199071

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HUMAN RESOURCES

SIMULATING MAINTENANCE MANNING
FOR NEW WEAPON SYSTEMS:

BUILDING AND OPERATING
A SIMULATION MODEL

By

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December 1974
Final Report for Period July 1971 — May 1974

Approved for public release; distribution unlimited.

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This final report was submitted by Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio 45433, under project 1124, with Hq Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235.

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This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFHRL-TR-74-97(II)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER ADA011987
4. TITLE (and Subtitle) SIMULATING MAINTENANCE MANNING FOR NEW WEAPON SYSTEMS: BUILDING AND OPERATING A SIMULATION MODEL		5. TYPE OF REPORT & PERIOD COVERED Final July 1971 — May 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Donald C. Tetmeyer William D. Moody		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Advanced Systems Division Air Force Human Resources Laboratory Wright-Patterson Air Force Base, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62703F 11240403
11. CONTROLLING OFFICE NAME AND ADDRESS Hq Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78235		12. REPORT DATE December 1974
		13. NUMBER OF PAGES
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

This report is the second in a series of 5 volumes.

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

maintenance
manpower
simulation

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

There is a need for a more responsive method for predicting maintenance manpower requirements for aircraft systems during development. This method should provide early estimates for use in trade offs and evaluations, and should be sensitive to the ways in which the new aircraft will be employed. A maintenance manpower simulation model was developed. In using the model, early estimates of maintenance task data for the new aircraft are based on Air Force experience with comparable subsystems and equipment on existing aircraft, factored for the new design and environment. These data are meshed with a detailed operations scenario and support concept assumptions in a model run on the Logistics Composite Model (LCOM) simulation program. The simulation output is iterated and

Item 20 (Continued)

analyzed in post-processor programs whose final output is a complete basic manning authorization document. This entire effort is reported in a five volume technical report. This volume II describes the procedures developed to build a maintenance simulation data base for a new aircraft, to run it with the Logistics Composite Model (LCOM) computer program, and to use the results to predict the maintenance manning required for a new aircraft flying a specific operations scenario. Computer programming knowledge is not necessary to follow and apply this instruction. The procedures presented have been tested and used at the Aeronautical Systems Division of Air Force Systems Command in building and operating simulation models of A-10 and A-7 aircraft.

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SUMMARY

Problem

There is a need for a more responsive method for predicting maintenance manpower requirements for aircraft systems during development. This method should provide early estimates for use in trade offs and evaluations, and should be sensitive to the ways in which the new aircraft will be employed.

Approach

A maintenance manpower simulation model was developed. In using the model, early estimates of maintenance task data for the new aircraft are based on Air Force experience with comparable subsystems and equipment on existing aircraft, factored for the new design and environment. These data are meshed with a detailed operations scenario and support concept assumptions in a model run on the Logistics Composite Model (LCOM) simulation program. The simulation output is iterated and analyzed in post-processor programs whose final output is a complete basic manning authorization document. This approach was evaluated by applying it to the A-10 Weapon System.

Results and Conclusions

The methodology and models were successfully applied on the A-10 program and are being considered for implementation on other aeronautical systems in or entering development. This method provides useful maintenance data in a more timely manner, can be rapidly updated, and can show the sensitivity of manning requirements to a wide range engineering design, support and operations alternatives. During the project procedures were developed to build a maintenance simulation data base for a new aircraft, to run it with the LCOM computer program, and to use the results to predict the maintenance manning required for a new aircraft flying a specific operations scenario. These are described in this report.

This report is the second of five volumes describing a new method for determining the maintenance manpower requirements of new aircraft.

Volume I – Maintenance Manpower Management During Weapon System Development
Volume II – Building and Operating a Simulation Model
Volume III – Maintenance Data Analysis Programs
Volume IV – Data Base Management Programs
Volume V – Manpower Programs

This volume provides a detailed description of the procedures for using the Logistics Composite Model (LCOM) to determine maintenance manpower required for a new weapon system. It is intended to service as a manual of instruction and methodological source document. These procedures were developed by a joint research and development team at the Advanced Systems Division, Air Force Human Resources Laboratory (AFSC), Wright-Patterson AFB, Ohio. The team included collocated members from the Headquarters Air Force Systems Command and the A-10 Program Office, under the general guidance of a steering group at Headquarters Air Force Systems Command. Laboratory work was conducted under Project 1124, Human Resources in Aerospace System Development and Operation, Melvin T. Snyder, project scientist, and Task 112404; Adaptation of Operational Research Techniques to Air Force Human Resources Problems, Major Donald C. Tetmeyer, task scientist.

The work was initiated in July 1971 when the proposed research and development plan was approved by the Air Force Systems Command Council. This plan was documented in AFHRL-TR-74-31.

All members of the team and participating organizations who worked on the simulation models contributed to the final methodology. In addition to the listed authors, they include Mr. Frank Maher, Mrs. Sharon Nichols, and Dr. Richard Luckew of the Air Force Human Resources Laboratory: Mr. Craig McLean, Maj Michael Vasilik, Capt Eugene Benson, Capt Paul Verdier, Capt Carroll Widenhouse, Capt David Welch, Capt John Mallar and SSgt Thomas Shipley of the A-10 Program Office; Maj Michael York of Hq Air Force Systems Command; and Mr. Wayne Jansen, Maj Bobby Green, and Mr. Nathan Davis of the Aeronautical Systems Division. The generous cooperation of the LCOM program author, Mr. William Drake of Headquarters Air Force Logistics Command, and of the Headquarters Tactical Air Command LCOM Simulation Modeling Team of Lt Col Gerald Thompson, Maj Richard Gunkel, Mr. Robert Leckliter, and Mr. Owen Dinger, made the work much easier. The effort might never have been brought to a successful conclusion without the visibility, support and guidance provided by the Headquarters Air Force Systems Command Steering Committee: Lt Col Robert Mathias and Lt Col William Pope of the Deputy for Systems, who served successively as chairman; Lt Col Thomas Castaldo and Lt Col Joseph Beardsley of the Deputy for Operations (Management Engineering) and Lt Col John Ahlborn of the Deputy for Science and Technology.

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I. INTRODUCTION

Why Use a Simulation?

Any model is a simplification of reality. A model is designed to answer a particular kind of question. Once tested and proven, the model can be used to predict and answer rather than having to find out by trial and error each time. The simplifications that are acceptable in any particular model depend on the question the model was designed to answer. The ideal model contains the minimum amount of information to give a useful result.

Mathematical models are the basis of science and engineering work, and are commonly used in many other fields as well. Mathematical models consist of equations. The simplification made in using mathematical models is in the number of variables and criteria that are considered at one time. For example, manning can be computed precisely from a maintenance manhour per flying hour equation: All you need to know is the MMH/FH factor for the airplane and the number of flying hours. The drawback of using this model is that maintenance manhours per flying hour is not really a constant (Donaldson & Sweetland, 1968). Variables other than these two determine the manning that will actually be needed in a given situation. The unit size; the takeoff pattern; frequency of turnarounds; and the sequence in which jobs by different specialists must be done; all effect where bottlenecks will occur, and the number of people required at particular times to overcome them. Information needed to answer questions about required manning and the support resource mix under specific operational conditions cannot be adequately handled in a single equation or set of equations.

Many people are not aware that mathematical equations are not the only kind of available model. Simulation models utilize the tremendous speed and storage capacity of modern digital computers to duplicate the complex sequence of events over time. In effect, the answer is obtained by trial and error experience run in a computer instead of in the real world. Simulation is ideally suited to answering complex questions about the manning and resource support mix that will be required by a new aircraft under a range of different operational conditions. However, it is not an answer to everything. Even large computers have capacity limits. The more complex a model, the more costly it is to run, and the greater the chance for preparation error. The principle that nothing should be included that does not affect the answer is just as important in simulation as in mathematical models, or the purpose and essential logic will be lost in a maze of sophisticated trivial data.

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An Overview of the Procedure

The method described in this report is based on using a Logistics Composite Model (LCOM) simulation (Drake et al., 1970) to predict the manning requirements for a new aircraft. The procedures cover how to build a data base and set up the model logic, how to run the simulation, and how to interpret and use the results.

Figure 1 illustrates the major elements in this modeling process. The maintenance tasks required on the new aircraft are estimated from Air Force experience with similar subsystems on existing aircraft, factored for differences in design. Experience data is obtained from a maintenance data bank, described in AFHRL-TR-74-97(III). The first block in Figure 1 represents use of the data bank programs to obtain comparable data from a number of current aircraft.

The second block in Figure 1 represents the maintenance task and operations scenario data bases that must be constructed for the new aircraft. When processed through a series of translation programs, these data comprise the input to the third block, the LCOM simulation.

The simulation model is iterated until the minimum manning necessary to accomplish the required scenario is determined. In the fourth block, the result of several simulation runs are taken to compute regression curves for direct manning, overhead factors added, and a manning document produced.

How the Simulation Works

The necessary inputs (Block 2) to the LCOM program (Block 3) include: daily mission schedules, defining when aircraft are to fly and for how long; main aircraft servicing networks, defining the tasks, times, and resources to prepare and launch an aircraft at its scheduled time and service it on return; corrective maintenance networks defining the tasks, times, and resources to fix each subsystem when it breaks; failure clocks and derements, defining how frequently each subsystem is likely to require corrective maintenance; and the initial quantities of each resource (aircraft by type, men by AFSC and shift, LRU spares, ground equipment).

Figure 2 is a simplified diagram showing how the program uses these inputs to simulate a sequence of maintenance activities that would take place in an operational unit attempting to fly the specified schedule. When the schedule calls for an aircraft to start preparation for a mission, the computer checks the number of aircraft in available status (those not flying nor in maintenance) and assigns those needed to the mission. Each of the assigned aircraft then begins processing through the appropriate main aircraft servicing network, using the resources needed for the simulated time specified in the task data. The computer keeps count of each resource. For example, when all the load teams are already working on aircraft of equal or higher priority, the loading task on another aircraft will be delayed until a load
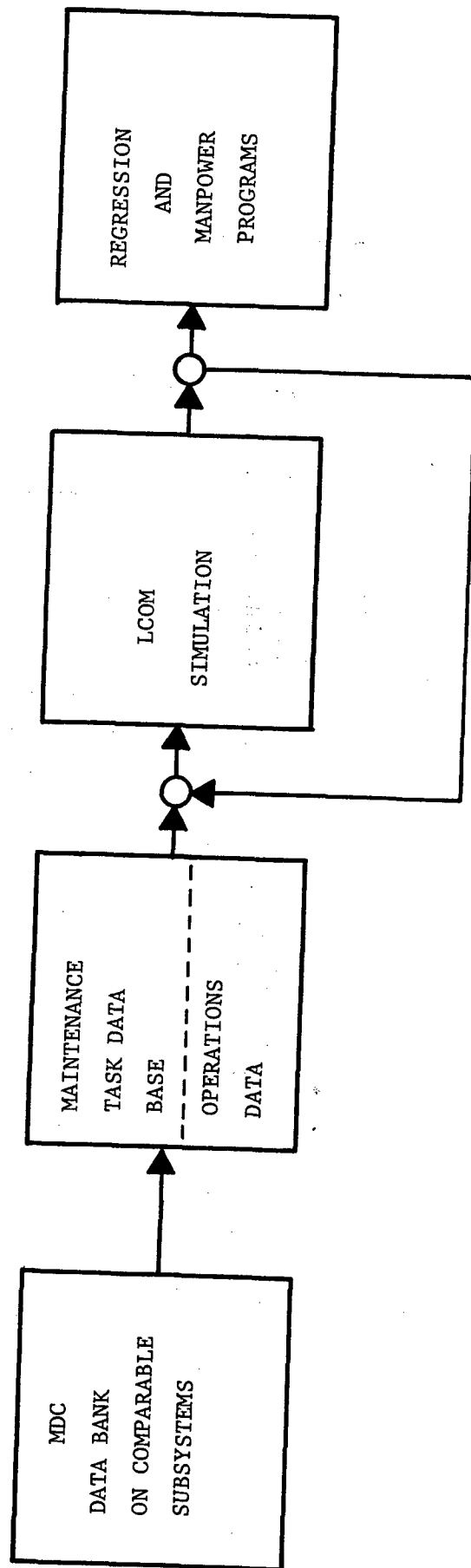
Figure 1. Model development and operation.
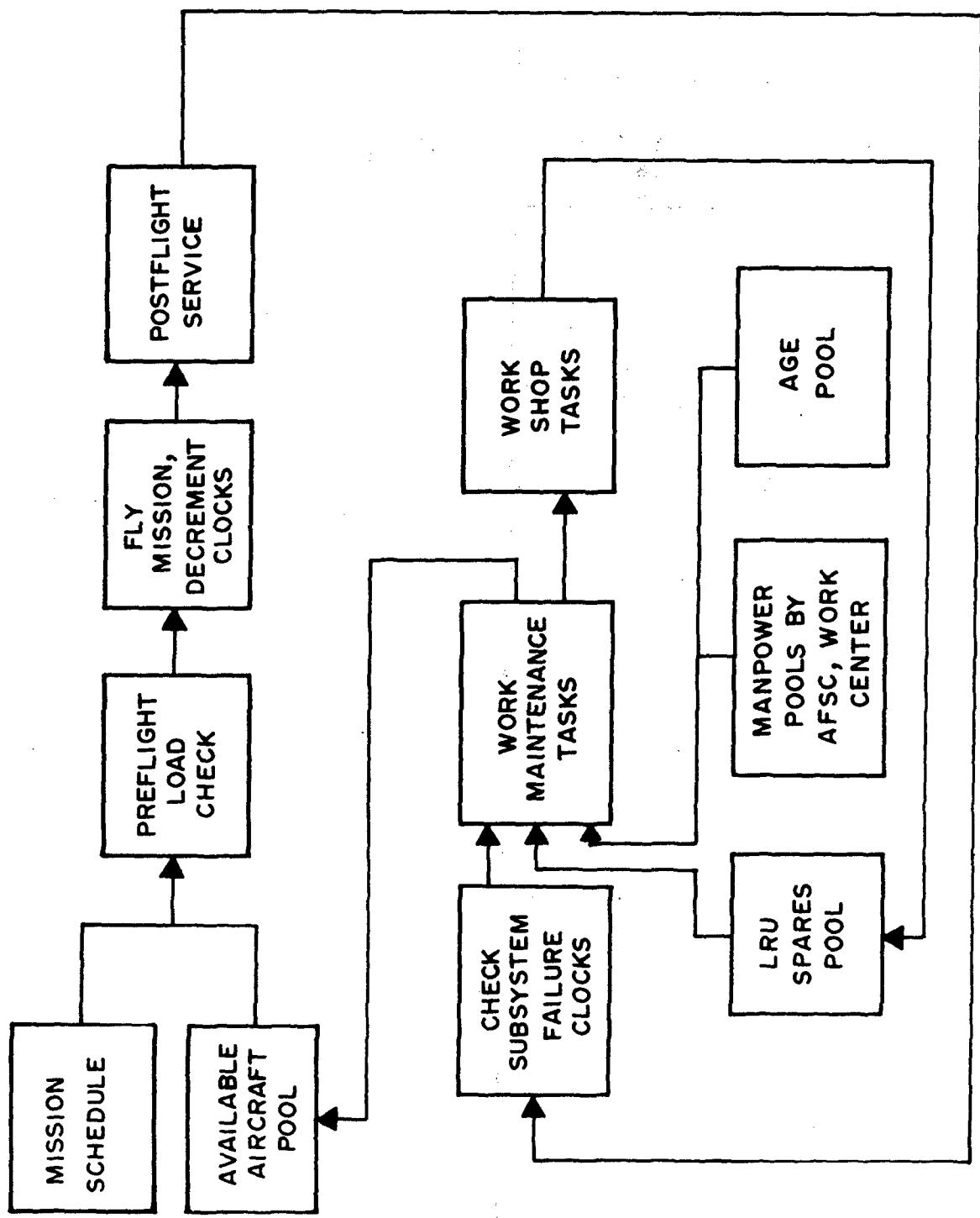
Figure 2. How the simulation works

team becomes available. If enough aircraft are ready to go by scheduled takeoff time, the planes are launched and "fly" for the specified mission duration. At the end of this time, they return to base and process through the post sortie servicing and maintenance tasks.

The program keeps a failure clock on each subsystem. A random draw is made from a subsystem failure distribution to determine the number of sorties until the next corrective maintenance action on that subsystem will be required. Whenever an aircraft flies, each failure clock on its subsystems is advanced one sortie. When the sum of sorties flown reaches the randomly drawn number for a subsystem, the computer lists it as a required corrective maintenance action on that aircraft. The tasks in the corrective maintenance network for that subsystem must be worked off before the aircraft can be returned to available status.

The lower the initial resource levels, the more tasks are delayed, air-craft take longer to return to available status, and fewer missions are accomplished. The extent of the mission loss depends on the timing of the mission schedule and resultant bunching of resource demands.

Relationship of the Input Formats

The hierarchic relationships among input data are illustrated in Figure 3. An operations schedule is contained on LCOM Forms 20. An LCOM Form 17 identifies the appropriate main aircraft servicing network to be processed for each mission type. These networks are entered into the data base on extended Forms 11. Networks define the sequences of tasks to be accomplished and the time and resources required for each task. The main networks also contain appropriate clock decrement and call tasks. Decrement tasks specify when and on what basis subsystem clocks are to be advanced, and the call tasks specify when they are to be checked and any required maintenance accomplished. The corrective maintenance networks and the failure distri-butions for each subsystem are entered into the data base on extended Forms 11.

The next four sections contain detailed instructions on how to develop and prepare input data. Section II covers the operations scenario (LCOM Forms 20, 17, and 15). Section III describes the main networks, Section IV the corrective maintenance networks, and Section V the phase and periodic inspection networks, all of which are entered into the maintenance data base on extended Forms 11. The methods and formats described have been developed to work with the LCOM program version and related data analysis and data management programs available on the Aeronautical Systems Division CDC 6600 computer. Minor variations may be necessary to work with LCOM versions programmed on other computer systems.

