and Mean LRUs Processed Between Maintenance Actions (MLPBMA) for test station component failure rates. MLPBMA is not a formal LCOM abbreviation, but we use it to describe the practice of expressing test station failure rates in terms of the average number of LRUs processed between each failure. We do not like this practice for situations where more than a few different LRUs are tested on the same test station. In this situation, calculation of an average number of LRUs becomes difficult, particularly if the test times and failure rates vary significantly between LRU types.

Time to Test. Time to test is the average time spent in testing an item to determine its serviceability status and diagnose the defective component for unserviceable items. The time to test is usually specified in terms of mean, variance, and population distribution.

Rectification Time. Rectification time is defined as that time required to restore an item to a serviceable state once the cause of unserviceability has been diagnosed. This time is usually specified in terms of mean, variance, and population distribution.

Time to Repair. Time to repair is the sum of the test and rectification times and represents the total time required to return an unserviceable item to a serviceable state. For the sake of simplification of LCOM networks, the repair action may be modeled as a single task rather than separating it into a test task and a rectification task. This approach is possible as long as the test equipment cannot be released for other tasks while the rectification is performed. When used, the time to repair is usually expressed in terms of mean, variance, and population distribution.

Repair Sequence. Repair sequence is the chronological ordering of all test and rectification tasks to accomplish a repair. For example, the repair of an LRU may involve the repair sequence of diagnostic testing, bench repair, and serviceability testing.

Tester Replaceable Unit. A Tester Replaceable Unit (TRU) is defined as a self-contained sub-unit of a piece of test equipment which is replaced to effect a first-level repair on the test equipment.

The following is a verbatim extract from the LCOM II Student Training Guide by Dengler:

From a general programming point of view, the Logistics Composite Software is a Monte Carlo simulation written in SIMSCRIPT II.5. The software consists of:
(1) a preprocessor program (Input Module);
(2) simulation (Main Module); and (3) a series of post processor programs (Post Processor Module). . . The function and operation of the modules are described briefly in the following sections.

Input Module

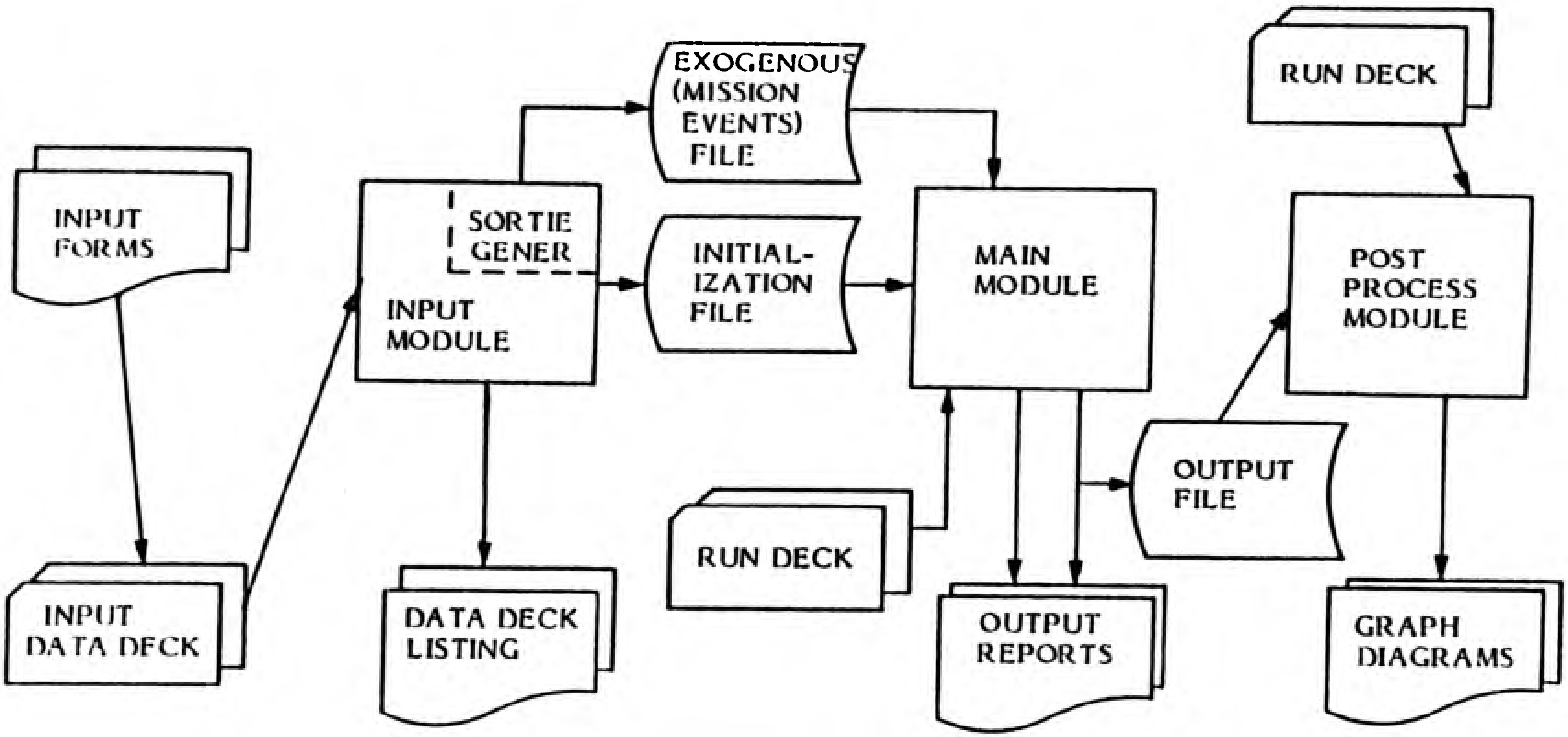
The primary function of the Input Module is to translate user supplied data into a form which can be used by the Main Module of the LCOM II Simulation Software.

The user provides input data that describes the operating environment for the simulation. The input data is then read by the Input Module. Refer to Figure 8 for a diagram of the relationship between the Input Module and the Main Module.

Besides translating user provided input data into the format required by the Main Module, the Input Module performs two independent functions:

1. All the input data, except Sortie Generation Data, is edited for errors or inconsistencies and converted into the initial conditions file commonly referred to as the "Initialization" file. This file describes the environment to be simulated and prescribes initial values for all required variables (i.e., resource levels, reliability factors, policy parameters, etc.). Included in this environment description are all the necessary servicing and maintenance tasks in support of the operations schedule. Service tasks include such items as refuelling and weapons loading. Maintenance tasks include the flight line aircraft maintenance, scheduled and unscheduled maintenance, the repair of components in the shop, and the repair and inspection of automatic and manual test stations.

When user input data contains an error, or has omitted data, or is found to be inconsistent with other data, an edit listing of the input data is printed with



PSR statistics graphs (results vs time)
Aircraft time line displays
Manpower Matrices (requirements vs
time of day)
Analysis of parts usage/availability
Mission statistical summary analysis
Support equipment usage matrices
Realized Flying Schedule (RFS) data

Figure 8. Overall Structure of LCOM Simulation Software

diagnostic messages. In a case where minor discrepancies are found, the program makes limited assumptions concerning the intentions of the user, e.g., forgot to enter number of men required on the job, and the assumption is made that one man is required. In this case, processing continues and a message is provided on what was found and what assumptions, if any, were made. In more serious cases, where such assumptions cannot be made, further processing continues but the Initialization file is not produced until the fatal errors are corrected. This procedure attempts to provide the user with information on all the errors in one execution.

2. The data is edited and used to build an "Exogenous" file. The Sortie Generation Exogenous file expresses mission requirements in terms of mission type, numbers of sorties per mission, sortie length, take-off time, cancel time, etc. NOTE: These two portions of the input data can be run together or separately. Generally, the Sortie Generation data is run separately.

Main Module

Driven by the exogenous data and using the initialization data, the Main Module is designed to simulate a broad range of aircraft operations, scheduling, maintenance, and supply functions at an Air Force base. The logic simulates the flying of an aircraft and the accomplishment of the tasks described in the initialization data. This module also handles the utilization and interaction of resources in the demand process, and the associated changes occurring in resource availability.

User provided input data determines the degree of detail for the actions to be simulated. These actions and their interrelations are described in the task networks. These networks identify and describe the maintenance tasks and processes that are accomplished in support of aircraft operations. For each network process or task, the user provides data which describes the task duration and identifies the types and quantities of resources required. In so doing, the user exercises direct control over the environment being simulated.

The program depicts the resources used in support processes according to specific identifiers provided by the user. The user normally specifies the following resources: (1) aircraft used; (2) types of maintenance personnel involved; (3) ground support equipment; (4)

specific spare parts; and (5) facilities (if required).

The resource mix and the total resources included are limited only by computer capacity. For each specified resource, the model keeps track of the quantities available, in-use, due-out,etc., in accordance with resource utilization taking place during the simulation.

There are two types of outputs from the Main Module. They are: (1) simulation reports during the simulation, and (2) a transaction file which is processed by the Post Processor Module.

The key simulation output product of the Main Module is the Performance Summary Report (PSR) produced at user specified intervals during the simulated period. This report presents 79 overall performance statistics divide into the following seven groups: (1) Operations (Missions); (2) Activities; (3) Aircraft; (4) Personnel; (5) Shop Repair (Parts); (6) Supply (Parts); (7) Equipment (Support Equipment/Facilities).

Consolidating the software output data into one major report helps the user considerably in analyzing the interactions taking place during the simulation. In addition to the PSR, if the user wishes, the program will provide, at specific simulation times, the following separate status reports for: (1) activities; (2) aircraft; (3) jobs backordered; (4) jobs in process; (5) jobs completed; (6) missions; (7) resources; and (8) others.

Besides the PSR output products discussed above, the Main Module provides the user with additional information, which is discussed in the Users Reference Guide, Chapter IV. Included in the simulation reports are: (1) a printout of the SPEC card selected run options; (2) a printout of the CHANGE card file as processed; (3) embedded diagnostics of a warning nature; (4) other user selected output reports; (5) timing and job processing statistics at the end of run; and (6) applicable diagnostics and trace-back information about any abort.