II. DEFINING AN OPERATIONS SCHEDULE

Coordinating the Assumptions

Often, the most difficult step in building an operations scenario is getting agreement on the specific mission requirements. These requirements

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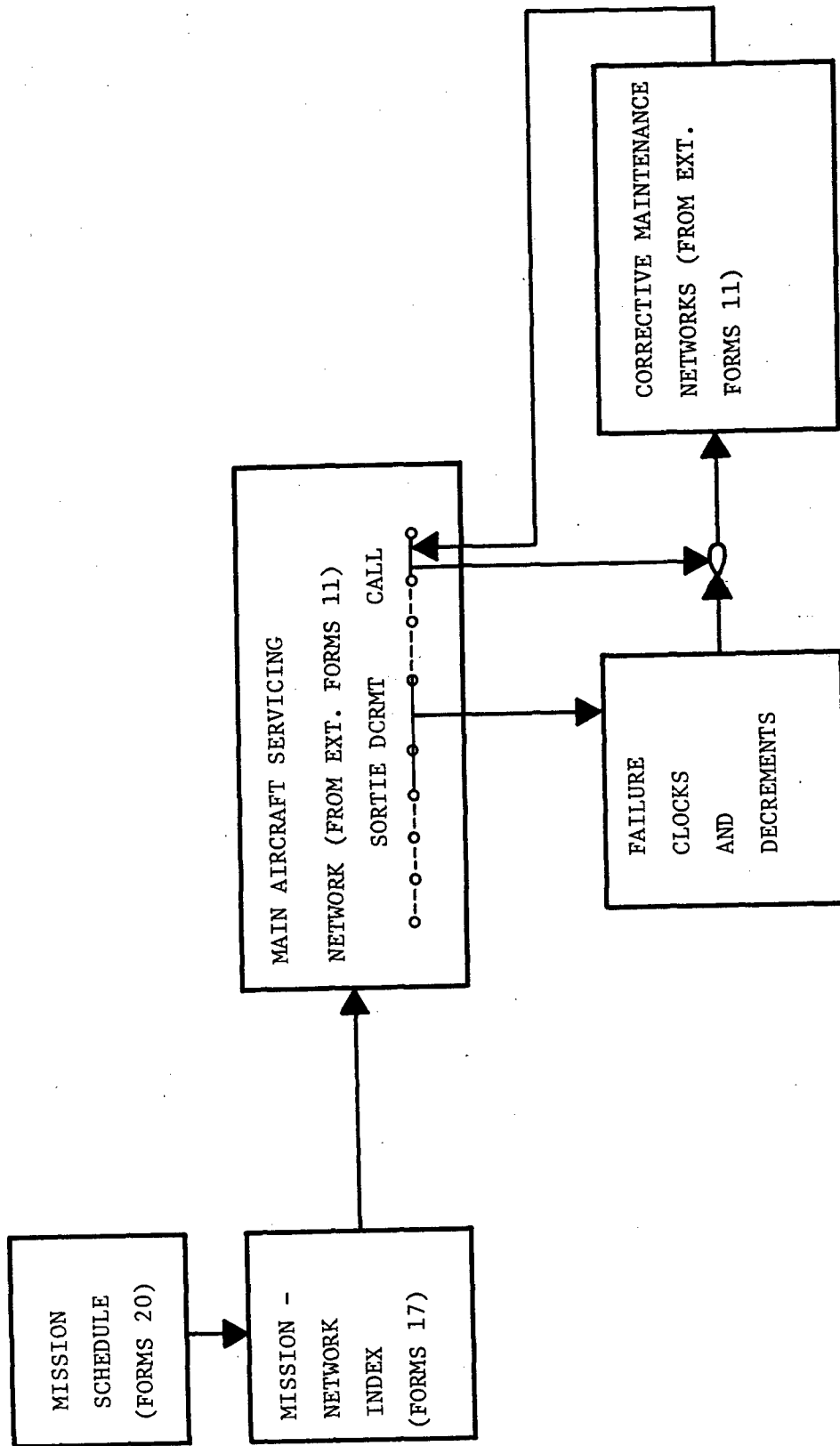
Figure 3. Relationship of inputs.

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must be coordinated and agreed to among the decision makers and organizations who are going to use the end results. Few combat aircraft have only a single mission and single possible mode of operation in all situations. Operations scenarios can range from a low sustaining rate of peacetime training flying by a full wing at an established CONUS base, to a round-the-clock combat surge by a single squadron deployed at a forward base. Scenarios must be defined that are appropriate to the decisions and plans that will be made with the model results. The CONUS wing training scenario cannot be used to determine manning for a deployed squadron in combat.

The requirements office in the operating command is a primary source of information on operations plans for new aircraft. The general questions that must be answered to define a scenario are:

Is it combat or peacetime?

How many aircraft are based at the same location?

What level of maintenance is available at the base? (e.g., do they have field maintenance capability, or is that provided at some other "home" base?)

Are there any other aircraft types sharing the same field maintenance shops and facilities?

What is the desired sortie generation rate, in sorties per aircraft per day?

What is the average sortie length?

Sortie rate x sortie length x flying days in a month gives flying hours per aircraft per month. Is this result acceptable?

What are the missions and load types? These should be defined in a mission-load matrix. Consider wing tanks, camera film, gun ammunition, pods, etc., as types of loads.

Which load configurations could be substitutes? (i.e., if a mission requires Load A, but an aircraft cannot be prepared in time, could a ready spare aircraft with Load B be used? If so, B is a substitute for A.)

What proportion of the total sorties does each mission type represent?

What is the average mission length, the desired number of aircraft, the minimum number of aircraft, and priority for each mission type?

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How soon after scheduled take-off time will a mission be cancelled
if the minimum number of aircraft are not ready?

What is the policy for preparation of ground spare aircraft?

What proportion of the aircraft scheduled to fly per day will be
turned to fly a second time if possible?

What is the proportion of day and night flying by mission type?

What is a typical daily schedule (fragmentation order)? Is it basically
similar for the entire period to be simulated?

Are all available aircraft that are not scheduled to fly preflighted
and available to load and fly if necessary?

What is the variability on mission lengths?

Do any aircraft stand alert? If so, how many and for how long? What
mission types fly off alert, and what is the sortie generation rate
for alert aircraft?

How many weather days and weather cancellations are likely, and what
mission types are affected?

What is the period or schedule for major inspections (Phase, corrosion,
gun, etc.)?

Developing a Basic Schedule

The first step is to reduce the number of load and mission types as
much as possible. Missions which have substitutable loads, require the
same load times and crews, require the same pre and post sortie servicing,
and have reasonably similar mission lengths can be grouped under a single
mission type, regardless of what they do in the air. LCOM simulates what
happens on the ground. Time in the air is just time the aircraft is out of
consideration as far as the simulation is concerned.

When the number of missions types are reduced to a minimum, a daily
flying schedule is laid out. Schedule the takeoff time of each mission
and identify the mission type, the number of aircraft per mission, and
whether the aircraft are on their initial flight of the day or were turned
after a previous flight. Alert missions are not scheduled. The sortie
rate, average mission length, and flying hours per aircraft per month
derived from this schedule, plus alerts, must match the respective assumptions.
This may require several iterations and adjustments of assumptions until a
consistent set is obtained. The computation is:

$$\text{Sortie rate} = \frac{\text{Scheduled sorties} + \text{Alert sorties}}{\text{Number of aircraft}}$$

The assumed proportion of spare aircraft are added, distributed across the non-substitutable mission types. These spares are put on initial flights. In order that they are not released too early, a proportional requirement for additional spares can be put on turnaround flights. This will hold any spare aircraft not used in the morning for afternoon or evening turnarounds. This method of handling spare aircraft is unique to the ASD CDC 6600 version of LCOM.

The same basic flying schedule should be repeated each simulated day wherever this is a reasonable assumption, since it greatly simplifies preparation of input data on the LCOM Forms 20 (sortie generation data).

Entering Mission Data on Forms 20

Each mission is a line entry on the Form 20 (Figure 4). All missions which fly on the first day have a 1 in column 7. Column 12 will always be 1, since a separate line entry is used for each mission. Takeoff time, in 24 hour clock time, is entered in columns 15 - 18. The aircraft type is entered in columns 20 - 25, and the mission type in columns 27 - 32.

A unique name is given to each mission type. Many missions of the same type may fly on the same day, or even at the same time, as long as each is a separate line entry on the Form 20. Mission types must be further subdivided according to the kind of preflight and postflight processing tasks required. The last digit (column 32) of the mission type identifies the processing mode, as follows:

    1 = Preflight to thruflight
    2 = Preflight to postflight
    3 = Thruflight to thruflight (also used for first flights when aircraft
        preflight is scheduled with a separate Form 20 line entry)
    4 = Thruflight to postflight

When preflight is scheduled separately from the missions, the preflight task is followed by a dummy "sortie" with a minimum constant "mission length" of one tenth of an hour. This is the minimum simulated time entry for processing with CDC 6600 LCOM. The dummy sortie does not represent any flying but is just a mechanism for scheduling a block of aircraft into the preflight task, and getting it listed in the simulation output statistics. The time when preflight should be completed is entered as "takeoff time" in columns 15 - 18.

The minimum number of aircraft that must be ready for the mission to fly is entered in columns 34 - 35, and the scheduled number in columns 36 - 37. If preparation of a ground spare is to be shown with a mission, is entered in column 39. For preflight dummy sorties, the maximum number to be preflighted if available is entered in column 36 - 37, and a minimum 2 is entered in column 35. No spares are ever indicated for a preflight dummy.

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LOGISTICS COMPOSITE MODEL

CARD I.D.	DAY	NUMBER OF MISSIONS	TAKEOFF TIME	AIRCRAFT I.D.	MISSION I.D.	MIN	MAX	SPARE	MEAN	VARIANCE	DIST	LEAD TIME	CANCEL TIME	PRIORITY	INT	STOP
20	1	1	0415	A7D	PREFLT	2	17	0	0.1H	.00	HC	4.1H	.1H	3	.1	1999
	1	1	0805	A7D	AGAT3	2	4	1	1.6H	.16	HN	3.7H	.5H	3	.1	1999
	1	1	0815	A7D	CAS3	2	2	1	1.6H	.16	HN	2.3H	.5H	3	.1	1999
	1	1	0825	A7D	TRNG4	2	2	0	1.8H	.18	HN	1.0H	.5H	4	.1	1999
	1	1	0840	A7D	CAS3	2	2	1	1.6H	.16	HN	2.3H	.5H	3	.1	1999
	1	1	1015	A7D	AAR4	2	4	0	2.5H	.25	HN	1.5H	.5H	3	.1	1999
	1	1	1530	A7D	AGAT4	2	4	1	1.6H	.16	HN	3.7H	.5H	3	.1	1999
	1	1	1540	A7D	CAS4	2	2	1	1.6H	.16	HN	2.3H	.5H	3	.1	1999
	1	1	1550	A7D	CAS4	2	2	0	1.6H	.16	HN	2.3H	.5H	3	.1	1999

Figure 4. Example of missions repeated daily.

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Mission length in hours, with decimal, is entered in columns 41 - 45, and standard deviation in columns 47 - 52, both right justified. An H is placed in columns 46 and 52 to indicate that the time units are hours. The distribution type is entered in column 53. N indicates a normal distribution. For tactical fighters, mission times are generally normally distributed with standard deviations about ten percent of the mean mission length, although this may vary for specific scenarios and aircraft with loiter capability.

Leadtime on the Form 20 has a unique meaning. It is not the amount of time it takes to get the aircraft ready, but rather the earliest time before takeoff when work would begin to get the aircraft ready. This can never be less than the sum of the mean task times, but must be somewhat greater to account for randomness in the task times and resource availability. The leadtime is entered as hours, with decimal, in columns 55 - 57, with an H to indicate the units in column 58.

Cancel time is the amount of time that will be allowed after scheduled takeoff for the mission aircraft to finish preparation and takeoff late, in the event the minimum number is not ready at takeoff time. Typical policies in tactical units are to allow a half hour to an hour before cancelling the mission, but this depends to some extent on the missions and situation being modeled. Longer cancel times can be used for preflight dummies. The cancel time is entered in hours, with decimal, in columns 60 - 62, and an H to show it is in hours is entered in column 63.

Numerical mission priorities are entered in columns 65 - 66. Priority 1 is highest, and is usually reserved for missions flown from alert. The cycle fields indicate how the scheduled is repeated on subsequent days. A 1 in column 70 indicates the mission is to be flown at the time shown in columns 15 - 18 every day, a 2 in column 70 indicates it is to be flown every other day, etc. If columns 68 - 70 are left blank, the mission is flown only on the day indicated in columns 5 - 7. When missions are repeated 999 should be entered in columns 71 - 73, unless there is a specific day when the repetition cycle is to stop. In that case, the day on which the mission stops recurring is entered in columns 71 - 73. A more detailed explanation of the various Form 20 entries can be found in the LCOM Users Reference Guide (Drake et al., 1970).

Phase and Periodic Inspections

Major inspections that tie an aircraft up a flying day or longer (such as phase or periodics), and major inspections that are done at fixed calendar time intervals (such as 45-day corrosion wash and annual gun teardown), are scheduled on the Forms 20. The inspection tasks follow a dummy "sortie" with "mission length" a constant one tenth of an hour. The dummy sortie does not represent any flying, but is just a mechanism for scheduling aircraft into inspections and getting data on inspections accomplished listed on the simulation output. The inspection dummy sorties are entered on the Forms 20 with unique identifying mission names. In this case, the inspection work

will follow the dummy sortie, so the time work is to begin is entered in columns 15 - 18. Work will not begin until the scheduled time, so a long leadtime can be entered to "grab" an aircraft.

The inspection frequency is computed for the programmed flying hours (scheduled plus alert) and number of aircraft. For example, if there are 72 aircraft, flying 50 hours per aircraft per month, and the phase interval is every 100 hours, each aircraft will require one phase every two months, and there will be 36 phases per month. This is scheduled on the Form 20 as one phase every day, and an additional line entry for a phase every 5 days (5 in column 70). If there are 72 aircraft, an annual gun inspection would come up every 5 days, and would be scheduled in a similar manner.

Entering Alert Missions on Forms 20 and Forms 15

Alert missions by their nature are not scheduled. The LCOM program provides a mechanism for launching a predetermined number of aircraft from alert at different randomly drawn times each day. Instead of specifying a takeoff time in columns 15 - 18 of the Form 20 line entry, an asterisk and distribution number are indicated.

The distribution is then defined on a Form 15 with the distribution number entered in columns 5 - 7 of the form. Column 9 contains an I (for continuous interpolation), and H is entered in column 11 to define the time units as hours. Cumulative probabilities from 0.0 to 1.0 are entered in columns 13 - 16, 23 - 26, 33 - 36, etc. The corresponding points on the takeoff time curve are entered as decimal hours in columns 17 - 22, 27 - 32, 37 - 42, etc. Figure 5 is an example of a cumulative probability curve of takeoff times for a night alert mission. The periods of greatest activity are from 0300 - 0700 and 2200 - 2400. The Form 15 entry for this curve is shown in Figure 6. Note that it can be continued on a second line where necessary.

When preflight is accomplished before aircraft are put on alert, and postflight is done while they are in alert status awaiting a mission, or after they are taken off alert, then 3 will be entered in column 25 for all alerts, since they will all process through the networks as mode 3, thruflight to thruflight. The preflight tasks to prepare aircraft for alert, and the postflight tasks after they are taken off alert, are scheduled as dummy missions with separate Form 20 line entries.

In order to make the program keep aircraft tied up on alert between missions, the average time between alert missions is entered as leadtime in columns 55 - 58. This is computed as the time on alert, less the time flying, divided by the number of sorties flown:

$$\text{Leadtime} = \frac{\text{Alert Duration} - (\text{Alert Sortie Rate x Avg. Sortie Length})}{\text{Alert Sortie Rate}}$$

TIME OF DAY IN DECIMAL HOURS
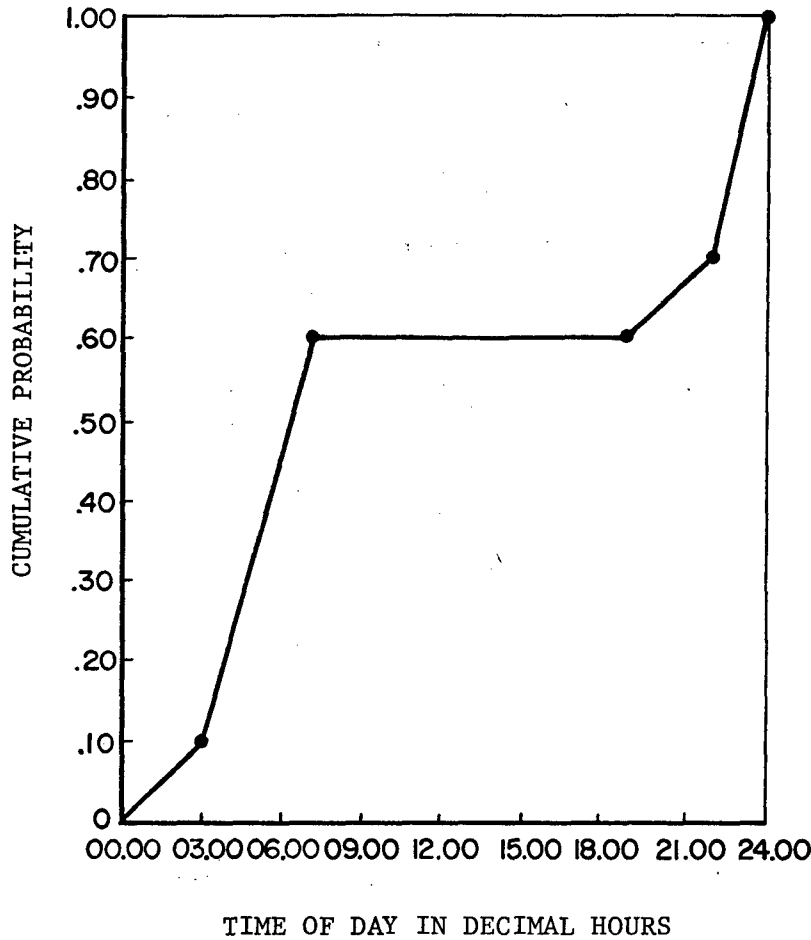
PERIOD OF DAY IN DECIMAL HOURS	PERCENT OF ALERT MISSIONS OCCURRING IN THIS PERIOD	CUMULATIVE PROBABILITY
00.00 - 03.00	10	0 + .10 = .10
03.00 - 07.00	50	.10 + .50 = .60
07.00 - 18.00	0	.60 + 0 = .60
18.00 - 22.00	10	.60 + .10 = .70
22.00 - 24.00	30	.70 + .30 =1.00

Figure 5. Cumulative probability distribution of takeoff times for night alert.

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LOGISTICS COMPOSITE MODEL

SECTION II - SIMULATION MODEL INPUTS
FORM 15 - DISTRIBUTIONS

CARD I.D.	DISTN I.D.	TYPE	FORMAT	1 PROB	1 VALUE	2 PROB	2 VALUE	3 PROB	3 VALUE	4 PROB	4 VALUE	5 PROB	5 VALUE	MULT
15	2	I	H	0.0 1.0	00.00 24.00	00.1	03.00	00.6	07.00	00.6	19.00	00.7	22.00	

TYPE: I = Interpolate
S = Step Function

Figure 6. Form 15 for night alert missions.

A sample Form 20 for alert missions is shown in Figure 7. In this example, there are 8 alert aircraft, a 3.0 alert sortie rate, 2.34 hour average sortie length, and a 24 hour alert duration, giving a 5.7 hour leadtime. Aircraft are prepared for alert before midnight. The "takeoff time" in columns 15 - 18 of the "on alert" dummy mission represents completion of the preflight. Sufficient time is allowed for completion of additional processing tasks shown in the mode 3 main aircraft servicing networks so that the new aircraft will be ready to fly at midnight when their alert turn begins. The "takeoff time" in columns 15 - 18 for the "off alert" dummy mission represents the latest time for starting postflight on aircraft coming off alert. The leadtime and "takeoff time" are both set to 4 hours in this example. This allows sufficient time to catch all aircraft returning from late alert flights. With this coding, any aircraft on the alert pad at midnight, and any returning from late alert missions within the next 4 hours, will process into a postflight. The relationship between dummy sortie takeoff times and their associated network tasks is discussed further in Section III.

Scheduling Total Requirements for Combat

In combat all available aircraft are usually preflighted every day, and preflights are accomplished as organizational maintenance mechanics can get to them, rather than at a single fixed time. Under these assumptions, preflight tasks for mission aircraft are entered within the mode 1 (preflight to thruflight) and mode 2 (preflight to postflight) networks. Preflight dummy missions are only required for the remaining available aircraft that are not scheduled to fly, and to bring aircraft up onto alert. All aircraft that fly must receive a postflight at the end of the day. Therefore, any aircraft scheduled for a mode 1 mission (preflight to thruflight) must also be scheduled for a mode 4 mission (thruflight to postflight) later that day. Enough time must be allowed between takeoffs to fly and do all between flights servicing tasks.

Under these assumptions the following relationships must be maintained on every simulated day:

Aircraft Scheduled =   (mode 1 missions maximum aircraft + mode 2 missions maximum aircraft + mode 1 mission spares + mode 2 mission spares + phase and scheduled inspection dummy missions + number of aircraft on alert)

Additional Preflights = Total Aircraft - Aircraft Scheduled

Mode 1 Missions Maximum Aircraft = Mode 4 Missions Maximum Aircraft

Aircraft must be assigned to mission and inspection requirements first. Additional scheduled preflights will not all be accomplished, since many of the remaining aircraft will be down for maintenance. To assure that mission requirements take precedence, the preflight dummy missions are scheduled so their scheduled time minus leadtime falls after the scheduled takeoff minus leadtime of the last mode 1 and morning mode 2 missions, but

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Figure 7. Alert missions.