<u>Post Processor Module</u>

Using data produced by the simulation module, the seven individual post processors within this module provide the user with additional data products. Refer to

Figure 8 for the relationship between the Main Module and the Post Processor Module, i.e., a single file of data is produced for the Post Processor to use. . . . The additional data products are:

1. Graph: This product consists of the same data contained in the Performance Summary Report but is presented by individual statistics across several PSR intervals in graphical form. It provides plots (on separate pages) of any of the PSR statistics at the users request.

2. Display: This product provides graphical displays for a selected aircraft. Each display identifies the processes incurred and the time in process for both the aircraft and the aircraft components removed for shop repair.

3. Manpower Matrix: This product provides overall summary data by AFSC (work center), by shift, for personnel utilization. The data reported is based on a 24 hour day divided into half hour increments. This product is also helpful during the manpower constraining phase of the simulation. The Work Center Matrix depicts graphically the manpower demand pattern for the work center during the period selected. It portrays the number of people that must be available in the work center in order to meet the demands for maintenance in an unconstrained run.

4. Parts: This product displays statistics relating to parts stock levels, demands, and backorders. Statistics are also reported for cycle time and condemn rates at base and depot levels. This product is also helpful during the parts constraining phase of the simulation by making parts level computations.

5. Mission: The mission post processor produces a Chronological Sortie History Report and a Mission Success Statistical Report. These reports are produced at user specified intervals and are used in the analysis of mission scheduling problems.

6. Support Equipment: This program provides graphic display of both modeled and actual demands for each item of support equipment. This product is used in determining optimum support equipment levels.

7. Realized Flying Schedule (RFS): This product provides flying schedule data used by the Mission Post

Processor. RFS data includes weather delay, weather cancel, attrition, air abort, sympathetic air abort, RAM, and alert replenishment codes. This data is used for both debug purposes and as input to other programs which analyze crew manpower requirements.

Simulation Modeling Process

The simulation process (i.e., the simulation logic) is perhaps the most complex portion of the manpower determination process. During the course of the simulation, the Main Module processes aircraft through presortie activities toward scheduled missions, and then processes the returning aircraft through postsortie activities as defined by the user. The actual sequence of events follows the process outlined in Figure 9. Based upon the mission schedule, the model draws on the aircraft pool and processes the appropriate number of aircraft (if available) through the presortie tasks. The lead time for all presortie processing is established according to the desires of the user. If the presortie tasks are completed in time to meet the mission schedule, the program "flies" the sortie(s). Concurrent with the accomplishment of the sortie, systems/subsystems and/or components may fail. When the aircraft lands, it receives a basic postflight or thruflight, according to the operations schedule, scheduled maintenance if required, and the program checks for any failures which may have occurred. If no failures are found, the aircraft is released to the available aircraft pool. If any items have failed, they must be corrected by means of unscheduled maintenance.

When unscheduled maintenance is required, the model calls upon the various resource pools (manpower, spares, and support equipment) to correct the malfunction. If the prescribed resources are depleted or devoted to another task, the aircraft must wait. The user can determine task priorities. Depending upon the priorities, tasks can preempt other tasks and the resources directed to higher priority action. After the failure has been corrected, the aircraft is returned to the pool and becomes available to fly again if required by the mission schedule. Failed components that are removed from the aircraft during unscheduled maintenance are channeled into the shop where they may be thrown away, repaired, or processed for shipment to the depot. Either of the last two actions will eventually result in the return of the component to the spares pool. As can be seen, the interaction among support resources and the

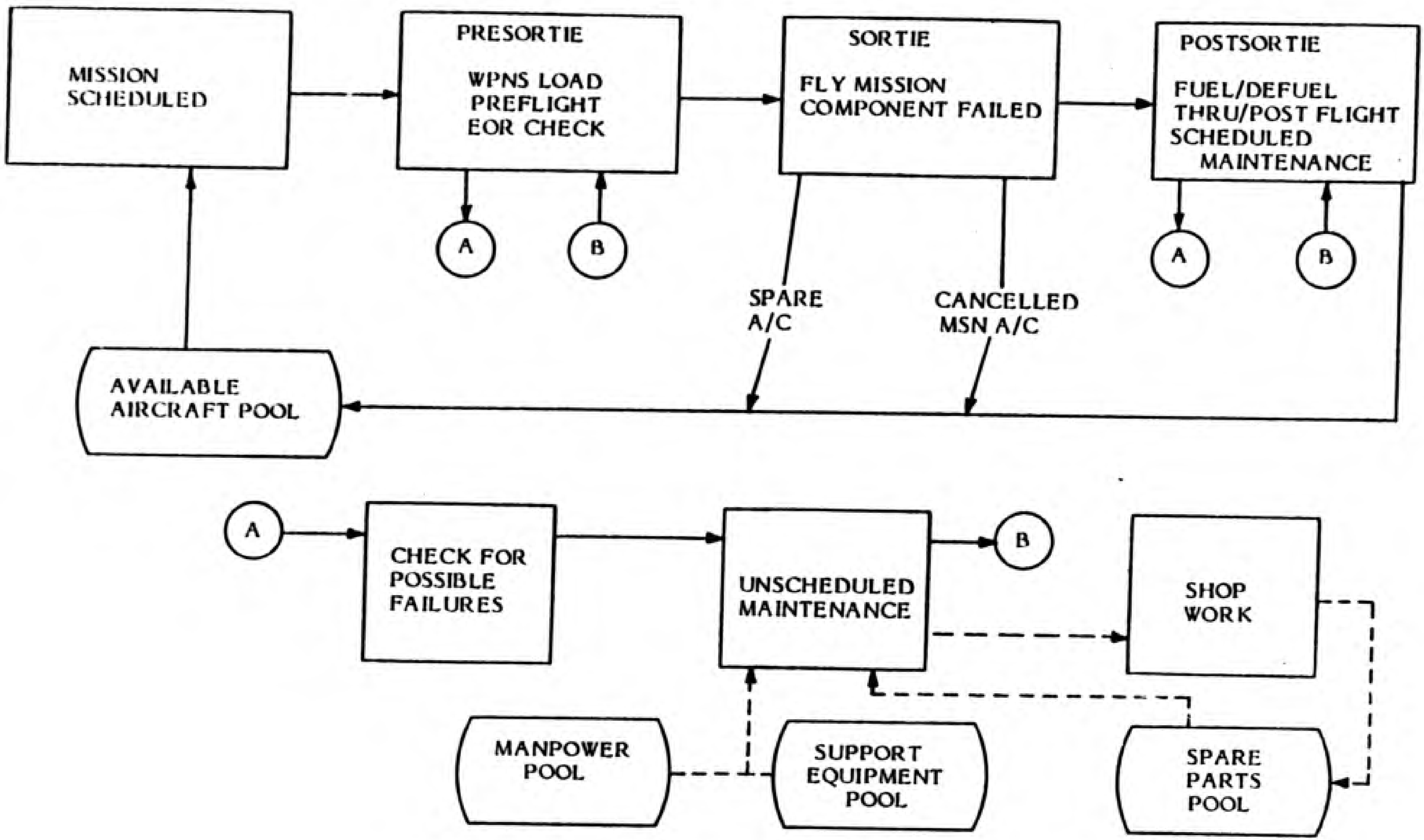


Figure 9. The Simulation Process

operational activities are numerous, in fact, so numerous, that only a computer can adequately capture these interactions and report on the results. These results are displayed as the output products of the program.

The Manpower Determination Process

The overall manpower determination process is depicted in Figure 10. As shown, the initial step in the process is to compile a data base which is normally structured from current field level maintenance concepts, policies, and data applicable to the weapon system. Inputs to the operations data base for the weapon system consist of concepts and parameters which define the manner in which the aircraft will be flown. Once the data base is established, the user must transcribe this data into a form which is acceptable by the Input Module. After this is accomplished, the Input Module can translate this user supplied data into the form required by the Main Module. Next, a number of simulation runs are made utilizing the simulation program. During this iterative phase, selected variables are changed between simulation runs and the run results compared and evaluated. This mode of operation continues until the study objectives have been achieved. During this phase, the Post Processor Module may or may not be used depending on the project objectives. (During manpower studies, the Manpower Matrix Post Processor is normally used during each simulation run.) Finally, the results of the simulation phase are converted into manpower authorization packages by either Direct Manpower Requirement Conversions (AFR 25-5, Vol IV, Table 3-1) or the use of Regression and Manpower Programs. For large studies, this operation, or segments of this operation, can be repeated many times and can require considerable time and effort.