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before the scheduled takeoff of the first mode 3 mission. An example combat
schedule for a 24 aircraft squadron is shown in Figure 8. The scheduled
sortie rate is 1.15 (Section II). There are 19 aircraft scheduled per day.
Phase and corrosion wash are done on alternate days.

Scheduling Total Requirements in Peacetime

In a peacetime CONUS scenario, aircraft are often preflighted at a fixed
time each day. In this case, the preflight can be scheduled separately on
the Forms 20, and all missions scheduled as mode 3 or mode 4. In a peace-
time scenario, there may not be any alert requirement. Aircraft not scheduled
to fly are not preflighted and must be taken out of the simulation with a
dummy mission that sends them "to the hangar" for the rest of the day.
However, the Form 20 entries must assign the available aircraft against real
requirements. If any aircraft are down for maintenance, it is the hangar
dummy and not the missions or inspections that should be shorted. The hangar
dummy mission is therefore given a scheduled time (columns 15 - 18) such that
the scheduled time minus the leadtime falls after the scheduled time minus
leadtime of the preflight and any phase or inspections, but before the takeoff
time minus leadtime of the first flight. This is easier to do if inspections
and phase are entered with long leadtimes.

Under the above assumptions, the following relationships must hold on
every simulated day:

Preflights = (Mode 4 first flight to post flight maximum aircraft +
              Mode 3 maximum aircraft + Mode 4 first flight to post
              flight spares + Mode 3 spares)

Total Scheduled = Preflights + Phase and scheduled inspection dummy
                  missions

Mode 3 maximum aircraft = Mode 4 turnaround to post flight maximum
                          aircraft

Hangar Dummies = Total Aircraft - Total scheduled

Figure 9 is an example schedule for a 24 aircraft squadron flying a 30
hour/aircraft/month peacetime program, with a 1.8 hour sortie length and
resultant .57 sortie rate. Low sortie rates are typical of peacetime flying.
For a 24 aircraft squadron, a .57 sortie rate is approximately 14 sorties
per day. Assuming 60% turnaround, and 10% ground spare policies, 8 aircraft
plus a spare will be preflighted each day, and 6 of these will fly a second
time. Since every aircraft that flies must have a postflight, there will be
6 mode 3 and 8 mode 4 missions scheduled. Enough time must be allowed on
turnarounds to complete the flight and all between flight servicing and
inspection tasks shown in both applicable networks.

Assuming a 45-day corrosion wash requirement, 16 of the 24 aircraft
must be washed each month, so a dummy wash mission is scheduled every other

LOGISTICS COMPOSITE MODEL

SECTION II – SIMULATION MODEL INPUTS
FORM 20 – SORTIE GENERATION DATA

CARD I.D.: **2 0**

DAY	NUMBER OF MISSIONS	TAKEOFF TIME	AIRCRAFT I.D.	MISSION I.D.	MISSION SIZE MIN	MISSION SIZE MAX	MISSION SIZE SPARE	MISSION LENGTH MEAN	MISSION LENGTH VARIANCE	MISSION LENGTH DIST	LEAD TIME	CANCEL TIME	PRIORITY	CYCLE INT	CYCLE STOP
1	– 1	0400	AXX	OFFALR	4	4	0	.1H	0	OHC	4.0H	0.5H	1	1	999
–	– 1	0630	AXX	PHASE	1	1	0	..1H	0	OHC	3.0H	2.0H	3	2	999
–	– 1	0740	AXX	ESC1	2	4	1	2.0H	.20	HN	4.5H	0.5H	2	1	999
–	– 1	0810	AXX	CAS1	2	4	1	2.2H	.33	HN	4.5H	0.5H	2	1	999
–	– 1	0830	AXX	CAS2	2	4	0	2.2H	.33	HN	4.5H	0.5H	2	1	999
–	– 1	0900	AXX	PREFLT	2	5	1	..1H	0	OHC	3.0H	2.0H	5	1	999
–	– 1	1345	AXX	CAS4	2	4	0	2.2H	.33	HN	2.2H	0.5H	2	1	999
–	– 1	1415	AXX	CAS4	2	2	0	1.8H	.18	HN	2.2H	0.5H	2	1	999
–	– 1	1530	AXX	REC4	2	2	0	2.0H	.33	HN	9.5H	0.5H	1	1	999
–	– 1	*1	AXX	ACAS3	2	2	0	2.0H	.33	HN	9.5H	0.5H	1	1	999
–	– 1	*2	AXX	ACAS3	2	2	0	4.0H	.50	HN	9.5H	0.5H	1	2	999
–	– 1	*2	AXX	SAR3	2	2	0	2.0H	.33	HN	9.5H	0.5H	1	1	999
–	– 1	*1	AXX	ACAS3	2	2	0	2.0H	.33	HN	9.5H	0.5H	1	1	999
1	– 1	2230	AXX	ONALRT	4	4	0	.1H	0	OHC	2.0H	0.5H	1	1	999
2	– 1	0630	AXX	CCWASH	1	1	D	..1H	0	OHC	0.5H	2.0H	3	2	999

Figure 8. Example of a 24 aircraft combat schedule.

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LOGISTICS COMPOSITE MODEL

SECTION II - SIMULATION MODEL INPUTS
FORM 20 - SORTIE GENERATION DATA

CARD I.D.	DAY	NUMBER OF MISSIONS	TAKEOFF TIME	AIRCRAFT I.D.	MISSION I.D.	MISSION SIZE MIN	MAX	SPARE	MISSION LENGTH MEAN	VARIANCE	DIST	LEAD TIME	CANCEL TIME	PRIORITY	CYCLE INT	STOP
20	1	1	0430	AXX	HANGAR	2	9	0	.1H		OHC	0.5H	0.5H	5		1999
	1	1	0600	AXX	PREFLT	2	14	0	.1H		OHC	4.0H	2.0H	2		1999
	1	1	0830	AXX	CCWASH	1	1	0	.1H		DHC	6.0H	2.0H	3		2999
	1	1	0850	AXX	DCM3	2	2	1	1.8H	.18H	HN	2.5H	0.5H	2		1999
	1	1	0915	AXX	AGAT3	2	2	0	1.8H	.18H	HN	3.2H	0.5H	2		1999
	1	1	0930	AXX	AGAT3	2	2	0	1.8H	.18H	HN	3.2H	0.5H	2		1999
	1	1	0950	AXX	BFCA54	2	2	1	1.6H	.20H	HN	2.0H	0.5H	2		1999
	1	1	1530	AXX	AGAT4	2	2	0	1.8H	.18H	HN	3.2H	0.5H	2		1999
	1	1	1540	AXX	AGAT4	2	2	0	1.8H	.18H	HN	3.2H	0.5H	2		1999
	1	1	1550	AXX	TRNG4	2	2	0	2.0H	.16H	HN	1.0H	0.5H	2		1999
	2	1	0830	AXX	PHASE	1	1	0	.1H		OHC	6.0H	2.0H	3		4999
	4	1	0430	AXX	HANGAR	1	1	0	.1H		OHC	0.5H	0.5H	5		4999

Figure 9. Example of a 24 aircraft peacetime schedule.

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day. Assuming a 100 hour phase requirement, each aircraft must go into a phase every 100 days. This equates to a phase on 7 of the 24 aircraft each month, or one phase approximately every 4 days. Washes are scheduled on odd days, phases every other even day. Using the relationships shown above, there are 10 aircraft scheduled per day out of 24, so 14 hangar dummies are needed. Every fourth day there are only 9 aircraft scheduled (no phase or wash) so one more hangar dummy is added.

Network Entry Points on Forms 17

The Form 17 is an index that tells the computer where to go to find the appropriate network to process for a specified mission type and mode. All mission names appearing on the Forms 20 must be listed in columns 5 - 10. Real missions are listed first, then dummies. The mission entries are numbered in sequence, beginning with 1, in columns 12 - 13. The appropriate network entry **node** is entered in columns 15 - 20. (These are explained in Section III). Several missions may have the same entry **node.**

Wherever an aircraft loaded for one mission can substitute as a spare for other missions, they are given a common spares substitution classification in columns 22 - 27. The substitute class is a feature of the ASD version of LCOM allowing aircraft that have missed a mission, or spares prepared but not flown, to serve as spares for other missions in the same class without further preparation or loading. Figure 10 shows an example Form 17 to match the missions scheduled in Figure 9.

Additional Scenarios

Once the basic scenarios are completed, variations in sortie rate can be produced by proportionally reducing or increasing missions of each type, and adjusting the dummies accordingly. At least 2 such variations are needed off each basic scenario to produce a full set of simulation runs.

III. MAIN AIRCRAFT SERVICING NETWORKS

Content and Data Sources

At this point it would be a good idea for the reader to go back and briefly review Figure 3. The Form 20, described in Section II, specify when missions are to be flown and the preparation leadtime. This controls when servicing and maintenance jobs must start. The task sequences, the resources needed, and the time it takes to do the work are put into the model in network format. These next 3 sections discuss how to prepare networks.

The main aircraft servicing networks cover work done by the organizational maintenance squadron and the munitions maintenance squadron load teams in launching and recovering aircraft. They also include certain scheduled inspections and service work by other specialists that is regularly done in conjunction with preflight or postflight inspections.

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LOGISTICS COMPOSITE MODEL

SECTION II – SIMULATION MODEL INPUTS
FORM 17 – MISSION ENTRY POINTS

CARD I.D.	MISSION I.D.	REPORT COLUMN	NETWORK ENTRY POINT NODE	SPARE SUBSTITUTE CLASS
17				
	DCM3	1	50011	A
	AGAT3	2	50041	A
	BFCAS4	3	50071	A
	TRNG4	4	50101	B
	AGAT4	5	50131	A
	CCMASH	6	50800	C
	PREFLT	7	50001	A
	HANGAR	8	50900	D
	PHASE	9	51000	C

Figure 10. Example of Form 17.

Maintenance data collection (MDC) data on similar systems is not much help in modeling munitions loading or crew chief work. Work unit codes for this area are not detailed enough, and the level of reporting is not that accurate. The operations concept for the new aircraft is a better starting point. The requirements office at the operating command head-quarters can assist in translating an operations concept into specific assumptions and task sequences. For example, do aircraft have to be towed into shelters when they land or do they taxi to revetments? If towed, will three man or five man tow teams be required? If they taxi, who guides them in and parks them? Taxi time and maintenance man's travel time could depend on the distance revetments are dispersed. What kind of fueling facilities will be available? Will aircraft taxi right to fueling pits, or wait for a truck to come around during postflight?

Visit an organizational maintenance squadron at a base flying aircraft of the same type and similar mission, and discuss in detail what they do, who does it, and in what order (Figure 11). Aircraft servicing tasks and sequences tend to be generally similar in the same command, and more so for aircraft flying the same type of missions. The preflight and postflight technical orders (checklists) for similar aircraft should be reviewed for similarities and differences with the new aircraft. The time estimates obtained from experienced line and crew chiefs on similar aircraft can then be adjusted for these differences, to get task estimates for the new aircraft. Published munitions loading standards can be a useful data source where loads, release mechanisms, and loading heights are comparable. Again, judgment must be used to factor for identified differences. Many safety standards and policies will apply across all aircraft in a command. A detailed review of the 04 series of special inspection work unit codes listed in -06 technical manuals for aircraft of the same type can suggest many inspection tasks that may be applicable. Service and inspection requirements identified by the contractor should be evaluated and included. However, contractor task times and crew sizes usually depict touch times rather than the time people are tied up on the job, and their crew sizes may not reflect actual practice. Experienced maintenance technicians from the operating command who have had a chance to observe maintenance on prototypes or test aircraft are a good source of information and more realistic estimates.

The access necessary in order to do each task should be analyzed as soon as mockups, prototypes, or test aircraft can be seen. Access is peculiar to the new aircraft design and cannot be identified from data on other systems. A-10 manning requirement was reduced by providing an easier way to get an engine oil sample during postflight. This change was made at an early mockup review before the design was firm. Main network tasks should be given a lot of attention because they can have the biggest impact on manning. Servicing and inspections are done every time an airplane flies. Cutting one man off a maintenance crew or saving time by an easier access, can have a big payoff in the manning that will finally be required.
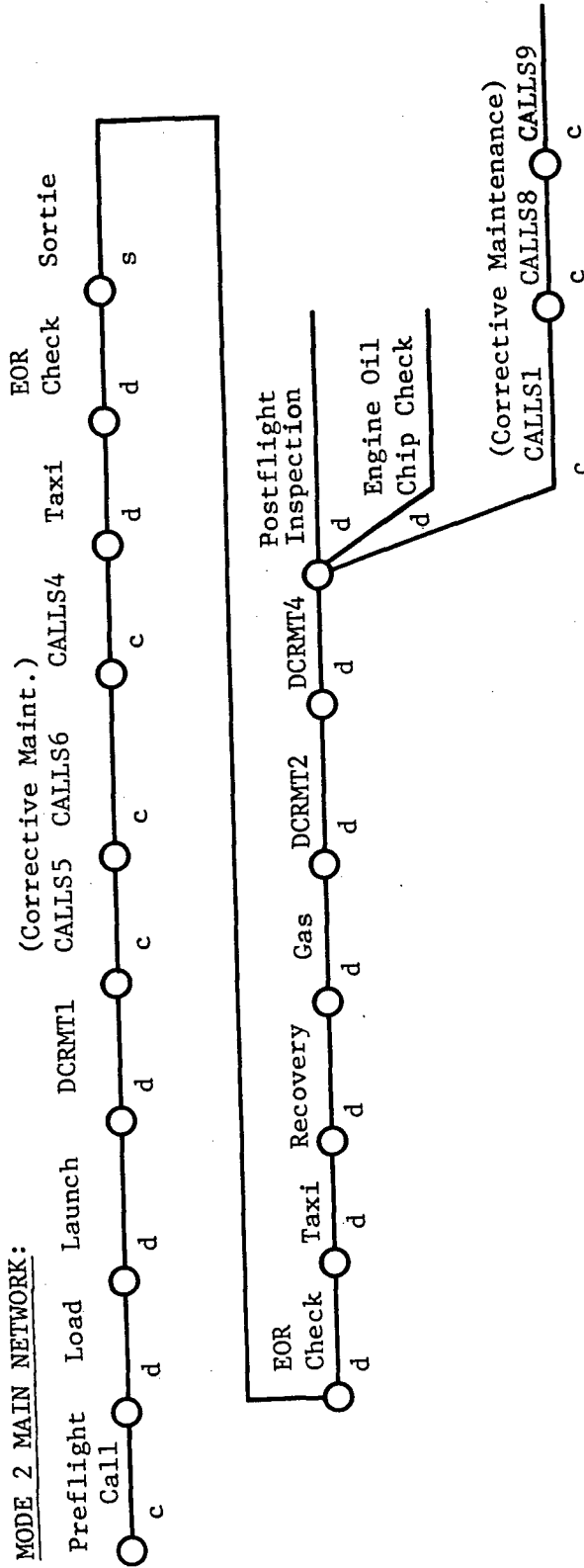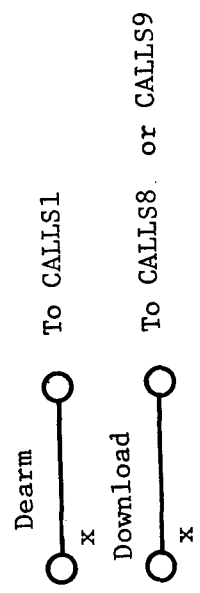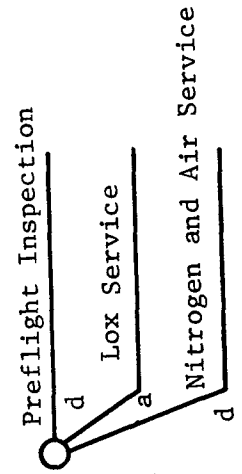
Figure 11. Example of mode 2 preflight to postflight network.

Coding the Networks

A network names the tasks that have to be accomplished, and shows the order in which they are to be done. It also identifies the time and resources needed for each task. Nodes or connection points specify the task processing sequence to the computer. However, every task does not always have to be done in the same sequence. Doing a task can be made contingent on a probability or on the occurrence of some other simulated event.

Network data is entered on an extended Form 11 (Figure 12). The task name goes in columns 12 - 17. Column 12 is a code identifying the action type. Task action codes used for main networks include:

B = Loading or downloading.
G = Fueling or defueling.
H = Inspections, servicing, scheduled checks.
J = Aircraft handling and moving.

The rest of the field (columns 13 - 17) is used to complete a unique name for each task. In addition to the codes listed above, there are some special task names reserved for specific uses:

Z00000 = Flying a sortie.
CALLS1 = Interrogating the unscheduled maintenance failure clocks and processing through the applicable corrective maintenance tasks to fix anything that broke.

The starting node number is entered in columns 5 - 10, and the next node number ending the task is entered in columns 19 - 24. This ending node is entered again as the starting node (columns 5 - 10) of the following task. When no more tasks follow, the ending node is left blank. Node numbers must be unique. If the same number is used on nodes in two different networks, the computer will not distinguish any difference, and will run all the tasks they connect through both of them. This causes all sorts of errors in the simulation. A systematic node numbering scheme by network will reduce the likelihood of such an error. Under the scheme recommended in this report main network nodes should be four numeric digits preceded by letter J.

Task processing logic is specified with a selection mode in column 26, followed by an appropriate parameter in columns 27 - 32. Selection mode codes used in main networks include:

A = Non-mutually exclusive probability. The task will be done the indicated proportion of times and if not done the tasks that follow from it will not be done either. The probability is entered as two digits right justified, without any decimal point. A probability of .2 would be entered as 20 in columns 31 - 32.

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INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sol. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Dist. Type	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE
				H						AAR2		PREFLITE	TO	POSTFLIGHT		
J0001		CALLL3	J0002	C		00010	0	3	1							
CALLL3		HPRFLT		D		00010	0	3	1	36		29L	1431X11	1D60	ILADER	
CALLL3		HLOXSV		A	40	00010	0	3	1	2		29L	2431X11	ILCART		
CALLL3		HNARSV		D		00010	0	3	1	2		29L	2431X11	INCART		
J0002		BLODR4	J0003	D		00010	0	3	1	10		10L	4462ZO	1MJ1	IAMOTL	
J0003		HENGST	J0004	D		00010	0	3	1	8		29L	1431X11	1MJ1		
J0004		DCRMT1	J0005	D		00010	0	3	1							
J0005		CALLS5	J0006	C		00010	0	3	1							
CALLS5		BDWNLD	CALLS8	X		00010	0	3	1	16		10L	4462ZO	1MJ1	IAMOTL	
J0006		CALLS6	J0007	C		00010	0	3	1							
CALLS6		BDWNLD	CALLS9	X		00010	0	3	1							
J0007		CALLS4	J0008	C		00010	0	3	1							
CALLS7		BDEARM	CALLS1	X		00010	0	3	1	8		10L	4462ZO			

PUNCH CARD TRANSCRIPT

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Figure 12. Example of mode 2 preflight to postflight network coding.

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INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sel. Mode	NCLOK Clock No.	Release	Type Task	Priority	% YAR	Dist. Type	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE
J0008	J	TAXI1	J0009	D	000010	0	31	1	2	29L	2462R0	2431R1		
J0009	H	RUNW1	J0010	D	000010	0	31	1	1	29L				
J0010	Z	00000	J0011	S	000010	0	11	1						
J0011	H	RUNW2	J0012	D	000010	0	31	1	1	29L	2462R0	1431R1	1D60	
J0012	J	TAXI2	J0013	D	000010	0	31	1	2	29L	1431X1	1421X3		1B4
J0013	H	RECOV	J0014	D	000010	0	31	1	1	29L	1431X1			
J0014	G	AS100	J0015	D	000010	0	31	1	2	29L	2431X1			
J0015	D	CRMT2	J0016	D	000010	0	31	1						
J0016	D	CRMT4	J0017	D	000010	0	31	1						
J0017	H	FPST1		D	000010	0	31	1	37	29L	1431X1	1D60	1B4	
J0017	H	CHPCK		D	000010	0	31	1	3	29L	1432X0			
J0017		CALLS1	J0018	C	000010	0	31	1						
J0018		CALLS8	J0019	C	000010	0	31	1						
J0019		CALLS9		C	000010	0	31	1						

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AF FORM 1530 FEB 69   PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

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Figure 12. Example of mode 2 preflight to postflight network coding (continued).

E = Mutually exclusive probability. The probability value is
    entered in the same manner as for A selection mode. All E
    probabilities from the same prior node must sum to 1.00, and
    one and only one will be selected on any given pass through the
    network. These probabilities are used for branching to one of
    a series of possible paths.
D = Do the task. The probability field is left blank.
S = Sortie. This selection mode must be used with all sortie tasks
    scheduled on the Form 20. The probability field is left blank.

A clock number is entered in columns 34 - 37. It is always 00010
for all main network tasks. Scheduled maintenance code 3 is entered in
column 40 for most main network tasks. The sortie task must have a 1 in
column 40, and certain dummy tasks that do not represent any flying,
maintenance, or service may be coded 5 (other). All main network tasks
are coded with priority class 1 in column 41. The mission priorities
specified on the Form 20 (Section II) determine the actual priorities
given to class 1 pre-sortie tasks during the simulation.

The average task time is entered in columns 43 - 47 in tenths of hours,
right justified, no decimal. Two hours is entered as 20 in columns 46 - 47.
The standard deviation is entered as a percent of the average time, right
justified, in columns 48 - 50. A Tactical Air Command work measurement
study indicated that 29 percent (29 in columns 49 - 50) is a good mainte-
nance task variability estimate. It has been used in modeling new aircraft
where more precise variability measures are not available. The same study
showed that maintenance task times generally conform to a lognormal distri-
bution. Task time distribution is specified in column 51. Applicable
codes are:

L = Lognormal
N = Normal
C = Constant (variability left blank)

The people and AGE required to do the work are entered in the balance
of the extended 11 Form. If it takes two 431X1 mechanics to preflight the
airplane, this would be entered with a 2 in column 53 and 431X1 in
columns 54 - 58. If they need a B-4 stand, this would be entered on the
same line with 1 in column 60 and B4 in columns 61 - 62. All resources
listed for a task must be available before the computer will begin task
processing, and all will be utilized for the indicated task time. The
same resource must always be entered with exactly the same name throughout
the model. It cannot be coded B-4 on one task and B4 on another. If more
than 4 resource fields are needed, they can be entered on a continuation
card. To do this, a C is entered in column 80 of the first card. The
continuation card with the additional resources must be placed immediately
after it, and carry the same task name and clock number.

All the resources required for a task must be defined on the extended
Form 11 at the first place that task appears in the model. If the same

task is repeated in another line entry, the resources are not entered again. For example, the identical preflight inspection task might be shown in several networks for different missions. The first time it is used all the resources must be defined. Each time the preflight task is listed after that the resource fields are left blank.

In addition to the task data entries, header cards can be used to enter descriptive nomenclature for individual tasks or networks of tasks. A header card has an H in column 25, the clock number in column 34 - 38, and the nomenclature starting in column 42.

Coding Network Call Sections

A call task is a dummy representing all the tasks in a section of network. All applicable tasks within the section must be done before the call task can be completed, or any following task started. Tasks which can be done in parallel but all constrain some subsequent task are coded in call sections. In ASD LCOM, no parallel tasks can precede a sortie unless they are in a call section. Call sections are also useful where the same group of tasks is repeated in several networks. The call section tasks are defined in the first place the call appears, and just the call task used to represent them thereafter.

The call task is coded with C in column 12, and the remainder of a unique task name in columns 13 - 17. The selection mode in column 26 must be C. The tasks comprising the call section are listed immediately after the call task in the first place it is used. This defines the call task. The name of the call task is entered as the starting node, or nodes, on the first tasks in the call section (see CALLL3 in Figure 12). Subsequent tasks in the call section are coded in the normal manner. Any number of tasks can be defined in a call section, from one by itself to hundreds in many parallel strings. However, a specific call task name must only be defined once in the entire model, at the first place it appears. After that only the call task name is used to represent all the tasks in that call section.

Including Provisions for Unscheduled Maintenance

The relationship between the main networks and unscheduled maintenance networks is shown in Figure 3. Aircraft break as a result of flying. The failure clocks and the unscheduled maintenance work to fix broken aircraft are defined in call sections. Corrective maintenance tasks are only called where the failure tasks clocks indicate something is broken. If nothing is broken or when it has been fixed the program proceeds on to the next main network task.

All unscheduled maintenance that could be done concurrently is defined in a single large call section named CALLS1. The data base processing programs automatically provide the necessary starting tasks to define CALLS1. Unscheduled maintenance that would conflict with other work and

must be done by itself is shown in separate sequential call sections. Examples of such work are repairs requiring aircraft jacking or towing the aircraft to a test cell for engine runup. These conflicting maintenance call sections are defined in a different manner covered later in Section VI. These unscheduled maintenance call sections are an exception to the general rule. They are the only call sections not defined where they first appear in the main networks.

When failures are discovered on a loaded aircraft just prior to a sortie, the munitions must be dearmed (cartridge ejectors removed) before any maintenance work is done. In some few cases, such as jacking or engine runup, the ordinance may have to be off-loaded. This work is shown in a change call section illustrated by CALLS5 and CALLS6 in Figure 12. The call section is defined by a single task or linear string of tasks with X selection modes in column 26. The end mode of the last task in the defining string is the name of the appropriate unscheduled maintenance call section. The X is a special selection mode for defining call sections in this situation. It is used to "carry forward" the failure clock from the unscheduled maintenance call section, so that the dearm or download is only done if a clock has failed and unscheduled maintenance is required. If there is no failure the simulation skips over this call and proceeds with the next main network task.

Decrement tasks are inserted in the main networks to show where failure clocks are to be advanced. The appropriate decrements advancing the clocks must precede the unscheduled maintenance call sections that check to see if there is a resulting failure. Decrements can be defined to advance clocks by a whole sortie or fractions of a sortie, and can be set up to advance some clocks and not others. Each uniquely named decrement task advances a particular set of clocks by a specific amount. For the example in Figure 12, the task DCRMT1 advances the clocks by a fraction of a sortie to account for possible failures prior to takeoff. The three call sections that follow check the unscheduled maintenance networks to see if any subsystems have failed as a result of this clock advance. After the flight DCRMT2 advances these clocks the balance of the sortie, and DCRMT4 advances certain clocks that involve work only done in postflight. The call sections to check and fix failures follow in sequence.

Decrement tasks are coded on the extended Forms 11 with a task name DCRMT and a unique number, with the D starting in column 12. Selection mode in column 26 is D. Probabilities and resources are left blank. The listing of clocks decremented and value of the decrement is entered in another format. Instructions for this input are covered in Section VI.

Preflight to Postflight Network

The remainder of this chapter illustrates main network coding and construction using a number of detailed examples of situations that were

encountered in developing LCOM models for tactical aircraft. Figure 11 is a schematic of a mode 2 (preflight to postflight) network for an A-7D, and Figure 12 shows how it is coded on extended Forms 11.

It takes one crew chief an average of 3.6 hours to preflight an A7. They do not double up to shorten the time, even in combat, although this could be done. LOX, nitrogen, and air are serviced during preflight. These are shown as separate tasks because different people do the work. The crew chief removes the LOX bottle and places it at the nose wheel if it needs refilling. It is needed on about 40% of the preflights so this task is coded with A selection mode and a probability value of 40 is placed in columns 31 - 32. On the average the task will be done on 40% of the preflights, and on the other 60% it will be skipped. To service LOX, one 431X1 goes around and picks up the bottles. Another 431X1 refills two at a time, taking an average of 15 minutes per bottle. The task is shown as requiring two 431X1s for .2 hours using one LOX servicing cart. Two other 431X1s take a service cart to each aircraft during preflight to replace nitrogen bottles as required, and to service tire air. This task requires two 431X1 APGs for .2 hour per aircraft. Since nitrogen and air are checked every time, selection mode D is entered in column 26. Since the crew chief preflight, LOX Service, and Nitrogen/air service are parallel tasks constraining start of the next main network task (loading), they must be coded in a call section.

The example mission involves a bomb load only (no gun or camera), and takes a 4 man load crew one hour using standard loading equipment. This time was computed by summing TACM 50-7 standards for the particular ordinance load and adding 15 minutes for travel. The launch (engine start) task covers all elapsed time from the point the pilot joins the crew chief at the aircraft for walkaround until start of taxi. It takes and average of .8 hours and includes time that the crew chief stands by while the pilot performs his checks and runs up the engine with the plane in chocks.

CONUS policies on download vary by base. Combat aircraft are never downloaded if at all possible. The only situations in which an aircraft must be downloaded are an engine problem requiring runup in the test cell, a jacking problem involving more than one wheel, failure of weapons control/release systems, work on the fuel cells, or it the aircraft must go into a hangar (phase). Of these, only engine problems and jacking have a fair likelihood of occurring as a ground abort (between engine start and takeoff). When a ground abort for engine or landing gear occurs, the download and upload are shown together in one task for networking convenience, even though the upload portion would occur much later. This simplification should not make any significant difference in the simulation results. In most cases, ground abort will only require a dearm task (removing cartridge ejectors), and then a rearm and repeat of stray voltage checks when the maintenance is completed. Dearm and rearm are also networked in a single task. The call sections are checked in sequence, and if there is no failure, the aircraft proceeds to taxi. The taxi task consumes time but not resources.

Three 431R1 APGs (four in combat) are stationed at the end of the runway for final launch check. One of these is a team chief who talks to the pilot via intercom. Two munitions men (462R0) are also part of the launch EOR team to pull the pins on ordinance. All EOR crews are stationed there for a full eight hour shift. EOR check is shown in the networks as a .1 hour task for 2 431X1s and 2 462R0s after a .2 hour taxi. A dedicated crew is not available for any other work and must be treated as a separate AFSC in LCOM. Runway checkers are uniquely identified by an R in the fourth digit of their AFSC.

The sortie task removes the aircraft from the simulation for a random time according to the sortie length distribution specified on the Form 20. The extended Form 11 does not require any time or resource entry for a sortie task. Sortie tasks are coded with an S selection mode in column 26 and 1 in column 40.

Two 462R0 munitions men are stationed at the other end of the runway to check returning aircraft for hung ordinance and to safety ordinance not dropped. One 431R1 APG is also part of the recovery EOR team to park the aircraft for the ordinance EOR check. While the aircraft is taxiing in, the crew chief and an age handler are getting ready for recovery in the parking area. Their work is shown on the taxi task. The crew chief then parks the aircraft in the .1 hour recovery task.

Aircraft are fueled in the parking area or revetment when the fuel truck arrives. The postflight is interrupted to allow two 431X1s and one POL driver to refuel the aircraft. For the purpose of modeling, fueling is shown prior to postflight. This slight disparity with the actual time sequence makes no difference in the LCOM output since fuel trucks are not constrained. Fueling an empty A7 requires .3 hours, and less time if the plane still has fuel aboard. In this example the plane returns from air refueling with partially full tanks, so the task time is .2 hours by 2 431X1s. The POL driver is not part of the maintenance unit for which manning is being determined, so need not be shown on the extended Form 11.

The aircraft is not to be turned for another mission and goes into a 3.7 hour end-of-day full postflight by the crew chief. End of day post-flights on the A-7 include an oil chip check requiring one 432X0 for .3 hours. Unscheduled maintenance is done in parallel with postflight except for engine or autopilot work requiring engine runup and/or functional checkflight, and work requiring jacking the aircraft. These call sections are networked in sequence after CALLS1 unscheduled maintenance is completed. After all required network tasks are finished, the aircraft is released for another assignment controlled by the Forms 20.

Networking Turnarounds and Scheduled Inspections

If an aircraft is to fly again the same day it is given a thruflight inspection rather than a full end of day postflight. The mode 4 network

for the next mission then picks up where the mode 1 network left off. It starts with the load task, which is determined by the next mission requirement and proceeds through sortie and postflight. Tasks shown after the sortie in the mode 1 network are common to all flying or depend on the type of mode 1 mission flown. All tasks which depend on the type of mode 4 mission are shown in the mode 4 network. An aircraft does not necessarily have to turn to the same kind of mission.

An example of the interface between mode 1 and mode 4 networks is shown in Figure 13. Figure 14 shows how the mode 4 network is coded on extended Form 11. Resources and times are not shown on any of the tasks because they were previously defined.

Figure 14 shows one method of networking scheduled maintenance done in conjunction with postflight. For this aircraft there is a basic gun postflight during end of the day postflight any time the gun is used. Other gun scheduled inspections are based on rounds fired. If an average combat mission with guns expends 500 rounds of 1,000 loaded, and 50% of the aircraft flying gun missions are turned, 1.5 gun sorties are flown and 750 rounds expended per gun postflight. The inspection requirements for this example are:

- Every 3750 RDS (5 gun postflights) torque bolts on A/C, two men two hours
- Every 30,000 RDS (40 gun postflights) remove bolt and change bolt spring in shop, two men 2.5 hours
- Every 30,000 RDS (40 gun postflights) remove and lubricate ammo chutes, three men six hours
- Every 30,000 RDS (40 gun postflights) change six gun barrels, three men three hours (old barrels are scrapped)

The frequency of this scheduled maintenance is related directly to gun use by only including it in gun mission networks. The tasks are coded, with E (mutually exclusive) selection modes because the actual inspection cycle is staggered. With E probabilities only one of the possible tasks will be done each time. A dummy task with no time or resources is inserted to account for the probability that no inspection falls due.

Networking Alert Missions

The method used to network alert depends on the particular assumptions and scenario. These can vary considerably and may be difficult to model precisely. A representative tactical alert situation is described below, and modeled in Figure 15. This example illustrates the simplifications that sometimes have to be made in modeling a complex situation. The key requirement is that the simplifications do not distort the relevant output measures.

MODE 1 NETWORK

Preflight Load Launch DCRMT1 CALLS5 CALLS6 CALLS4 Taxi Check Sortie   EOR
c   d   d   d   c   c   c   d   d   s

(Unscheduled Maint.)

EOR Check Taxi Recovery Gas DCRMT2 DCRMT3 Thruflight Inspection
d   d   d   d   d   d

(Unscheduled Maint.)
CALLS1 CALLS8 CALLS9
d   d   d

MODE 4 NETWORK

Load Launch DCRMT1 CALLS5 CALLS6 CALLS4 Taxi Check Sortie   EOR
d   d   d   c   c   c   d   d   s

(Unscheduled Maint.)

EOR Check Taxi Recovery Gas DCRMT2 DCRMT3 DCRMT4 Postflight Inspection
d   d   d   d   d   d   d

Torque Bolts
Bolt Spring
Chutes
Barrels
None
e   e   e   e   e

Gun Postflight
Oilchip Check
d   d   d

(Unscheduled Maintenance)
CALLS1 CALLS8 CALLS9
c   c   c

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INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Dist. Type	N	AFSC/AGE	N	AFSC/AGE	N	AFSC/AGE	N	AFSC/AGE	N	AFSC/AGE
J00061		BLODT4	J0062	H		00010	D			GAT4(THRUFLITE TO POSTFLIGHT)												
J00062		HENGST	J0063	D		00010	0	3	1	18	,DL	446220		,MJ1		,AMOTL						
J00063		DCRMT1	J0064	D		00010	0	3	1													
J00064		CALLS5	J0065	D		00010	0	3	1													
J00065		CALLS6	J0066	C		00010	0	3	1													
J00066		CALLS4	J0067	C		00010	0	3	1													
J00067		JTAXI1	J0068	C		00010	0	3	1													
J00068		HRUNW1	J0069	D		00010	0	3	1													
J00069		N00000	J0070	A		00010	0	1	1													
J00070		HRUNW2	J0071	S		00010	0	3	1													
J00071		JTAXI2	J0072	D		00010	0	3	1													
J00072		HRECOV	J0073	D		00010	0	3	1													
J00073		GAS200	J0074	D		00010	0	3	1	3	29L	2431X11											

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Figure 14. Example of mode 4 thru flight to postflight network coding.

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	VAR	Dist. Type	N AFSC/AGE
J0074	D	CRMT2	J0075	D		0001	D	3	1				
J0075	D	CRMT3	J0076	D		0001	0	3	1				
J0076	D	CRMT4	J0077	D				3	1				
J0077	H	FPST2		D				3	1				
J0077	H	DRDPF	J0078	D	20			3	1	24	29L		1462X0
J0078	H	GTORQ		E	3			3	1	20	29L		2462X0
J0078	H	GBOLT		E	3			3	1	25	29L		2462X0
J0078	H	GCHUT		E	3			3	1	60	29L		3462X0
J0078	H	GBARL		E	71			3	1	30	29L		3462X0
J0078	H	GNONE		D				3	1				
J0077	H	CHPCK		C				3	1				
J0077	C	ALLS1	J0079	C				3	1				
J0079	C	ALLS8	J0080	C				3	1				
J0080	C	ALLS9		C				3	1				

PUNCH CARD TRANSCRIPT

Figure 14. Example of mode 4 thru flight to postflight network coding (continued).

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	VAR %	Dist. Type	N AFSC/AGE
ALR01		CALLL3	ALR02	H		00010				PREFLIGHT			ALERT AIRCRAFT
				C		00010	0	3	31				
ALR02		200000		S		00010	0	1	11				
ALR10		JTOWAL	ALR11	H		00010	0			ALR3			COMBAT ALERT
ALR11		JTOWAP	ALR12	D		00010	0	3	31		1	29L	5431X1 1TUG
ALR12		HALRCK	ALR13	D		00010	0	3	31		2	29L	3431X1 243IA1 1TUG
ALR13		BLODAL	ALR14	D		00010	0	3	31		5	29L	1431A1
ALR14		BARMAL	ALR15	D		00010	0	3	31		7	29L	8462220
ALR15		HENGSL	ALR16	D		00010	0	3	31		2	29L	2462ZO
ALR16		JTAXIL	ALR17	D		00010	0	3	31		1	29L	1431A1
ALR17		HRUNAL	ALR18	D		00010	0	3	31		1	29L	
ALR18		200000	ALR19	S		00010	0	3	31		1	29L	2431R1 2462R0
ALR19		HRUNM2	ALR20	D		00010	0	3	31				

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Figure 15. Example of alert mission network.

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Rel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Dist. Type	N AFSC/AGE	Continuation
ALR20	J	TTAXIT2	ALR21	D		00010	0	3	1					
ALR21	H	RECOV	ALR22	D		00010	0	3	1					
ALR22	G	AS200	ALR23	D		00010	0	3	1					
ALR23	D	CRMTS	ALR24	D		00010	0	3	1					
ALR24	H	CHPCK	ALR25	X		00010	0	3	1					
ALR25	H	FPST2	ALR26	X		00010	0	3	1					
ALR26	H	ORDPF	ALR27	X		00010	0	3	1					
ALR27	J	000000	CALLS1	X		00010	0	3	1					
ALR27	J	000000	CALLS8	X		00010	0	3	1					
ALR27	J	000000	CALLS9	X		00010	0	3	1					
				H						TAKE AIRCRAFT OFF ALERT				
ALR90	Z	000000	ALR91	S		00010	0	1	1		3			
ALR91	J	TOWAF	ALR92	D		00010	0	3	1		3	79L	5A31IX11	
ALR92	H	FPST2		D		00010	0	3	1					

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Figure 15. Example of alert mission network (continued).