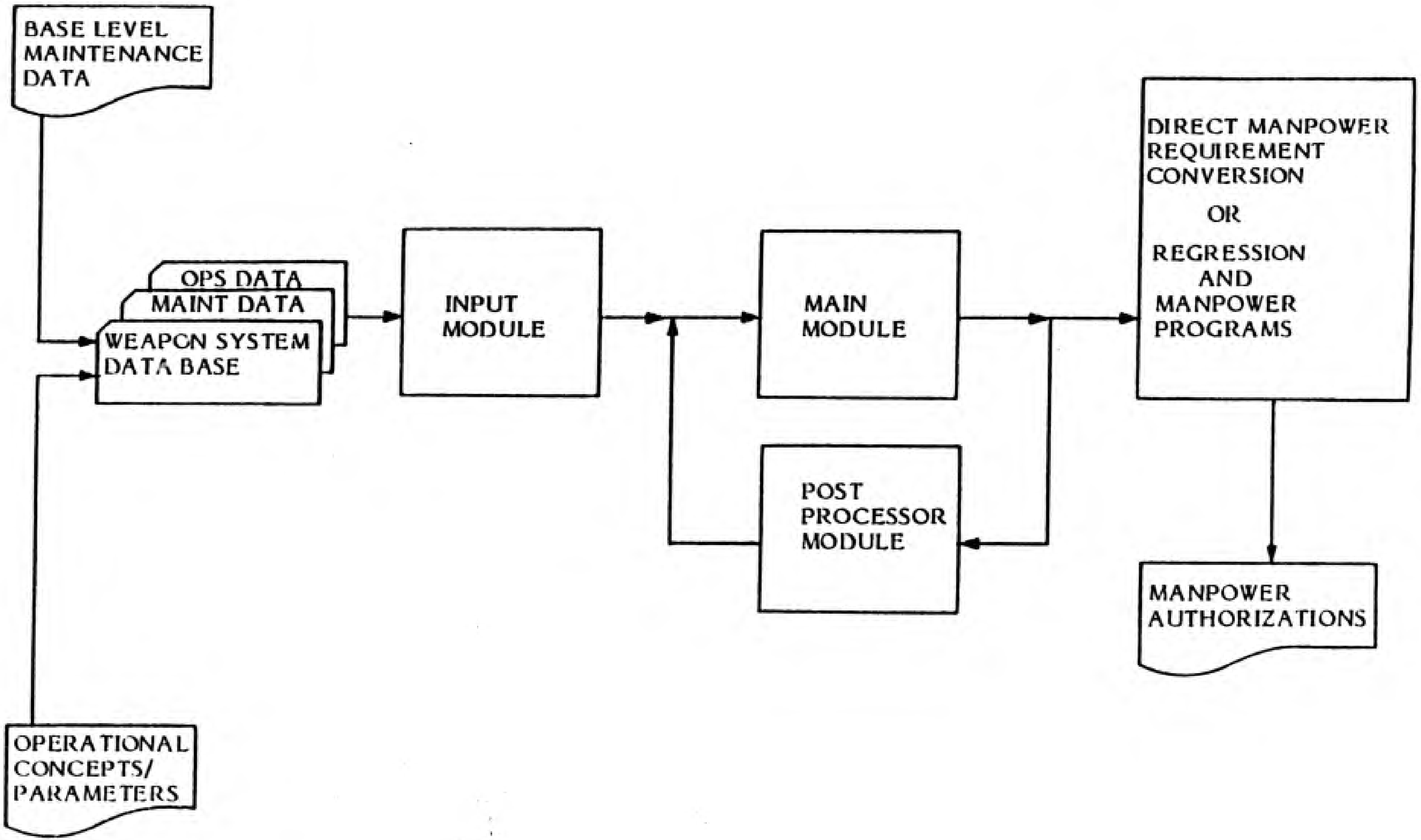


Figure 10. Manpower Determination Process

APPENDIX C

JOB CONTROL LANGUAGE FOR USE OF LCOM ON THE AMDAHL COMPUTER

Job Control Language for Producing Exogenous Flying Schedule File

```
//GATSCD JOB (1103,L31,,40),'AFITTHESIS',MSGLEVEL=1,                    X
//       REGION=900K,TIME=12,CLASS=Z
/*MESSAGE CPU=12 MIN,WALL CLOCK=24 MIN.
//GO EXEC PGM=INPTSTND
//STEPLIB DD DSN=E780109.LCOMCOMP,DISP=SHR
//SIMU17 DD DISP=SHR,DSN=A750265.CACI.SIMERR8
//SIMU06 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1330)
//SIMU05 DD *
SPEC FORM=5 EXOG=9 PRNT=6 INFO=3


********************
INSERT FORM 20s HERE
*******************


/*
//SIMU09 DD DSN=E780109.AFIT.EXOG,DISP=OLD
//
*EOR
*EOF
```

Job Control Language for Running the Simulation

```
//GAT    JOB (1103,L31,,40),'NEWAIS-RUN1',MSGLEVEL=1,                 X
//       REGION=1200K,TIME=42,CLASS=Z,NOTIFY=WER
//GO EXEC PGM=MAINSTND
//STEPLIB DD DSN=E780109.LCOMCOMP,DISP=SHR
//SIMU17 DD DSN=A750265.CACI.SIMERR8,DISP=SHR
//SIMU06 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1330)
//SIMU05 DD *
SPEC CHNG=5 INIT=7 EXOG=9 POST=3 DATA=2 PRNT=6
RCYC       4
WARMUP    50
RFREQ          50.0
NOCLWM
STOP          250.0
/*
//SIMU07 DD DSN=E780109.AFIT.INIT,DISP=SHR
//SIMU09 DD DSN=E780109.AFIT.EXOG,DISP=SHR
//SIMU02 DD DUMMY,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1330)
//SIMU03 DD DUMMY
//
*FOR
*EOF
```

Job Control Language for Initializing a Job

```
//GAT JOB (1103,L31,,20),'NEW-RUN2 ',MSGLEVEL=1,                       X
//        REGION=900K,TIME=12,CLASS=Z
//INP EXEC PGM=INPTSTND
//STEPLIB DD DSN=E780109.LCOMCOMP,DISP=SHR
//SIMU17 DD DSN=A750265.CACI.SIMERR8,DISP=SHR
//SIMU06 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1330)
//SIMU05 DD *
SPEC FORM=1 PRNT=6 INIT=7 INFO=3
/*
//SIMU07 DD DSN=E780109.AFIT.INIT,DISP=OLD
//SIMU01 DD *


**********************
INSERT FORMS FILES HERE
**********************


/*
//
*EOR
*EOF
```