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In this scenario aircraft are put on alert for 24 hour periods. Before an aircraft goes on alert it is preflighted, loaded, (but not armed) and towed to the alert pad. The towing takes .3 hours by a crew of five. Two 431X1s drop off after .1 hour when the aircraft is out of the congested area, and two of the alert crew chiefs take their place to help park the plane in the alert area. The alert crew chief assigned to the aircraft does a .5 hour check to accept it for alert. Two 462Z0 munitions loaders then arm the aircraft in .2 hours. For alert aircraft, engine start (launch) requires only .1 hour, taxi .1 hour, and end of runway check .1 hour. After flying, alert aircraft go through the same sequence of end of runway check, taxi to the parking area, recovery, and fueling in the parking area. If nothing is broken they are then towed back to the alert area where they are given a thruflight inspection by the alert crew chief and loaded. Load and thruflight are at last partly concurrent, and load may be done by a double crew in half the normal time. If the aircraft returns needing some corrective maintenance it is not towed to the alert pad, but repaired and given a postflight in the parking area. Another available aircraft is loaded and towed to the alert pad to replace it.

Since a new aircraft may be run into alert at any time, the presortie tasks in an alert mission network should follow directly from the last network that aircraft had completed. This would be either a mode 1 mode 2 scheduled mission network. The same alert network should also apply to an alert aircraft that returns in good shape and goes back on alert. When one alert network is used for both conditions load and tow tasks cannot always be shown in the correct sequence.

An alert mission network is shown in Figure 15. It is mode 3 since preflight and postflight are in separate networks. If various missions are flown from alert more than one network might be required, but they would all be mode 3 and would follow the same general logic. The network in Figure 15 shows the aircraft towed to the alert pad, checked by the alert crew chief, loaded by a double crew, and armed. If the aircraft is coming onto alert after preflight, or is being run in as a replacement, the network has load and tow in the wrong order. This is not significant since it does not affect the time to get the plane on alert or the resources demanded. If the aircraft came off a previous alert mission, the alert crew chief's time for thruflights is only partly covered in the check shown in the network. But turn time for the alert aircraft is about correct since at least part of the thruflight can be done in parallel with load. The alert crew chief's time is not a relevant output since he is dedicated for the full shift anyway. Alert crew chiefs are coded 431A1 in the network. No decrements or unscheduled maintenance calls are shown before alert sorties because the aircraft have been kept cocked and ready by the dedicated crew chief. The DCRMT5 task after the sortie advances all clocks a full sortie. The X tasks interrogate the failure clocks and send the aircraft to postflight and corrective mainte-nance only if something is broken. None of the post sortie tasks involve 431A1s, and all were previously defined in other networks, so times and resources are not shown.

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This example network does not precisely duplicate all the given assumptions, but it does capture the correct aircraft turnaround times, demands for resources, and working time that are needed to make mission accomplishment and manning predictions. A different network and choice of simplifications might be needed to obtain other kinds of unbiased output.

Networks for Peacetime Flying

Examples of preflight and hangar networks with dummy sortie tasks are shown in Figure 16. They match the operation schedule shown in Figures 9 and 10, Section II. The Form 20 lead time for the dummy pre-flight sortie must be greater than the 3.6 hour elapsed task time for preflight, and allow for variability. The task time entered for hangar on the extended Form 11 must be sufficient to hold the aircraft from the time scheduled on the Form 20 until the end of the day. Figure 16 shows a time of 19.5 hours, which corresponds to the Form 20 scheduled time of 0430 for the dummy hangar mission. Task type 5 is entered in column 40 on the hangar task. This code is a catchall for time that an aircraft is tied up other than services, maintenance, or flying.

Mode 3 mission networks represent first flights of the day when preflight is networked separately. The Form 20 lead time for these flights must be greater than the sum of presortie task times in the mode 3 network but does not have to cover preflight. Figure 16 shows an example mode 3 carrying air to air rockets. In this case DCM3 was the first net-work entered, so all task time and resources were defined on the extended Forms 11. This network shows towing the aircraft to a safe area for rocket or missile loading. This is generally a CONUS peacetime procedure. In wartime, each aircraft parks in a revetment for all servicing and loading.

IV. CORRECTIVE MAINTENANCE NETWORKS

Content and Data Sources

The networks covering unscheduled corrective maintenance tasks are organized by subsystem. They are called from the main networks via the failure clock mechanism explained in Section I. Each network must start with a failure clock and parameter value of mean sorties between mainte-nance actions. This controls the frequency with which the network tasks will be processed. It must cover all the times a specialist is called to the airplane in the field to fix an apparent problem, including cases where only some minor adjustment is required or the system checks out OK. This definition of maintenance frequency differs substantially from reliability measures of failure that consider only confirmed breakage under controlled test conditions.

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Dist. Type	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE	Continuation
J00011		CALLL3	J00002	H		00010				MORNING	PREFLIGHT							
CALLL3		HPRFLT		C		00010	0	3/										
CALLL3		HLØXSV	40	D		00010	0	3/		36	29L	1431XI	1	D60	1LADER			
CALLL3		HNARSV		A		00010	0	3/		2	29L	2431XI	1	1LCART				
J00002		300000		D		00010	0	3/		2	29L	2431XI	1	1NCART				
				S		00010	0		DCM3	FIRST	FLIGHT	TO	THRUFLITE					
J00011		JTOWAR	J00012	H		00010	0	3/		3	29L	543IXI						
J00012		BLØDM4	J00013	D		00010	0	3/		6	10L	496220						
J00013		HENGST	J00014	D		00010	0	3/		8	29L	1431XI	1					
J00014		DCRMTI	J00015	D		00010	0	3/										
J00015		CALLS1	J00016	D		00010	0	3/										
J00016		CALLS8	J00017	C		00010	0	3/										
J00017		CALLS9	J00018	C		00010	0	3/										

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Figure 16.   Example of mode 3 network coded with preflight and hangar dummies.

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Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF/Prob	NCLOK Clock No.	Release	Type Task	Priority	Hours (Tenths)	% VAR	Dist. Type	N	AFSC/AGE	N	AFSC/AGE	N	AFSC/AGE	N	AFSC/AGE
J00018	J	TAXII1	J00019	D		00010		3	1											
J00019	H	RUNWI1	J00020	D		00010		3	1		2	29L	2431	R1	2462	R0				
J00020	2	00000 0	J00021	S		00010		1	1											
J00021	H	RUNW2	J00022	D		00010		3	1		1	29L	1431	X1	2462	R0	1D60		134	
J00022	J	TAXI12	J00023	D		00010		3	1		2	29L	1431	X1	1421	X3				
J00023	H	RECOY	J00024	D		00010		3	1		1	29L	1431	X1						
J00024	G	GAS200	J00025	D		00010		3	1		2	29L	2431	X1						
J00025	D	CRMT2	J00026	D		00010		3	1											
J00026	H	TPST2		D		00010		3	1		28	29L	1431	X1	1D60		164			
J00026	C	ALLSI	J00027	C		00010		3	1											
J00027	C	ALLS8	J00027	C		00010		3	1											
J00028	C	ALLS9		C		00010		3	1											

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Figure 16. Example of mode 3 network coded with preflight and hangar dummies (continued).

INPUT No. 2
EXTENDED FORM 11

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Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	VAR %	Dist. Type	N AFSC/AGE	Continuation
J0900	Z	Z00000	J0901	H		00010				HANGAR	HANGAR	DUMMY		
J0901		HANGAR		S		00010		11						
				D		00010		51		195		OC		

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Figure 16. Example of mode 3 network coded with preflight and hangar dummies (continued).

The networks also contain task times for work on-aircraft and in field shops. They represent the time a technician is tied up on the job and not available for other work. They must consider time to get to a job, time to fault isolate and check out the system, time to clean up, time to get parts, and standby time on multiple crew tasks. They are substantially different from the touch times developed in contractor-prepared maintainability studies. A cockpit mounted radio that can be changed in a few minutes by removing 6 screws might occupy a man for half an hour when total job time is considered.

The maintenance crew size shown for network tasks represents the number of people typically dispatched to the job. Crew size depends on safety factors, maintenance practice in the operating command to account for level of skill and qualification, the need for technical data while working, policy on checking work, accessibility, and on-the-job training. More people will generally be dispatched than are indicated by a strictly touch-time task analysis.

Maintenance frequency, task times, and crew sizes are developed from Air Force experience on similar equipment wherever possible. The Air Force maintenance data collection (MDC) System is the basic information source on what it takes to maintain current equipment. Air Force engineers and experienced maintenance technicians must then evaluate differences and apply judgment factors to the MDC data in order to estimate task requirements for the new design. The development contractor is the primary source of design identification and engineering information.

Procedure

The first step is to define the proposed design of the new aircraft. Definition must be at least to subsystem level and preferably to line replaceable unit (LRU) level. The contractor's development proposal, submitted at the end of validation phase, will usually encompass this level of design definition. Much useful information can be obtained through visits to the contractor's facility and thorough inspection of any mockups, prototypes, or test aircraft under construction. If there is a flying prototype, experienced Air Force technicians should be assigned to observe and evaluate maintenance procedures and requirements.

Given suitable design definition, the next step is to identify comparable systems and subsystems on existing aircraft. Comparability is assessed in terms of function, design concept, complexity, operating environment, and maintainability features. The Air Force engineers assigned to the program office and their "home office" supporting cadre should conduct this analysis, and it should be coordinated by the program reliability/maintainability officer. It is essential that the analysis and rationale be completely documented and then kept current in each participating program office engineering group.

The comparability analysis should be structured according to contractor's preliminary work unit code manual at subsystem level. The special criteria for identifying comparability must be defined for each subsystem at the outset. Experienced maintenance personnel in the program office and/or operating command should be brought in to familiarize each group of engineers with maintenance problems typically associated with their equipment, and jointly establish appropriate criteria. Getting both maintenance and engineering input is critical. In one comparability study, airframe engineers initially based their criteria on the similarity of the heavy load bearing structures to resist stress and fatigue cracking. The maintenance people pointed out that most day-to-day airframe repair work involves fitting skin panels, fitting access doors, and replacing fastners; not fixing broken wing struts. The kind of fastners, curvature, and stress on surfaces, and simple size of the aircraft, may have more bearing than structural design on the comparability of flight line and field shop maintenance. However, vibration absorbing properties of the structure relate to a cause of skin maintenance and cannot be ignored either.

Once the criteria are established, the engineers compare the designs of similar aircraft, drawing on the experience of associates who have worked on various programs, contractor data, and Air Force technical orders, as necessary. The results are then written up by subsystem (3 digit) work unit code, to include: identification of comparable aircraft and subsystem work unit code(s); any additional LRUs in the new subsystem or LRUs by work unit code in the comparable system that are not applicable; any factors that should be applied to the comparable subsystem failure rates or task times in estimating for the new subsystem; and a narrative analysis specifying the criteria used and supporting rationale for choosing the comparable subsystem and factors. Any scheduled maintenance considerations should also be mentioned. In some cases, an item is so new or so changed that there is nothing reasonably comparable. In that case, the best source of data (contractor, etc.) should be identified, and appropriate factors and degree of confidence discussed. Study results should be reviewed in conjunction with experienced maintenance personnel to be sure no maintenance considerations were missed. The comparability study requires a considerable effort on the part of program office engineers, but has a payoff in their better understanding and heightened awareness of maintenance considerations when they review contractor proposed designs, and design change proposals.

The next step is to obtain MDC data tapes on aircraft with comparable subsystems, and process the information through a series of specially designed computer programs. These programs and full processing instructions are described in AFHRL-TR-74-97(III). The program outputs are in a convenient format for use in developing a simulation data base. However, some base visits will be essential to verify and correctly interpret certain aspects of MDC coding for the comparable subsystems, and help identify requirements and procedures for using powered age.

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The verified MDC data for comparable systems, factored for identified design differences, is used to build an LCOM maintenance data base for the new aircraft. When this data base is completed the networks, times, and particularly the crew sizes and AFSCs, should be reviewed with experienced Air Force maintenance personnel. Operational command technicians on prototype or test aircraft make ideal reviewers. This review is an iterative process.

The basic procedure of design identification, comparability identification, model construction with MDC data, and maintenance review is repeated on design changes to keep the data base current throughout the development and production phases. Test and operational evaluation data is considered as it becomes available. An accurate and fully developed model can be transferred to the operating command for their use when the aircraft becomes operational.

The rest of this section explains how unscheduled maintenance networks are developed from the outputs of the MDC processing programs, and provides examples of networks of varying complexity.

Network Structure

The basic task sequencing for a corrective maintenance network is shown in Figure 17. It must begin with an F task identifying a failure clock and F selection mode. This serves as a gate controlling how often the subsequent network tasks are done. The gate is only opened and tasks processed when the clock on the F task indicates an apparent failure has occurred. The F task is followed by the on-aircraft maintenance tasks needed to describe the corrective work:

A task to get and set up powered age.
X task to gain access to the subsystem or LRU, particularly when done by a different AFSC than does the corrective action.
T task to troubleshoot the subsystem.
R task to remove and replace an LRU.
M task for any on-aircraft fix not involving LRU removal.
V task to perform an inspection or functional check to verify that the subsystem has been fixed.

These tasks are coded with D, E, or A selection mode to describe the appropriate sequence of work at subsystem level. The R task is an average for all LRUs in the subsystem that are done by the same AFSC and crew size. If some items are removed by a different AFSC, these must be grouped into a parallel R task representing the set of LRUs removed by that AFSC and crew size. E selection mode probabilities determine which corrective task is processed.
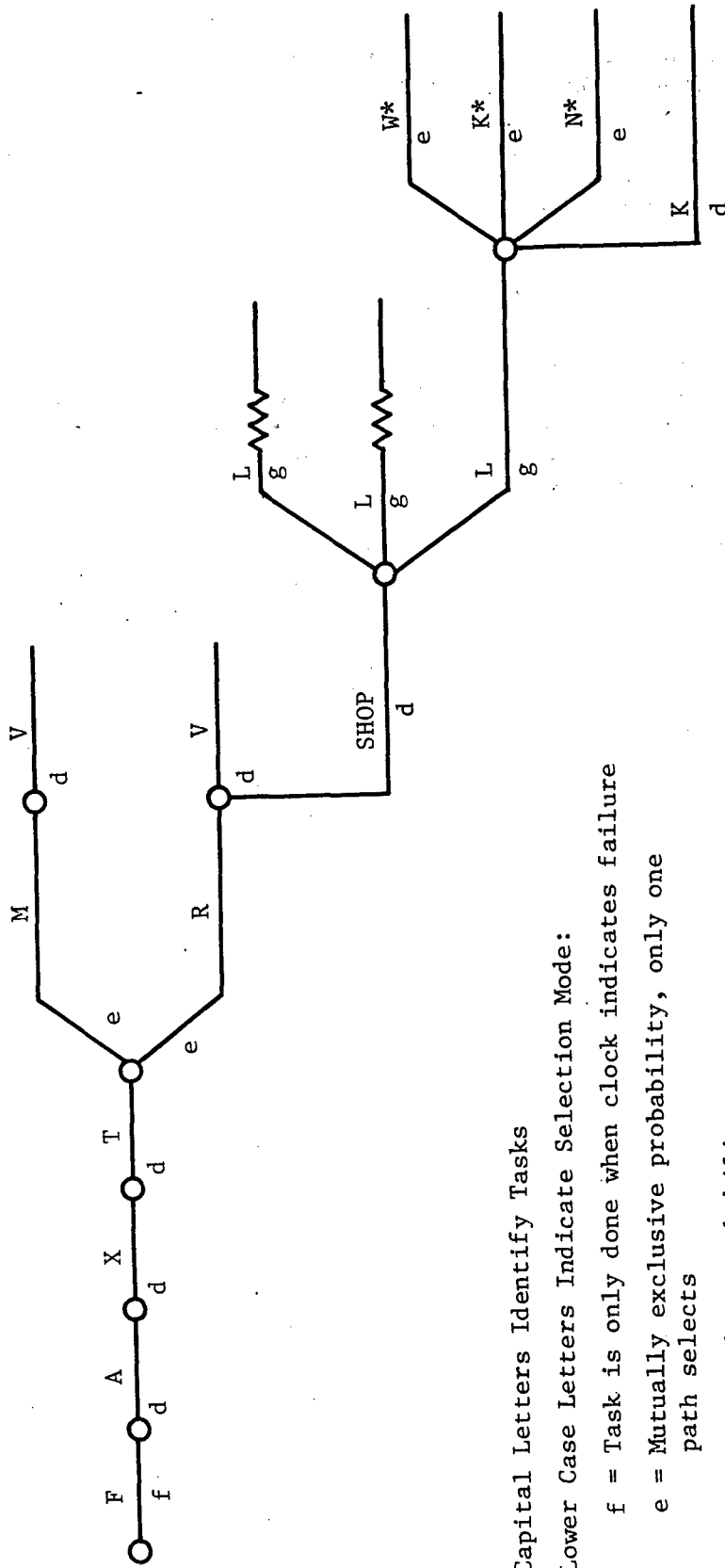
Capital Letters Identify Tasks

Lower Case Letters Indicate Selection Mode:

f = Task is only done when clock indicates failure

e = Mutually exclusive probability, only one path selects

g = Independent probability, one or more paths selected

d = Task is always done

* = This and any subsequent work is on the LRU, and does not necessarily detain the aircraft

Figure 17. Subsystem corrective maintenance network basic logic.

R tasks are normally followed by a shop entry task. This is a dummy because E and G Selection logic cannot be run out of the same network node. It is followed by parallel L tasks representing failed LRUs. Six selection mode probabilities determine which LRU(s) within the subsystem were removed. The following tasks are used to represent the possible shop actions on a removed LRU:

W to bench check and repair the LRU.
K to bench check the LRU and find it serviceable.
N to bench check the LRU, find it NRTS, prepare it for shipment, and order a new one from depot.

An asterisk can be placed in column 39 of the extended Form 11 to indicate that a shop task will not hold up the aircraft if a spare LRU is available. A Q task must be included with selection mode D and no asterisk in order to draw a spare LRU from supply. The asterisked N, W, and K tasks must be coded with selection mode E to assure only one is processed to match each supply demand. The asterisk tells the computer that an LRU is now being processed instead of an aircraft, and should be returned to supply when the task or task sequence is complete. It effectively separates the shop network from the aircraft network unless there was no spare to draw from supply.

Coding Conventions

Node numbers for on-aircraft maintenance tasks are 5 digits, right justified. The first 3 digits correspond to the first 3 digits of the subsystem work unit code, except that the first digit is entered as the corresponding alphabetic character. The last two digits indicate the task sequencing. For example, for the 14A00 subsystem, node numbers would be A4A00, A4A01, A4A02, etc. For the 42C00 subsystem they would start with D2C00, D2C01, D2C03, etc.

The mode following the shop dummy task and preceding the L task is 6 digits, with an S in the first position, followed by the subsystem work unit code. Subsequent nodes for shop tasks are also six digits, with I in the first position, the first 4 digits of the LRU work unit code, and the last position used for task sequencing as described above. For example, the prior node to the L task in the 14A00 network would be coded SA4A00, and the next node might be IA4AA0. These node numbering conventions may seem a bit confusing at first, but they are quickly mastered, and if followed help prevent serious node duplication errors when networks are modified and updated later. The node starting a task is entered in columns 5 - 10, and the next node in columns 19 - 25, on extended Forms 11.

The appropriate task action code is entered in column 12, followed by the first four digits of the work unit code. Column 17 is reserved

for task identification. It is zero unless there is more than one task with the same action code in the network. For example, if there were two R tasks in the 14A00 network, the first would be coded R14A00 in columns 12 - 17, and the second coded R14A01. Alpha characters can be used in column 17 if needed. Two common tasks are used which do not follow these rules. The shop entry dummy task following an R action is simply coded SHOP in columns 12 - 15. Since it is a dummy with no time or resources the same task name can be used in all networks. On occasion, it may be necessary to specify a task to account for depot turnaround time on a NRTS LRU. If the standard time is applicable, this task may be coded PDEPOT in columns 12 - 16 and no time or resources entered. Use of a standard depot task is discussed further in the examples and in Section VI.

The clock number for the network is entered in columns 34 - 38. This must match the work unit code entered in columns 13 - 17 on the F task. The same clock number is entered on every task in the network that follows the F task. It identifies which failure clock initially triggered the action.

The mean sorties between maintenance actions is entered in columns 27 - 32 on the F task. It is a whole number, right justified, and represents the average number of flights between a corrective maintenance action of any kind on the subsystem. Task type 2 is entered in column 40 for all tasks in the unscheduled maintenance networks. Priority 1 is entered in column 41 for on-aircraft work, and priority 3 for shop work on removed LRUs (task action codes N,W,K, and PDEPOT task). The Q task is coded priority 1. Standard deviation 29 percent of the mean and lognormal distribution are assumed to apply if more precise data are not available. These are entered as 29L in columns 49 - 51.

Each network is preceded by a header card, immediately followed by the F task. The header card has an H in column 25, the clock number in columns 34 - 38, and subsystem nomenclature in columns 42 - 66. Additional header cards can be inserted to change nomenclature where desired. Each L task is preceded by a header card with the LRU work unit code in columns 13 - 17, H in column 25, clock number in columns 34 - 38, and LRU nomenclature in columns 42 - 66. This LRU work unit code must be used in columns 13 - 17 of the Q task to correctly identify the item drawn from supply.

Using the MDC Data Bank

The remaining sections of this section illustrate the use of MDC data runs on comparable subsystems to develop and code unscheduled maintenance networks. The data bank computations and outputs are explained in detail in AFHRL-TR-74-97(III).

The on-aircraft maintenance (no phase) run at 5 digit work unit code
level, and field shop maintenance run at 5 digit level contain the
applicable data on unscheduled maintenance. These runs include summaries
at 3 digit and 4 digit level. The special inspection 04 codes in the
work unit code manual and the **data run showing the task data for this work**
need to be reviewed and verified with technicians in the field to
identify any unscheduled maintenance that is not coded to subsystem work
unit codes. The special inspection run includes a listing of access
work and cannot duplicate (CND) troubleshoots. Access is usually peculiar
to each design and cannot be extrapolated from data on other aircraft,
but such data may give clues on what to look for and can identify where
joint removal and checkout is done. The circumstances causing high rates
of CND troubleshooting on a comparable subsystem have to be investigated
to decide whether they apply to the new aircraft flying the assumed
scenario.

The 3 digit summary from an on-aircraft data printout for a VHG-FM
radio (62ADD) is illustrated in Figure 18. It shows average reported
time for each applicable task action code by AFSC and crew size, and
the number of such actions occurring during the period of the data sample.
It does not show AGE or access. The mean job time is an overall average
time per corrective action for the full sequence of on-aircraft work. A
clock value of 39 mean sorties between maintenance actions (MSBMA) is
shown on the next line, with quantity per aircraft equal to 1. This
means that there is only one such radio on the aircraft. If the QPA were
more than one, the MSBMA rate shown could be on a per unit basis.
Conversely, if there were two radios on the new aircraft, the unit MSBMA
rate taken from the data would have to be adjusted to take this into
account. The appropriate computations are discussed in the next section.
The matrix printed after the line of stars shows the E probabilities of
an R or M corrective action by each AFSC that works on the equipment, and
the average times without regard to crew size.

Figures 19 and 20 show how this data is networked and coded on
extended Forms 11. The radio set is located in the cockpit of the aircraft.
It was determined from discussion with experienced radio maintenance
technicians that a ground power unit was required for troubleshoot and
check, and that the crew chief (AFSC 431X1) would have to remove panels
for access if the radio technician needed to check and repair the wiring.
An access task by a 431X1 is generally required wherever panels with high
torsion fasteners have to be removed.

The network shows an F task with a clock of 39 MSBMA. This is
followed by an A task, covering delivery of AGE by a 421X3 and hookup by
the 431X1 crew chief. The corrective action is either a remove and
replace (.73 E probability) by 328X0, or access by the crew chief (.27 E
probability) and repair by 328X0. The typical crew dispatched is 2
328X0 technicians. Troubleshoot and check were reported separately less
than 15% of the time, so they are included in with the R and M tasks,
using the mean job time. Note, however, that 36 troubleshoots were
reported under a 2 digit 62000 work unit code. Including these trouble-
shoots increases the mean job times by .1 hour:

WUC=62A	AFSC=328X0E	NOM=TEAM WORK AFSC GROUP	CREW= 4	4.0 HR	1 T ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 1	1.5 HR	9 M ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 2	1.2 HR	89 M ACTIONS
WUC=62A	AFSC= 328X0	NCM= AV RADIO	CREW= 3	1.7 HR	2 M ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 4	1.2 HR	1 M ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 1	1.4 HR	24 R ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 2	1.4 HR	244 R ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 3	1.9 HR	2 R ACTIONS
WUC=62A	AFSC= 328X0	NCM= AV RADIO	CREW= 1	2.1 HR	1 V ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 2	.8 HR	31 V ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 1	.9 HR	2 T ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 2	1.0 HR	21 T ACTIONS
WUC=62A	AFSC= 328X0	NOM= AV RADIO	CREW= 3	1.0 HR	2 T ACTIONS

FOR WUC 62A ,AFSC 328X0,MEAN M JOB TIME= 1.4, MEAN R JOB TIME= 1.5
WUC=62A   UNIT MSBMA= 39.   QPA= 1

	AFSC	R ELAP	RMA	RPROB	M ELAP	MMA	MPROB
WUC= 62A	328X0	1.39	270	.73	1.27	101	.27

****

WUC=6200	AFSC= 328X0	NOM= AV RADIO	CREW= 2	.7 HR	3 M ACTIONS
WUC=6200	AFSC= 328X0	NOM= AV RADIO	CREW= 1	1.0 HR	6 T ACTIONS
WUC=6200	AFSC= 328X0	NOM= AV RADIO	CREW= 2	1.0 HR	28 T ACTIONS
WUC=6200	AFSC= 328X0	NOM= AV RADIO	CREW= 3	6.3 HR	1 T ACTIONS

WUC=6200   UNIT MSBMA= 4795.   QPA= 1

****

	AFSC	R ELAP	RMA	RPROB	M ELAP	MMA	MPROB
WUC= 6200	328X0	0.08	0	0.00	.73	3	1.00

Figure 18. Data bank printout for VHF radio on-aircraft work.

ALTERNATE METHOD OF
NETWORKING 62AA0:
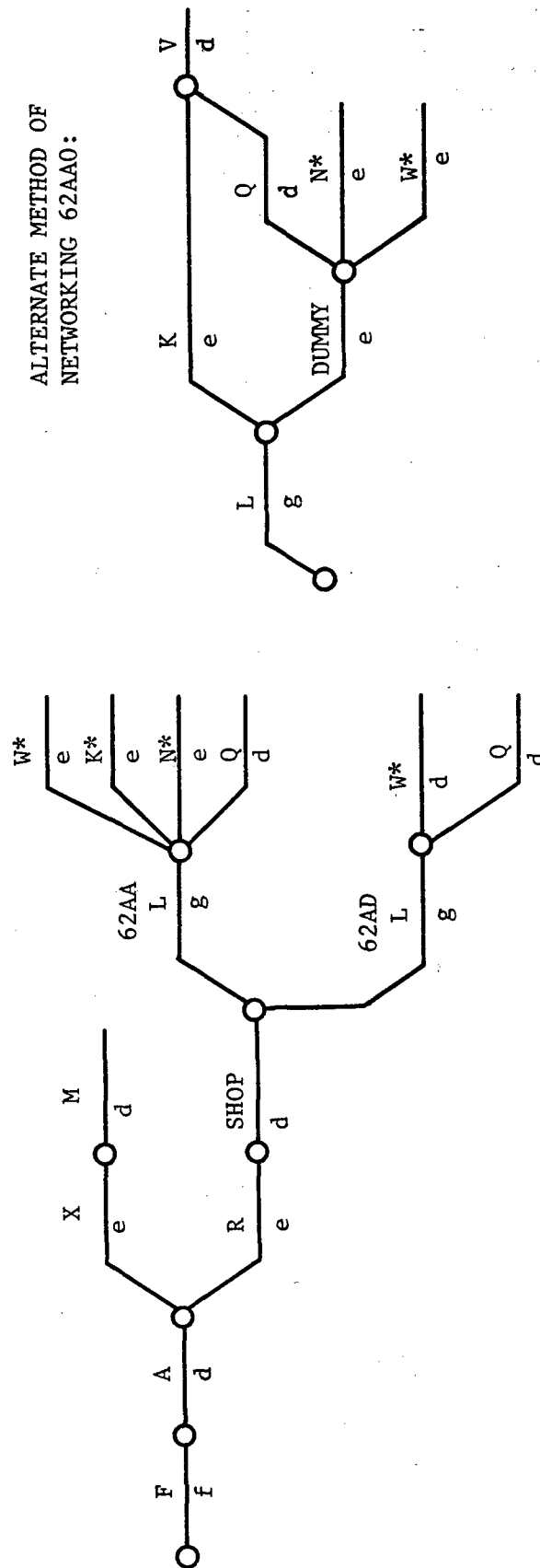
Figure 19. Schematic of VHF radio network.

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Dist. Type	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE	Continuation
				H						VHF RADIO							
F2A00	F	F62A00	F2A01	F	39	62A00	0	21									
F2A01	A	A62A00	F2A02	D		62A00	0	21		02	29L		1421 X3	1421 X1	1D60		
F2A02	R	R62A00	F2A03	E	73	62A00	0	21		16	29L		2328 X0	1D60			
F2A02	X	X62A00	F2A04	E	27	62A00	0	21		05	29L		1431 X1	1431 X1			
F2A04	M	M62A00				62A00	0	21		15	29L		2328 X0	1D60			
F2A03	S	SH0P	SF2A00			62A00	0	21									
SF2A00		62AA0		H		62A00	0			VHF R/T UNIT							
IF2AA0	L	L62AA0	IF2AA0	G	016 96	62A00	0	23		41	29L		2328 X0				
IF2AA0	M	M62AA0		E	85	62A00	*23			15	29L		2328 X0				
IF2AA0	K	K62AA0		E	12	62A00	0 *23			38	29L		2328 X0				
IF2AA0	N	N62AA0		E	03	62A00	*23										
	Q	Q62A00		D		62A00	0	21		VHF CONTROL							
		62AD0		H		62A00											

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Figure 20. VHF radio network coding.

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Rel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Distr. Type	N AFSC/AGE
SF2ADO	L	L62ADO	IF2ADO	G	000S6	62AOO			23				
IF2ADO	W	W62ADO		D		62A00	0*	23			25	29L	2328X0
IF2ADO	Q	Q62ADO		D		62A00	0	21					
ALTERNATE METHOD ØF NETWORKING 62AAO:													
SF2AOO	L	L62AAO	IF2AAO	G	01696	62ADO	0	21					
IF2AOO	R	R62AAO		E	66	62A00	0	21			30	29L	2328X0
IF2AOO	J	J00000	IF2AA1	E	34	62A00	0	23					
IF2AA1	W	W62AAO		E	91	62A00	0*	23			77	29L	2328X0
IF2AA1	N	N62AAO		E	09	62A00	0*	23			38	29L	2328X0
IF2AA1	Q	Q62AAO		D		62A00	0	21					

PUNCH CARD TRANSCRIPT

AF FORM 1530
FEB 69   PREVIOUS EDITIONS OF THIS FORM WILL BE USED UNTIL STOCK IS EXHAUSTED.

AFLC—WPAFB—JAN 74 500

Figure 20. VHF radio network coding (contin''d).

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$$\frac{36 \text{ more T actions} \times 1.1 \text{ Avg. T Hours}}{373 \text{ Total R} + \text{M Actions}} = .1 \text{ Hours}$$

There are two LRUs that show any significant frequency of removal on the shop printout (Figure 21). Both are repaired in the radio shop. The receiver transmitter has a G probability of .01696 and the control has a G probability of .00056. The G probability is the per sortie probability that the LRU will be removed. It is used to assess the relative proportion or removals among the LRUs in the subsystem network. It is entered in columns 28 - 32 on the extended Form 11 right justified without a decimal. When a G probability is indicated, at least one of the alternate L tasks must be chosen by the program.

Shop data print-outs show two types of W tasks. A WA is a bench check and repair, but a WF is a repair following a separately reported bench check (code C). Two kinds of summary matrices are provided to assist in networking.

Data in the first matrix applies when the removed unit is always replaced from supply stock if available. This matrix shows the E probability and elapsed times for W, N, or K actions in shop. The NRTS is broken out to 4 digit and 5 digit level LRUs. Figure 20 shows how this situation is coded. A D selection mode is used on the W task for the control unit because W is the only possibility. No N or K tasks were indicated in the data.

Figure 20 also shows 62AA0 networked by the alternate method to illustrate the difference. This applies to situations where the unit is bench checked when removed. If it checks OK or is fixed in a short time, it is put back on the airplane. A spare is only drawn from supply if a long repair is required. The repair work is then deferred to a later time. In this case, the K task code represents a combined bench check OK and WA bench check. It is priority 1 and is not asterisked since the aircraft is tied up awaiting the bench check, and no units are withdrawn from or returned to supply. The W task represents bench check and deferred repair only. The W and N tasks are asterisked and priority 3 because the aircraft is fixed with a unit drawn from supply.

Computations with MSBMA

The MSBMA clock value may have to be recomputed or adjusted in the course of coding a network. Since it is an inverse number, the correct computations are not always intuitively obvious. The relationship of MSBMA to the probability of a maintenance action on the subsystem is:

$$P_M = \frac{1}{MSBMA}$$

To combine two MSBMA values, interactions can usually be ignored and their probabilities added:

```
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 2   4.8 HR    66 WF ACTIONS
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 3   6.1 HR     4 WF ACTIONS
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 4   1.9 HR     1 WF ACTIONS
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 1    .9 HR     2 K  ACTIONS    85.0
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 2   1.5 HR    28 K  ACTIONS   438.2
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 1   3.0 HR     2 C  ACTIONS
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 2   3.0 HR    72 C  ACTIONS   542.6
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 1   1.6 HR     5 WA ACTIONS
WUC=62AA   AFSC= 328X0   NCM= AV RADIO          CREW= 2   2.1 HR   126 WA ACTIONS
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 3   4.0 HR     1 WA ACTIONS    35.4
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 1   1.0 HR     1 N4 ACTIONS
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 2   5.7 HR     3 N4 ACTIONS    14.4
WUC=62AA   AFSC= 328X0   NOM= AV RADIO          CREW= 2   2.4 HR     3 N5 ACTIONS

                         FOR WUC=62AA   REMOVALS=255   ADJUSTED COUNT=252   Q FACTOR=1.012   TOTAL IN SHOP= 244.
                         WUC=62AA   UNIT MSBF= 67.   G PROB= .01696   QPA= 1
```

*****IF REMOVED ITEM REPLACED FROM SUPPLY WHEN AVAILABLE:
WUC=62AA

AFSC	N ELAP	WMA	MPROB	K ELAP	KMA	KPROB	N ELAP4	NMA4	NPROB4	N ELA[
328X0	4.11	207	.85	1.45	30	.12	4.55	4	.02	2.4[

*****IF REMOVED ITEM ALWAYS BENCH CHECKED BEFORE REPLACEMENT:
WUC=62AA

AFSC	PROB KWA	KWA ELAP	PROB NOT KWA	COND PROB WF	ELAP WF	COND PROB N4	ELAP N4	CO[
328X0	.66	1.96	.34	.91	7.71	.05	4.55	

```
WUC=62AD0   AFSC= 328X0   NOM= AV RADIO          CREW= 2   2.9 HR     2 WF ACTIONS    11.6
WUC=62AD0   AFSC= 328X0   NOM= AV RADIO          CREW= 2   1.1 HR     2 C  ACTIONS     4.4
WUC=62AD0   AFSC= 328X0   NOM= AV RADIO          CREW= 1    .8 HR     1 WA ACTIONS    23.0
WUC=62AD0   AFSC= 328X0   NOM= AV RADIO          CREW= 2   2.2 HR     5 WA ACTIONS
FOR WUC=62AD0 AFSC= 328X0   MEAN CK+RPR TIME= 2.5
               FOR WUC=62AD0   REMOVALS= 12   ADJUSTED COUNT= 12   Q FACTOR=1.000   TOTAL IN SHOP= 8.
               WUC=62AD0   UNIT MSBF= 1798.   G PROB= .00056   QPA= 1
```

Figure 21. Data bank printout for VHF radio shop work.

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$$\frac{1}{MSBMA_{Total}} = \frac{1}{MSBMA_1} + \frac{1}{MSBMA_2}$$

$$\text{or:} \quad MSBMA_{Total} = \frac{1}{\left(\dfrac{1}{MSBMA_1} + \dfrac{1}{MSBMA_2}\right)}$$

If an LRU with an MSBMA of every 50 sorties is included in a subsystem with a clock of 100, the new clock value is:

$$MSBMA = \frac{1}{\left(\dfrac{1}{50} + \dfrac{1}{100}\right)} = \frac{100}{3} = 33$$

The new clock value is not the average of the two MSBMA values, but is a number lower than either of them. This makes sense when one realizes that if another source of failure is added to a subsystem that is already failing every 50 sorties, it is going to fail more often. More frequent failures mean a lower value of MSBMA.

The relative significance of MSBMA values is also deceiving. Large differences in large MSBMA numbers are often insignificant while even relatively small differences in small MSBMA values represent important differences. Consider MSBMA values of 2000 and 1000. The difference in terms of probability of a maintenance action is:

$$P \text{ Diff.} = \frac{1}{1000} - \frac{1}{2000} = \frac{1}{2000} = .0005.$$

On the other hand, the difference between MSBMA values of 10 and 5 is:

$$P \text{ Diff.} = \frac{1}{5} - \frac{1}{10} = \frac{1}{10} = .1000$$

The latter difference is 200 times greater in terms of frequency of failure. For this reason, subsystems which fail less than once in 2000 sorties can often be ignored in building networks, but changes and modifications which affect low MSBMA numbers may have considerable impact on the simulation results.

When the aircraft being modeled has more than one of a given subsystem installed, the unit MSBMA taken from the data bank must be divided by the number installed to get the correct total maintenance rate. For example, if an aircraft has 2 identical hydraulic pumps with the same work unit code identification, and the data bank shows that a single pump requires maintenance every 50 sorties, then the average MSBMA rate for the 2 pumps will be once every 25 sorties.

If the comparability study indicates a 25% improvement in reliability for a new subsystem, it will only fail .75 times as often. The data bank MSBMA for the comparable unit must be divided by .75 to get the larger MSBMA value for the new subsystem.

Network with Expendable LRUs

The remainder of this section give examples of some more complex networking problems.

There are many throwaway electrical items coded as on-aircraft remove/replace jobs in MDC reporting which never go into the shop. These include relays, switches, and circuit breakers throughout the aircraft. The shop data bank printout gives the counts of items reported removed and reported in shop, and also shows a G probability of no shop. However, differences in these reported actions do not necessarily mean throwaways. They could be due to bad reporting or have another explanation. LRUs should not be networked as expendable unless it has been confirmed with maintenance technicians in the field.