APPENDIX D

FLYING SCHEDULE FORM 2ØS

```
//GATSCD JOB (1103,L31,,40),'AFITTHESIS',MSGLEVEL=1,                  X
//       REGION=900K,TIME=12,CLASS=Z
/*MESSAGE CPU=12 MIN,WALL CLOCK=24 MIN.
//GO EXEC PGM=INPTSTND
//STEPLIB DD DSN=E780109.LCOMCOMP,DISP=SHR
//SIMU17 DD DISP=SHR,DSN=A750265.CACI.SIMERR8
//SIMU06 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1330)
//SIMU05 DD *
SPEC FORM=5 EXOG=9 PRNT=6 INFO=3
 20
LIST360 AFIT01
 20   1    2  0700 F111A  TEST    1 1    3.00   .25 N  2.0  4.0  3   1999
 20   1    2  0800 F111A  TEST    1 1    3.00   .25 N  2.0  4.0  3   1999
 20   1    2  0900 F111A  TEST    1 1    3.00   .25 N  2.0  4.0  3   1999
 20   1    2  1000 F111A  TEST    1 1    3.00   .25 N  2.0  4.0  3   1999
 20   1    2  1100 F111A  TEST    1 1    3.00   .25 N  2.0  4.0  3   1999
 20   1    2  1200 F111A  TEST    1 1    3.00   .25 N  2.0  4.0  3   1999
 20   1    2  1300 F111A  TEST    1 1    3.00   .25 N  2.0  4.0  3   1999
/*
//SIMU09 DD DSN=E780109.AFIT.EXOG,DISP=OLD
//
```

APPENDIX E

SCREENING OF CANDIDATE LRUS

INDEX NUMBER	WUC	SPEC- IFIED IN CON- TRACT	IN TAC DATA BASE	INCL- UDED IN OUR MODEL	TESTED BY	TESTER VERIFIED OR ASSUMED
1	14HAD	YES	YES	YES	COMMON	VERIFIED
2	14HAK	YES	YES	YES	COMMON	VERIFIED
3	42ACD	YES	YES	YES	COMMON	VERIFIED
4	42CAG	YES	YES	YES	COMMON	VERIFIED
5	51ABE	YES	YES	YES	COMMON	VERIFIED
6	51ABG	YES	YES	YES	COMMON	VERIFIED
7	51ABH	YES	YES	YES	COMMON	VERIFIED
8	51ABN	YES	YES	YES	COMMON	VERIFIED
9	51ABP	YES	YES	YES	COMMON	VERIFIED
10	51ACO	YES	YES	YES	COMMON	VERIFIED
11	51ADO	YES	YES	YES	COMMON	VERIFIED
12	51BBO	YES	YES	YES	COMMON	VERIFIED
13	51CAA	YES	YES	YES	COMMON	VERIFIED
14	51CAC	YES	YES	YES	COMPUT	VERIFIED
15	51CCO	YES	YES	YES	COMPUT	VERIFIED
16	52AAA	YES	YES	YES	COMPUT	VERIFIED
17	52AAF	YES	YES	YES	COMPUT	VERIFIED
18	52ABA	YES	YES	YES	COMPUT	VERIFIED
19	52ABF	YES	YES	YES	COMPUT	VERIFIED
20	52ACA	YES	YES	YES	COMPUT	VERIFIED
21	52ACH	YES	YES	YES	COMPUT	VERIFIED
22	52ADA	YES	YES	YES	COMMON	VERIFIED
23	52BAA	YES	YES	YES	COMMON	VERIFIED
24	52BAF	YES	YES	YES	COMMON	VERIFIED
25	52BBR	YES	YES	YES	COMMON	VERIFIED
26	52CAA	YES	NO	YES	COMMON	VERIFIED
27	61BAO	YES	YES	YES	RF	VERIFIED
28	61BBO	YES	YES	YES	COMMON	VERIFIED
29	61BCO	YES	YES	YES	RF	VERIFIED
30	64BAO	YES	YES	YES	COMMON	VERIFIED
31	64BBO	YES	YES	YES	COMMON	VERIFIED
32	71CAO	YES	YES	YES	RF	VERIFIED
33	71CBO	YES	YES	YES	RF	VERIFIED
34	71DAA	YES	YES	YES	COMMON	VERIFIED
35	71DAO	YES	YES	YES	COMMON	VERIFIED
36	71DBO	YES	NO	YES	RF	VERIFIED
37	73AAO	YES	YES	YES	COMPUT	VERIFIED
38	73ABO	YES	YES	YES	COMPUT	VERIFIED
39	73ACC	YES	YES	YES	COMMON	VERIFIED