Figures 22 and 23 show on-aircraft and shop data bank printouts for an aircraft lighting system with expendable LRUs. Only the anti-collision lights 44AGO and 44AHO are processed in the shop. All the rest are throwaways. The four and five digit level shop data were examined to see who removed the items that were processed into the shop. Since it appeared that either 431X1s or 423X0s can do any of these removals, both R tasks lead to a common shop entry node. The G probability of no shop work is included as a dummy task in Figure 24. In this network there are three AFSCs who do work on the equipment. Troubleshoot and functional checks are always done by electricians, but either the electricians or the crew chief can repair or replace failed lighting system components. On rare occasions, the machinist is called out for a mechanical repair. E probabilities for the various specialist corrective tasks were taken from the matrix in Figure 22. The 531X0 probability was rounded up so that they sum to 1.00.

The mean job times shown in Figure 22 are not much help in this case since troubleshoot and repair may be done by different specialists. The R and M task times shown in the matrix are entered on the extended Form 11. Troubleshoot was not separately reported in every case, so the 14 hour average time reported is "spread" over the total number of jobs by all specialists:

$$1.4 \text{ Hours} \times \left(\frac{93 \text{ Reported + Actions}}{219 \text{ Total R + M Actions}} \right) = .6 \text{ Hours}$$

There were not enough functional checks reported separately to warrant a separate task. This work was included within the electricians' troubleshoot time. The additional time is:

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```
WUC=44A     AESC=423X00     NOM=TEAM WORK AFSC GROUP     CREW= 4     1.0 HR     1 R ACTIONS
                  FOR WUC 44A   ,AFSC 423X0    ,MEAN M JOB TIME= 0.0, MEAN R JOB TIME= 1.0

WUC=44A     AFSC= 423X0     NOM= FM ELECTRICAL          CREW= 1     1.1 HR      7 M ACTIONS
WUC=44A     AFSC= 423X0     NOM= FM ELECTRICAL          CREW= 2     1.3 HR     34 M ACTIONS
WUC=44A     AFSC= 423X0     NCM= FM ELECTRICAL          CREW= 1      .9 HR     11 R ACTIONS
WUC=44A     AESC= 423X0     NOM= FM ELECTRICAL          CREW= 2     1.3 HR     40 R ACTIONS
WUC=44A     AFSC= 423X0     NOM= FM ELECTRICAL          CREW= 1      .3 HR      9 V ACTIONS
WUC=44A     AESC= 423X0     NCM= FM ELECTRICAL          CREW= 2      .6 HR     29 V ACTIONS
WUC=44A     AFSC= 423X0     NOM= FM ELECTRICAL          CREW= 1     1.0 HR     10 T ACTIONS
WUC=44A     AESC= 423X0     NOM= FM ELECTRICAL          CREW= 2     1.5 HR     82 T ACTIONS
WUC=44A     AFSC= 423X0     NOM= FM ELECTRICAL          CREW= 3     2.0 HR      1 T ACTIONS
                  FOR WUC 44A  ,AESC  423X0,MEAN M JOB TIME= 2.9, MEAN R JOB TIME= 2.9

WUC=44A     AESC= 431X1     NOM= OM FLIGHT LINE         CREW= 1     1.1 HR     28 M ACTIONS
WUC=44A     AFSC= 431X1     NOM= OM FLIGHT LINE         CREW= 2     1.2 HR     14 M ACTIONS
WUC=44A     AFSC= 431X1     NOM= OM FLIGHT LINE         CREW= 1      .9 HR     46 R ACTIONS
WUC=44A     AFSC= 431X1     NOM= OM FLIGHT LINE         CREW= 2      .9 HR     30 R ACTIONS
WUC=44A     AESC= 431X1     NCM= OM FLIGHT LINE         CREW= 3      .5 HR      2 R ACTIONS
WUC=44A     AFSC= 431X1     NOM= OM FLIGHT LINE         CREW= 4      .8 HR      3 R ACTIONS
                  FOR WUC 44A  ,AESC  431X1,MEAN M JOB TIME= 1.2, MEAN R JOB TIME= .9

WUC=44A     AFSC= 531X0     NOM= FM MACHINE SHOP        CREW= 1     1.3 HR      3 M ACTIONS
                  FOR WUC 44A   ,AFSC 531X0,MEAN M JOB TIME= 1.3, MEAN R JOB TIME= 0.0
WUC=44A           UNIT MSBMA=  66.    QPA= 1

*****************
```

WUC= 44A AFSC	R ELAP	RMA	RPROB	M ELAP	MMA	MPROB
423X00	1.00	1	.00	0.00	0	0.00
423X0	1.20	51	.23	1.25	41	.19
431X1	.89	81	.37	1.16	42	.19
531X0	0.00	0	0.00	1.33	3	.01

Figure 22. Data bank printout for external lighting on aircraft work.

```
WUC=44AG    AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 1    .4 HR    3 K ACTIONS    1.1 ?
WUC=44AG    AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 1   1.0 HR    1 C ACTIONS    8.4 ?
WUC=44AG    AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 2   1.2 HR    3 C ACTIONS
WUC=44AG    AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 1   3.3 HR    4 WA ACTIONS  204.8 M
WUC=44AG    AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 2   3.5 HR   28 WA ACTIONS
       FOR WUC=44AG      REMOVALS= 25   ADJUSTED COUNT= 24   Q FACTOR=1.042   TOTAL IN SHOP= 35.
          WUC=44AG    UNIT MSBF=  450.   G PROB= .00243    QPA= 1
```

*****IF REMOVED ITEM REPLACED FROM SUPPLY WHEN AVAILABLE:
   WUC=44AG

AFSC	N ELAP	NMA	WPROB	K ELAP	KMA	KPROB	NMA4	NPROB4	N ELAP?
423X0	3.44	32	.91	.37	3	.09	0	0.00	0.00

*****IF REMOVED ITEM ALWAYS BENCH CHECKED BEFORE REPLACEMENT:
   WUC=44AG

AFSC	PROB KWA	KWA ELAP	PROB NOT KWA	COND PROB WF	ELAP WF	COND PROB N4	ELAP N4	CON[
423X0	1.00	3.18	0.00	0.00	0.00	0.00	0.00	

```
WUC=44AH0   AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 1   1.8 HR    1 WF ACTIONS   3.4 MM
WUC=44AH0   AFSC=   423X0   NCM= FM ELECTRICAL   CREW= 2    .8 HR    1 WF ACTIONS
WUC=44AH0   AFSC=   423X0   NCM= FM ELECTRICAL   CREW= 1   4.0 HR    1 C ACTIONS   63.2 MM
WUC=44AH0   AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 2   2.1 HR    4 C ACTIONS
WUC=44AH0   AFSC=   423X0   NCM= FM ELECTRICAL   CREW= 4   5.1 HR    1 C ACTIONS
WUC=44AH0   AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 1   2.7 HR    6 WA ACTIONS  271.1 MM
WUC=44AH0   AFSC=   423X0   NOM= FM ELECTRICAL   CREW= 2   3.3 HR   39 WA ACTIONS
WUC=44AH0   AFSC=   423X0   NCM= FM ELECTRICAL   CREW= 2   1.0 HR    2 N4 ACTIONS   4.2 MM
FOR WUC=44AH0 AFSC=   423X0   MEAN CK+RPR TIME= 3.2   ADJUSTED COUNT= 33   Q FACTOR=1.061   TOTAL IN SHOP= 49.
          WUC=44AH0   UNIT MSBF=  294.   G PROB= .00341    QPA= 1
```

Figure 23.   Data bank printout for external lighting shop work.

******IF REMOVED ITEM ALWAYS BENCH CHECKED BEFORE REPLACEMENT:
  WUC=44AH

AFSC	PROB KWA	KWA ELAP	PROB NOT KWA	COND PROB WF	ELAP WF	COND PROB N4	ELAP N4	C(
423X0	.92	3.19	.08	.50	4.23	.50	1.05	

WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 1	1.8 HR	1 WF ACTIONS	3.4
WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 2	.8 HR	1 WF ACTIONS	
WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 1	.4 HR	3 K ACTIONS	1.1
WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 2	2.5 HR	2 C ACTIONS	71.6
WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 2	1.7 HR	7 C ACTIONS	
WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 4	5.1 HR	1 C ACTIONS	
WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 1	3.0 HR	10 WA ACTIONS	475.9
WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 2	3.3 HR	67 WA ACTIONS	
WUC=44A	AFSC=	423X0	NOM=	FM ELECTRICAL	CREW= 2	1.0 HR	2 N4 ACTIONS	4.2

FOR WUC=44A   REMOVALS=153   ADJUSTED COUNT=140   Q FACTOR=1.093   TOTAL IN SHOP= 84.
WUC=44A   UNIT MSBF= 173.   G PROB= .00598   QPA= 1

******IF REMOVED ITEM REPLACED FROM SUPPLY WHEN AVAILABLE:
  WUC=44A

AFSC	W ELAP	WMA	K ELAP	KMA	WPROB	KPROB	N ELAP4	NMA4	NPROB4	N EL
423X0	3.30	79	.37	3	.94	.04	1.05	2	.02	0.

******IF REMOVED ITEM ALWAYS BENCH CHECKED BEFORE REPLACEMENT:
  WUC=44A

AFSC	PROB KWA	KWA ELAP	PROB NOT KWA	COND PROB WF	ELAP WF	COND PROB N4	ELAP N4	C
423X0	.95	3.19	.05	.50	3.53	.50	1.05	

Figure 23 (Continued)

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sol. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	VAR %	Dist. Type	N	AFSC/AGE	N	AFSC/AGE	N	AFSC/AGE	N	AFSC/AGE	N	AFSC/AGE	Continuation
				#		44A00				EXTERNAL	L	LIGHTS											
D4A00	F44	F444A00	A44A01	F	66	44A00			1			L		1421X3		1431X1	1D60					
D4A01	A44	A444A00	D44A02	D		44A00		2	1	02	29L		2423X0		1D60							
D4A02	T44	T444A00	D44A03	D	37	44A00		2	1	07	29L		1431X1									
D4A03	R44	R444A00	D44A04	E	19	44A00		2	1	09	29L		1431X1									
D4A03	M44	M444A00		E	23	44A00		2	1	12	29L		2423X0									
D4A03	R44	R444A00	D44A04	E	19	44A00		2	1	12	27L		2423X0									
D4A03	M44	M444A00		E	02	44A00		2	1	13	29L		1531X0									
D4A03	M44	M444A00	SD4A00	A		44A00		2	1	13	29L											
D4A04	SH0P	SH0P		#	00243	44A00				UPPER ANTICOLLISION LIGHT												
SD4A00	44AG0	44AG0	ID4AG0	G	23	44A00		23		34												
ID4AG0	L44	L444AG0	ID4AG0	E	91	44A00		*23			27L		2423X0									
ID4AG0	W44	W444AG0		E	09	44A00		*23		4	29L		1423X0									
ID4AG0	K44	K444AG0																					

PREVIOUS EDITIONS OF THIS FORM WILL BE USED
UNTIL STOCK IS EXHAUSTED.
AF FORM 1530 FEB 69

PUNCH CARD TRANSCRIPT

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Figure 24. External lighting network coding.

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Figure 24. External lighting network coding (continued).

$$.5 \text{ Hours} \times \left(\frac{38 \text{ reported V Actions}}{219 \text{ Total R + M Actions}}\right) = .1 \text{ Hours}$$

The average troubleshoot time over all corrective actions on the subsystem is .7 hours. These times computed from the data bank runs are only the initial cut at networking. They should be factored for any significant design differences and verified by experienced maintenance specialists.

Engine Network

MDC data is of relatively little value in developing a network for a basic engine. Data bank print-outs are available to show engine work on aircraft, work on entire engines in the engine shop, shop work on components removed from the engine, special inspections, and removals for access. However, so much of the unscheduled maintenance is reported against 04 inspection codes and even 09 shop general that the data bank probabilities often are not meaningful.

It may not be feasible to determine the frequency of engine removals from MDC data since there is no standard way of reporting an engine removal for failure. For example, on the A7D work unit codes 23B, 23AJ, and removal for access (to the internal parts) are variously used. The AFLC depot engine managers require separate reporting of each engine removal for cause, and these are listed in the monthly base K-18 maintenance summary. The average K-18 count over the past year from bases of interest may be the best estimate of mean removal rate for a comparable engine.

The engine removal task sequence through functional check flight, and the proportion of on-aircraft troubleshoot-adjust-fix to removal, should be based on information obtained from the engine shops maintaining comparable engines, and modified for the maintenance concept and requirements of the new engine.

An example engine network is shown in Figure 25. When an engine is changed, the aircraft is towed to the test cell for trim and runup, and then taken up for a functional check flight. The engine goes into the shop for teardown. Portions of the engine may be removed and replaced, and the engine reassembled for use as a spare on the next aircraft requiring and engine change. The parts that were removed from the engine are processed through the field shops, and when repaired are returned to stock.

Engine network coding is shown in Figure 26. The example only depicts one of the engine sections in the shop to illustrate the technique. The first asterisk is on the engine teardown task. This tells the computer it is now working on an engine (WUC 23000) and no longer holds up the aircraft. A Q task draws the replacement engine from spare stocks if available. At the next stage the Q task draws an assembly to be replaced on the engine. The asterisk at this level tells the computer that the work is on the removed assembly and does not hold up the engine.
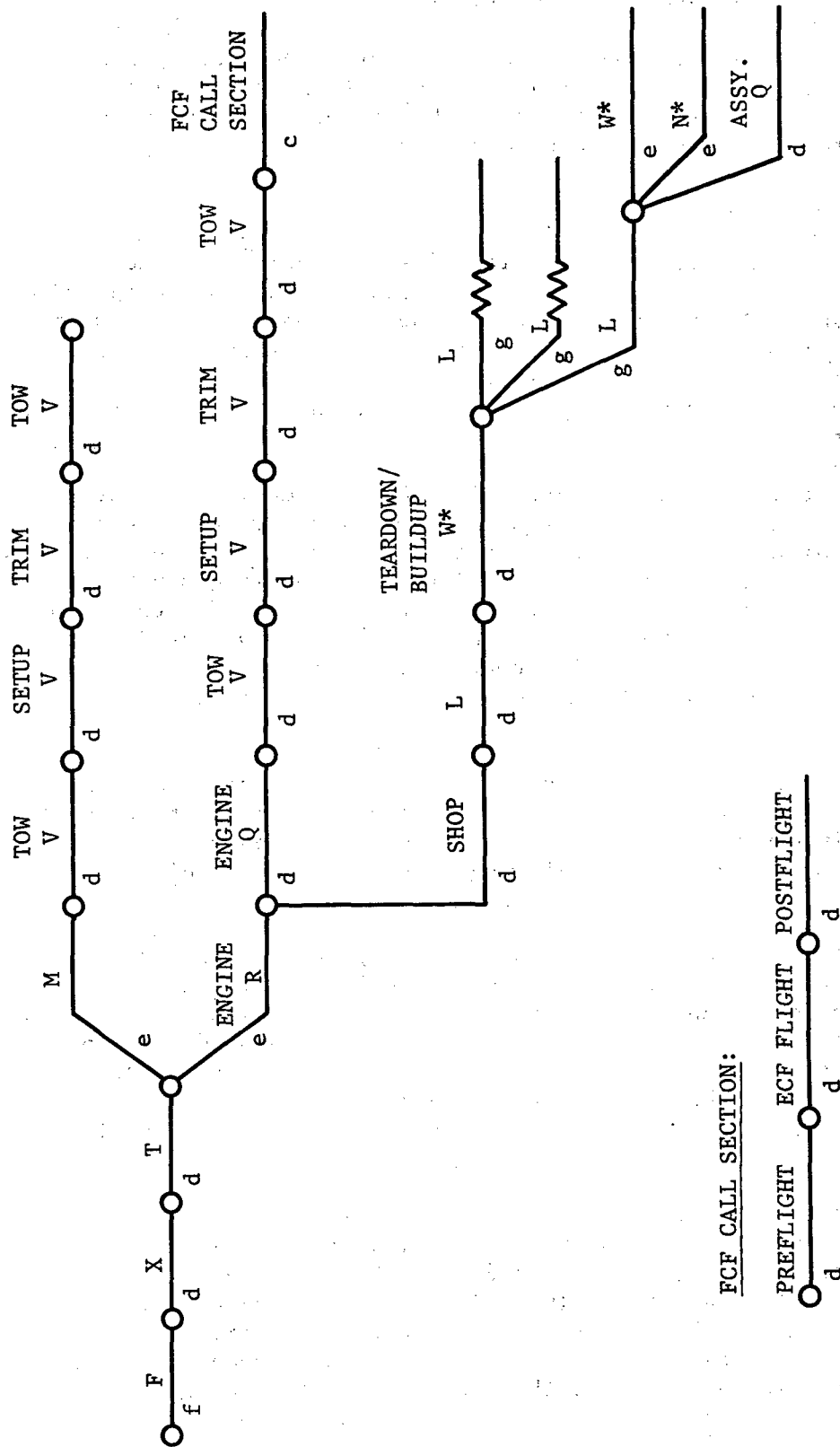
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Figure 25. Schematic of engine network.

INPUT No. 2
EXTENDED FORM II

Prior Node	ACT	WUC	Next Node	Sol. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	VAR	Dist. Type	N AFSC / AGE
B3B00				H		23B00	0			BASIC ENGINE			
B3B01	F	23B00	B3B01	F	28	23B00	0	2	1		29L		3431X1
B3B02	X	23B00	B3B02	D		23B00	0	2	1	60	29L		3432X0
B3B03	T	23B00	B3B03	D		23B00	0	2	1	74	29L		3432X0
B3B03	M	23B00	B3B04	E	90	23B00	0	2	1	13	29L		2432X0
				H		23B00	0			TOW AIRCRAFT, PUT IN CELL			
B3B04	V	23B00	B3B05	D		23B00	0	2	1	07	29L		3431X1 ITUG
B3B05	V	23B01	B3B06	D		23B00	0	2	1	RUN UP AND TRIM	29L		
						23B00	0			02	29L		6431X1
B3B06	V	23B02	B3B07	D		23B00	0	2	1	25	29L		3431 TO 2431X1
				H		23B00	0			TOW AIRCRAFT BACK			
B3B07	V	23B03		D		23B00	0	2	1	09	29L		5431X1 ITUG
				H		23B00	0			ENGINE CHANGE, RUNUP, TRIM			
B3B03	R	23B00	B3B08	E	10	23B00	0	2	1	48	29L		4432X0

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Figure 26. Engine network coding.

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Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	VAR	Dist. Type	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE	Continuation
B3B08	G	23B00	B3B09	D		23B00		2	1							
B3B09	V	23B00	B3B10	D		23B00		2	1							
B3B10	V	23B01	B3B11	D		23B00		2	1							
B3B11	V	23B02	B3B12	D		23B00		2	1							
B3B12	V	23B03	B3B13	D		23B00		2	1				FUNCTIONAL CHECK FLIGHT			
B3B13			B3B14	H C		23B00		2	1							
CALLS7	V	CALLS7	B3B15	D		23B00		2	1	18	29L		2431X1	1D60	1B4	
CALLS7	V	PRFLT	B3B16	D		23B00		2	1	10	29L		1111.5K	2431X1		
B3B15	V	FCFDD		D		23B00		2	1	25	29L		2431X1	1D60	1B4	
B3B16	V	PSTFL	S B3B00	D		23B00		2	1							
B3B14		SHOP		H		23B00							ENGINE TEARDOWN, BUILDUP			
SB3B00		23B00	I B3B00	D		23B00		13	13							
IB3B00	L	23B00	H B3B01	D		23B00		23		80	29L		2432S0			
	W	23B00				23B00 *23										

PUNCH CARD TRANSCRIPT

AF FORM 1530
PREVIOUS EDITIONS OF THIS FORM WILL BE USED
UNTIL STOCK IS EXHAUSTED.

AFLC–WPAFB–JAN 74 500

Figure 26. Engine network coding (continued).

INPUT No. 2
EXTENDED FORM 17

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	* VAR	Distr. Type	N AFSC/AGE	Continuation
IB3B0I		23BA0		H		23B00				BASIC	E		ENGINE ASSEMBLY	
IB3BA0	L	23BA0	IB3BA0D	D		23B00			23					
IB3BA0	W	23BA0		D		23B00	*23			18	29L		1532XD	
IB3BA0	Q	23BA0		D		23B00			23					

PUNCH CARD TRANSCRIPT

Figure 26. Engine network coding (continued).

The engine work center may be subdivided into different sections which do not do each other's work. This is one of the maintenance concept assumptions that must be obtained from the operating command. In Figure 26, the flight line dispatch crew is coded 432X0, technicians assigned exclusively to shop work are coded 43250, and the crew dedicated to the test cell is coded 432T0. The pilot who does the functional check flight is coded 1115K. He is treated as a dedicated resource and is normally only available during daylight shifts. The functional check flight is coded as a maintenance task rather than as a sortie task because it is not scheduled on a Form 20. Note the use of header cards to supply nomenclature for the string of check tasks following engine change or on-aircraft fix. Also note that resources are not shown for these tasks when they are repeated.

Engine accessories and accessory systems removed and replaced on aircraft are shown in separate networks (engine fuel system, engine electrical system, engine oil system, etc.). These networks can be satisfactorily modeled from MDC data and were not illustrated for this example.

Complex Avionics Networks

The A7D forward looking radar (WUC 73A00) is one of several integrated subsystems comprising the A7D bombing avionics. It is one of the most complex networking problems a model builder is likely to encounter. Some of the troubleshooting and radar boresighting are reported under 04 series work unit codes. Much of the troubleshooting is reported as cannot-duplicate (CND). If the initial troubleshoot does not locate the fault, another specialist will be called in to check his subsystem, until the problem is found or clearly cannot be duplicated. Some corrective actions require multiple removals for access, and some access removals are checked in the shop. When NRTS items return from depot they are given a full bench check, and in some cases may be NRTS back again.

The 3 digit on-aircraft data bank summary output is shown in Figure 27. The FLR is maintained by 322X1 technicians. The few instances of work by other AFSCs total less than 1% of the maintenance actions and can be ignored. Part of the special inspection data bank output is shown in Figure 28. The 04128 and 04129 codes report troubleshooting and/or boresighting of the whole bombing system. Some of these involve work on the FLR. Figure 29 shows the CND troubleshoot matrix for the whole bombing system. The subsystems and special inspection codes are listed on the vertical axis. The first column shows the number of CND trouble-shoots reported against these codes in the data sample. The next columns show how many of these CNDs were associated with a corrective action on another of the integrated subsystems. The last column shows how many were true CNDs not associated with any subsequent corrective action. The matrix shows 162 true CNDs for 73A in this data sample.