INDEX NUMBER	WUC	SPEC-IFIED IN CON-TRACT	IN TAC DATA BASE	INCL-UDED IN OUR MODEL	TESTED BY	TESTER VERIFIED OR ASSUMED
40	73ADO	YES	YES	YES	COMPUT	VERIFIED
41	73BAO	YES	YES	YES	RF	VERIFIED
42	73BBO	YES	YES	YES	RF	VERIFIED
43	73BCO	YES	YES	YES	COMMON	VERIFIED
44	73BDO	YES	YES	YES	RF	VERIFIED
45	73BEO	YES	YES	YES	COMMON	VERIFIED
46	73BFO	YES	YES	YES	VIDEO	VERIFIED
47	73BHO	YES	YES	YES	COMMON	VERIFIED
48	73BKO	YES	YES	YES	VIDEO	VERIFIED
49	73CBO	YES	YES	YES	COMMON	VERIFIED
50	73DCO	YES	YES	YES	VIDEO	VERIFIED
51	73DDA	YES	NO	NO	COMMON	VERIFIED
52	73DDO	YES	YES	YES	COMMON	VERIFIED
53	73DEG	YES	YES	YES	COMMON	VERIFIED
54	73DEO	YES	YES	YES	COMMON	VERIFIED
55	73DFO	YES	YES	YES	RF	VERIFIED
56	73DHA	YES	YES	YES	COMMON	VERIFIED
57	73KBO	YES	YES	YES	RF	VERIFIED
58	73KDA	YES	NO	NO	COMMON	VERIFIED
59	73KEO	YES	YES	YES	COMMON	VERIFIED
60	73KGO	YES	YES	YES	RF	VERIFIED
61	73KJO	YES	NO	NO	COMMON	VERIFIED
62	73KKO	YES	YES	YES	COMMON	VERIFIED
63	73KMO	YES	YES	YES	VIDEO	VERIFIED
64	74AAA	YES	YES	YES	VIDEO	VERIFIED
65	74AAB	YES	YES	YES	COMMON	VERIFIED
66	74AAM	YES	NO	NO	COMPUT	VERIFIED
67	74ACA	YES	NO	NO	VIDEO	VERIFIED
68	76ACO	YES	NO	YES	ECM	VERIFIED
69	76ADO	YES	NO	YES	ECM	VERIFIED
70	76BAO	YES	NO	NO	ECM	VERIFIED
71	76BBO	YES	NO	NO	ECM	VERIFIED
72	76BCN	YES	NO	NO	ECM	VERIFIED
73	76BCO	YES	NO	NO	VIDEO	VERIFIED
74	76BDO	YES	NO	NO	ECM	VERIFIED
75	76CBO	YES	YES	YES	ECM	VERIFIED
76	76CC0	YES	YES	YES	ECM	VERIFIED
77	76EAE	YES	YES	YES	ECM	VERIFIED
78	76EAO	YES	YES	YES	VIDEO	VERIFIED

INDEX NUMBER	WUC	SPECIFIED IN CONTRACT	IN TAC DATA BASE	INCLUDED IN OUR MODEL	TESTED BY	TESTER VERIFIED OR ASSUMED
79	76KGO	YES	YES	YES	ECM	VERIFIED
80	76KHF	YES	NO	NO	ECM	VERIFIED
81	76KHG	YES	NO	NO	ECM	VERIFIED
82	76KHH	YES	NO	NO	ECM	VERIFIED
83	76KJO	YES	YES	YES	ECM	VERIFIED
84	76KKO	YES	YES	YES	ECM	VERIFIED
85	76KLO	YES	YES	YES	ECM	VERIFIED
86	76KMO	YES	YES	YES	ECM	VERIFIED
87	76KNO	YES	YES	YES	ECM	VERIFIED
88	76KPO	YES	YES	YES	ECM	VERIFIED
89	76LCO	YES	NO	NO	VIDEO	VERIFIED
90	76LDO	YES	NO	NO	COMMON	VERIFIED
91	76LGO	YES	NO	NO	COMPUT	VERIFIED
92	23YCO	NO	YES	YES	COMMON	ESTIMATE
93	46ABA	NO	YES	YES	COMMON	ESTIMATE
94	51ABF	NO	YES	YES	COMMON	ESTIMATE
95	61CAO	NO	YES	YES	RF	ESTIMATE
96	61CBO	NO	YES	YES	COMMON	ESTIMATE
97	61CDO	NO	YES	YES	COMMON	ESTIMATE
98	73BFL	NO	YES	YES	COMPUT	ESTIMATE
99	73BME	NO	YES	YES	COMMON	ESTIMATE
100	73CAO	NO	YES	YES	RF	ESTIMATE
101	73CAP	NO	YES	YES	COMMON	ESTIMATE
102	73DAO	NO	YES	YES	COMMON	ESTIMATE
103	73DBO	NO	YES	YES	RF	ESTIMATE
104	74ABA	NO	YES	YES	COMMON	ESTIMATE
105	76DBO	NO	YES	YES	ECM	ESTIMATE
106	51ABK	NO	YES	YES	COMPUT	ESTIMATE
107	51ABL	NO	YES	YES	COMPUT	ESTIMATE
108	51BAF	NO	YES	YES	COMMON	ESTIMATE
109	52AAD	NO	YES	YES	COMPUT	ESTIMATE
110	52ABD	NO	YES	YES	COMPUT	ESTIMATE
111	52ACF	NO	YES	YES	COMPUT	ESTIMATE
112	52ACG	NO	YES	YES	COMPUT	ESTIMATE
113	52BAQ	NO	YES	YES	COMMON	ESTIMATE
114	52BAR	NO	YES	YES	COMMON	ESTIMATE
115	52BAX	NO	YES	YES	COMMON	ESTIMATE
116	52BBT	NO	YES	YES	COMMON	ESTIMATE
117	61BAA	NO	YES	YES	COMMON	ESTIMATE

INDEX NUMBER	WUC	SPECIFIED IN CONTRACT	IN TAC DATA BASE	INCLUDED IN OUR MODEL	TESTED BY	TESTER VERIFIED OR ASSUMED
118	61BBB	NO	YES	YES	COMMON	ESTIMATE
119	73CAD	NO	YES	YES	COMMON	ESTIMATE
120	73DCE	NO	YES	YES	COMMON	ESTIMATE
121	74AAK	NO	YES	YES	COMMON	ESTIMATE
122	76DAO	NO	YES	YES	ECM	ESTIMATE
123	76DDO	NO	YES	YES	ECM	ESTIMATE
124	76MAO	NO	YES	YES	ECM	ESTIMATE
125	52ABE	NO	YES	YES	COMMON	ESTIMATE
126	73BPO	NO	YES	YES	COMMON	ESTIMATE
127	73DEH	NO	YES	YES	COMMON	ESTIMATE
128	74AAH	NO	YES	YES	COMMON	ESTIMATE
129	76DCO	NO	YES	YES	ECM	ESTIMATE
130	76DFO	NO	YES	YES	ECM	ESTIMATE

Legend

COMMON - LRU can be tested on the Computer, Video, or RF Test Station.
VIDEO - LRU can be tested on the Video Test Station only.
COMPUT - LRU can be tested on the Computer Test Station only.
RF - LRU can be tested on the RF Test Station only.
ECM - LRU can be tested on the ECM Test Station only.

APPENDIX F

UUTS WHICH MAY REQUIRE
TEST STATION RESOURCES

14HAB	14HAJ	14HAM	14HAN	16AFC	23BDO	23VBO
23YAO	23YBO	23YDO	23YEO	44LTE	46FAA	51ABA
51ABB	51ABC	51ABD	51ABJ	51ABM	51ABQ	51ACA
51ACB	51ACC	51ACD	51ADB	51ADC	51ADD	51CAD
51CCA	51CCB	51CCD	51CCF	51CCG	51CCH	51CDC
51CDD	51CDG	51CDH	52AAB	52AAC	52AAG	52ABB
52ABC	52ABG	52ACB	52ACC	52ACD	52ACE	52ACJ
52ADB	52ADC	52ADD	52ADE	52ADH	52ADL	52BAP
52BBA	52BBB	52BBC	52BBD	52BBE	52BBG	52BBH
52BBJ	52BBP	52BBU	52BBV	52BCC	55AAO	55AAA
55ACB	61BBG	61CAA	61CAC	61CAD	61CAG	61CAJ
61CBA	61CBF	63AAA	63AAD	63AAF	63AAG	63AAJ
63AAO	63AAQ	63AAU	63AAV	63ABO	63ACB	63ADO
63BAO	63BAA	63BAF	63BAG	63BAH	63BAO	63BAM
63BAR	64BCC	65AAO	65AAQ	65AAS	65AAW	65AAX
65ABA	65ABB	65ABC	65ABD	65ABE	65ACB	65ACD
71CAA	71CAP	71CBJ	71CBN	71DAB	71ZAO	71ZBO
71ZCO	73AAA	73AAB	73AAC	73AAE	73AAF	73AAG
73AAH	73AAJ	73AAK	73AAL	73ABA	73ABB	73ABC
73ABD	73ABE	73ABF	73ABG	73ABH	73ABJ	73ABK
73ABL	73ABM	73ABN	73ABP	73ABQ	73ACA	73ACD
73ADA	73ADB	73ADE	73ADF	73BAG	73BCA	73BCD
73BCF	73BCG	73BCH	73BDA	73BDB	73BDC	73BDD
73BDE	73BDG	73BDJ	73BDK	73BFB	73BFC	73BFG
73BFH	73BFJ	73BFN	73BFP	73BFR	73BFU	73BMB

73BMC	73BMD	73BMF	73BMG	73BMH	73BMJ	73BMM
73BMN	73BMP	73BPA	73CAA	73CAB	73CAC	73CAE
73CAF	73CAT	73DAN	73DBA	73DCA	73DCB	73DCC
73DCD	73DCF	73DCG	73DEB	73DFA	73DFB	73DFC
73KBA	73KBB	73KBC	73KBD	73KBE	73KBL	73KBN
73KBP	73KEO	73KEC	73KED	73KEF	73KEJ	73KEK
73KKO	73KKB	73KKC	73KKD	73KKE	73KKF	73KKG
73KKJ	73KKK	73KKL	73KKM	73KKN	74AAP	74AAQ
76CAB	76CBA	76DAB	76DAC	76DAD	76DAF	76DAH
76DAP	76DAQ	76DCN	76DDE	76DDG	76DDJ	76DDK
76DDM	76DDP	76DDR	76DDS	76DDT	76DEB	76DGE
76DHO	76DJA	76EAC	76KJE	76KJF	76KKA	76KKB
76KKE	76KKG	76KKK	76KKL	76KKM	76KKN	76KKP
76KKX	76KKZ	76KLA	76KLC	76KLE	76KLG	76KMJ
76KNC	76KPN	76KOO	76MAH	76MAM	76MAW	

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