```
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 1    1.2 HR      4 M ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 2    1.2 HR    3?3 M ACTIONS
WUC=73A    AESC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 3    1.4 HR     86 M ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 4    1.6 HR      8 M ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 1    3.2 HR      6 R ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 2    2.2 HR    819 R ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 3    2.4 HR    2?7 R ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 4    2.4 HR     22 R ACTIONS
WUC=73A    AFSC= 322X1    NCM= AV WEAPONS CONTROL    CREW= 5    1.1 HR      5 R ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 1     .6 HR     20 V ACTIONS
WUC=73A    AFSC= 322X1    NCM= AV WEAPONS CONTROL    CREW= 2     .8 HR     70 V ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 3    1.5 HR      5 V ACTIONS
WUC=73A    AFSC= 322X1    NCM= AV WEAPONS CONTROL    CREW= 4    2.3 HR      1 V ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 1    1.1 HR      4 T ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 2    1.6 HR    3?2 T ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 3    2.5 HR    117 T ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 4    4.0 HR     16 T ACTIONS
WUC=73A    AFSC= 322X1    NOM= AV WEAPONS CONTROL    CREW= 5    4.4 HR      2 T ACTIONS
           FOR WUC 73A ,AFSC  322X1,MEAN M JOB TIME=  1.9, MEAN R JOB TIME=  2.9

WUC=73A    AFSC= 325X1    NOM= AV INSTRUMENTS        CREW= 2    1.9 HR      2 R ACTIONS
WUC=73A    AFSC= 325X1    NOM= AV INSTRUMENTS        CREW= 3    1.4 HR      1 R ACTIONS
           FOR WUC 73A ,AFSC  325X1,MEAN M JOB TIME=  0.0, MEAN R JOB TIME=  1.7

WUC=73A    AFSC= 431X1    NCM= OM FLIGHT LINE        CREW= 1    1.4 HR      2 M ACTIONS
           FOR WUC 73A ,AFSC  431X1,MEAN M JOB TIME=  1.4, MEAN R JOB TIME=  0.0

WUC=73A    AFSC= 531X0    NOM= FM MACHINE SHOP       CREW= 1    2.0 HR      6 M ACTIONS
WUC=73A    AFSC= 531X0    NOM= FM MACHINE SHOP       CREW= 2    1.8 HR      1 M ACTIONS
           FOR WUC 73A ,AFSC  531X0,MEAN M JOB TIME=  2.0, MEAN R JOB TIME=  0.0
WUC=73A    UNIT MSBMA=    9.   QPA= 1

*************************
```

WUC= 73A

AFSC	R ELAP	RMA	RPROB	M ELAP	MMA	MPROB
322X1	2.24	*49	.70	1.25	4.91	.30
325X1	1.73	3	.00	0.00	0	0.00
431X1	0.00	0	0.00	1.40	2	.00
531X0	0.00	0	0.00	2.00	7	.00

Figure 27. Data bank printout for FLR on-aircraft work.

WUC	AFSC	NOM/NOT	CREW	HR	ACTIONS
WUC=04124	AFSC= 322X1	NOM= AV INSTRUMENTS	CREW= 1	1.5 HR	15 V ACTIONS
WUC=04124	AFSC= 325X1	NOT= AV INSTRUMENTS	CREW= 2	1.5 HR	354 V ACTIONS
WUC=04124	AFSC= 325X1	NOM= AV INSTRUMENTS	CREW= 3	1.6 HR	50 V ACTIONS
WUC=04124	AFSC= 525X1	NOV= AV INSTRUMENTS	CREW= 4	1.3 HR	2 V ACTIONS
WUC=04124	AFSC= 431X1	NOM= OM FLIGHT LINE	CREW= 1	1.3 HR	25 V ACTIONS
WUC=04124	AFSC= 431X1	NOM= OM FLIGHT LINE	CREW= 2	2.1 HR	28 V ACTIONS
WUC=04124	AFSC= 431X1	NOM= OM FLIGHT LINE	CREW= 3	.5 HR	3 V ACTIONS
WUC=04124	AFSC= 431X1	NOM= OM FLIGHT LINE	CREW= 4	6.0 HR	1 V ACTIONS
WUC=04127	AFSC= 325X1	NOM= AV INSTRUMENTS	CREW= 2	1.0 HR	1 V ACTIONS
WUC=04128	AFSC=322X1G	NOM=TEAM WORK AFSC GROUP	CREW= 5	1.2 HR	1 V ACTIONS
WUC=04128	AFSC= 322X1	NOM= AV WEAPONS CONTROL	CREW= 1	1.8 HR	2 V ACTIONS
WUC=04128	AFSC= 322X1	NOM= AV WEAPONS CONTROL	CREW= 2	1.4 HR	200 V ACTIONS
WUC=04128	AFSC= 322X1	NOM= AV WEAPONS CONTROL	CREW= 3	1.5 HR	71 V ACTIONS
WUC=04128	AFSC= 322X1	NOM= AV WEAPONS CONTROL	CREW= 4	2.4 HR	15 V ACTIONS
WUC=04128	AFSC= 322X1	NOM= AV WEAPONS CONTROL	CREW= 5	1.0 HR	3 V ACTIONS
WUC=04128	AFSC= 323X4	NOM= AV DOPPLER-INERTIAL NAV	CREW= 1	.5 HR	2 V ACTIONS
WUC=04128	AFSC= 323X4	NOM= AV DOPPLER-INERTIAL NAV	CREW= 2	.7 HR	10 V ACTIONS
WUC=04128	AFSC= 328X4	NOM= AV DOPPLER-INERTIAL NAV	CREW= 3	1.0 HR	1 V ACTIONS
WUC=04129	AFSC= +322X1	NOM= AV WEAPONS CONTROL	CREW= 3	1.2 HR	0 V ACTIONS
WUC=04129	AFSC= +323X4	NOM= AV DOPPLER-INERTIAL NAV	CREW= 2	.5 HR	0 V ACTIONS
WUC=04129	AFSC=322X1P	NOM=TEAM WORK AFSC GROUP	CREW= 4	1.1 HR	1 V ACTIONS
WUC=04129	AFSC= F322X1	NOM= AV WEAPONS CONTROL	CREW= 2	1.0 HR	0 V ACTIONS
WUC=04129	AFSC= F431X1	NOM= OM FLIGHT LINE	CREW= 2	1.1 HR	0 V ACTIONS
WUC=04129	AFSC= 322X1	NOM= AV WEAPONS CONTROL	CREW= 2	1.6 HR	86 V ACTIONS
WUC=04129	AFSC= 322X1	NOM= AV WEAPONS CONTROL	CREW= 3	2.4 HR	46 V ACTIONS
WUC=04129	AFSC= 322X1	NOM= AV WEAPONS CONTROL	CREW= 4	2.8 HR	6 V ACTIONS
WUC=04129	AFSC= 325X1	NOM= AV INSTRUMENTS	CREW= 2	1.4 HR	2 V ACTIONS
WUC=04129	AFSC= 328X4	NOM= AV DOPPLER-INERTIAL NAV	CREW= 2	.7 HR	2 V ACTIONS

Figure 28. Data bank printout for bombing system special inspections.

# OF JCNS WITH RCOS	72A00 R OR M	73A00 R OR M	73B00 R OR M	73C00 R OR M	73D00 R OR M	73E00 R OR M	73F00 R OR M	73G00 R OR M	74E00 R OR M	CND OR NO R/H
74E00 462Y0 — 42	0	4	3	1	1	3	1	1	2	30
73G00 328X4 — 106	4	10	11	11	11	16	9	8	0	54
73F0C 328X4 — 501	13	54	57	35	33	33	33	18	1	280
73E00 322X1 — 383	13	60	19	30	23	28	33	9	3	226
73D00 328X4 — 206	6	23	13	18	5	18	28	7	0	119
73C00 325X1 — 73	5	9	9	5	5	3	11	0	2	42
73B00 322X1 — 302	14	46	27	20	17	25	36	9	2	152
73A00 322X1 — 273	17	29	16	14	21	28	18	2	0	162
72A00 328X1 — 54	1	7	5	5	3	7	4	3	0	27
04129 322X1 — 168	7	15	18	11	5	7	25	4	2	102
04128 322X1 — 380	7	68	28	19	9	40	23	5	3	211

NTYPE=0

Figure 29. Data bank printout of integrated avionics system CND troubleshoot.

The CND matrix is also used to determine the probabilities that a corrective action on a specific subsystem was preceded by CND trouble-shoots on other parts of the bombing system. This is found by summing CND actions by each AFSC in the column representing corrective actions against the subsystem. The AFSCs have been noted on the vertical axis. The FLR (73A) is found in the third column. Summing from the top, there are 4 prior CNDs by 46240, 87 by 328X4, 218 by 322X1, 9 by 325X1, and 7 by 328X1.

The 162 true CND troubleshoots for the FLR are actions over and above the corrective actions that went into computation of the failure clock. If it is determined that they should be included, the clock must be adjusted. Figure 27 shows a total of 1652 R and M actions.

There were 14,386 sorties in this particular data sample. The revised 73A clock is:

$$\frac{14,386}{(1652 + 162)} = 8 \text{ MSBMA}$$

The CND is networked in parallel with the 73A troubleshoot, and of course, leads to no further action. The E probabilities on these troubleshoots are simply:

$$E_{73A} = \frac{1652}{(1652 + 162)} = .92$$

$$E_{CND} = \frac{162}{(1652 + 162)}$$

The preceding CND on other subsystems that were determined from the matrix do not affect the 73A clock. These are simply additional actions in sequence leading to a networked R or M corrective action on 73A. They are shown before the 73A access task as parallel E probabilities. A dummy represents the probability that no prior CND troubleshoot was done. The probabilities are:

$$E_{328X4} = \frac{87}{(1652 + 162)} = .04$$

$$E_{322X1} = \frac{218}{(1652 + 162)} = .09$$

$$E_O = 1.0 - (.04 + .09) = .87$$

These networks are diagramed in Figure 30 and the coding is shown in Figure 31. It is important that prior CNDs be shown in the networks containing the

Figure 30. Schematic of FLR network.

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% YAR	Distr. Type	N AFSC/AGE	N AFSC/AGE	N AFSC/AGE
G3A00				H						FORWARD		LØØK	RADAR	APQ126	
G3A01	F	73A00	G3A01	F	7	73A00	0	2	1	02	29	L	1421X3	1D60	1431/X1
G3A02	A	73A00	G3A02	D		73A00	0	2	1		29	L			
G3A02	T	73001	G3A03	E	09	73A00	0	2	1	13	29	L	2322X1	1D60	
G3A02	T	73A004	G3A03	E	04	73A00	0	2	1	13	29	L	2328X4	1D60	
G3A03	T	73A000	G3A03	E	87	73A00	0	2	1		29	L			
G3A03	X	73A00	G3A04	D		73A00	0	2	1	05	29	L	1431X1		
G3A04	T	73A00	G3A05	E	92	73A00	0	2	1	10	29	L	2322X1	1D60	
G3A04	T	73A0C		E	08	73A00	0	2	1	13	29	L	2322X1	1D60	
G3A05	R	73A00	G3A06	E	71	73A00	0	2	1	19	29	L	2322X1	1D60	
G3A05	M	73A00	SG	E	27	73A00	0	2	1	9	29	L	2322X1	1D60	
G3A06	SH	SHØP	SG3A00	D		73A00	0	2	1						
		73AE9		H		73A00	0		1	AC RMVL		11AC	73EA	76FF	PC
G3A05	X	73AE11	G3A07	E	02	73A00	0	2	1	17	29	L	2322X1		

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Figure 31. Integrated avionics FLR subsystem network.

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Dist. Type	N	AFSC/AGE
G3A07	X	73AE2	G3AD8	D		73A00	00	2	1	110	29	L	34	31C1
G3A08	X	73AE3	G3AD9	D		73A00	00	2	1	17	29	L	23	28X3
G3A09	R	73AE0	G3A10	D		73A00	00	2	1	18	29	L	23	22X1
G3A10	S	SHOP	IG3AE0	D		73A00	00	2	1					
G3A10	X	73AE4	G3A11	A		73A00	00	2	1	18	29	L	23	22X1
G3A11	V	PRES1	G3A12	D		73A00	00	2	1	30	29	L	24	22X1
G3A12	V	PRES2		D		73A00	00	2	1	240		OC		
		73AE0		H		73A00				AIR NAV MULT INDICATOR				
SG3A00	L	73AE0	IG3AE0	G	022204	73A00	00	23						
IG3AE0	W	73AE0		E	86	73A00	*23	23		46	29	L	23	22X1
IG3AE0	K	73AE0	IG3AE1	E	10	73A00	*23	23		14	29	L	23	22X1
IG3AE0	N	73AE0	IG3AE2	E	04	73A00	*23	23		21	29	L	23	22X1
IG3AE1	P	DEPOT		D		73A00	00	23						
IG3AE2	K	73AE1		D		73A00	00	23		14	29	L	23	22X1

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Figure 31. Integrated avionics FLR subsystem network (continued).

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INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sol. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	VAR %	Dist. Type	N AFSC/AGE	Continuation
IG3AEO	Q	73AEO		D		73A00		2	1					
		73AJO		H						RADAR SET MOUNT				
SG3A00	L	73AJO	IG3AJO	D		73A00		2	3					
IG3A00	N	73AJO		D		73A00	✳	2	3	10	29L	1322X1		
HG3N00	Q	73AJO		D		73A00		2	1					
IG3A00	V	73AJ		D		73A00		2	1	60	29L	2322X1		

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Figure 31. Integrated avionics FLR subsystem network (continued).

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eventual corrective action so that the simulation clocks and frequencies of dispatch are not distorted.

Access problems are peculiar to each design and usually cannot be extrapolated from data on another aircraft. However, this example of an A7D access problem is shown to illustrate the impact a poor design can have, and emphasize the importance of a thorough review of mock ups, prototypes, and test aircraft to highlight and correct any such condition.

The FLR Air Navigation Multiple Indicator, WUC 73AEO, is mounted in the cockpit. There is no difficulty in removing and replacing this indicator. However, there is a small plug behind it that sometimes needs replacement. It does not even have a work unit code. This plug can only be reached if the windshield is removed. Changing windshields is an 11-hour job by three 431C1 Aero Repair Specialists. Before they can do it though, two 322X1s must remove the HUD and two 328X3s must remove the RHAW indicator. After the multiple indicator and plug are changed and all the rest put back together, the 422X1s must do a cabin pressure check. This requires 322X1s to swing out the forward looking radar system so that pressure lines can be hooked up through the nose. After everything is connected, there is a 24 hour cure time for the test. Because of poor access, the failure of one small plug can tie down an aircraft for about two days.

Only two of the nine FLR LRUs are illustrated in Figure 31. The shop entry for the indicator coming off the long access goes directly to the appropriate shop tasks, bypassing the G probability. The NRTS task is followed by a depot turnaround time dummy. The time for this task is set by the program and no extended 11 time entry is required. A task is shown for bench check on return from depot. This task does not appear in MDC data runs. A maintenance concept assumption from the operating command and/or the opinion of experienced technicians should be sought to determine whether such checks ought to be in the data base for a new aircraft.

One more unusual network feature is shown in Figure 31. When the mount breaks or is damaged, the radar set has to be realligned by dry boresighting. This is a six hour job. It is shown in parallel to the Q task following the G probability that determines whether the mount had to be changed.

V. NETWORKS FOR PHASED AND PERIODIC SCHEDULED MAINTENANCE

Phased Inspections

The number and frequency of phases is a policy assumption to be provided by the operating command. Networks for phased inspection work are based on phase procedures for similar aircraft under a similar inspection concept and must be developed through interview with experienced technicians in the field. The inspection work cards are too detailed to network directly and MDC reporting is far too gross. The work done in each phase and the task sequences, times, and crew sizes for each AFSC who has a scheduled task, must

be set out in network form. A linear series of work card tasks by the same crew should be networked as a single task. The simplest phase network would show each specialist crew's work as one task and all these tasks would be shown in parallel. It is not usually so simple since there may be constraints and access requirements among the work by various specialists that must be identified and shown in the network. Any scheduled removals which go to the shop for servicing must also be shown. For example, hydraulic filters are regularly replaced and sent to the shop for clearning, generating a task workload in the hydraulics shop.

The phase tasks for comparable systems must be carefully reviewed in terms of the new aircraft design and maintenance concepts in order to delete inapplicable tasks, modify others, and add any new tasks. Contractor recommendations, engineering evaluations, opinions of experienced maintenance personnel, and operating command policy assumptions need to be sought and considered in making these judgments.

Unscheduled corrective maintenance in phase may be estimated from MDC data on similar systems and subsystems. An MDC run of corrective maintenance in phase is shown in Figure 32. Data are grouped by AFSC to match the way the inspection portions of phase are networked. For each AFSC and work unit code it shows the frequency of R or M corrective actions per phase and the average time per action. The summary also shows manhours per action, which can be converted to average elapsed time by dividing by typical crew size.

Portions of an example phase inspection network are shown in Figure 33. The frequency (e.g., every 100 hours) is scheduled on the Form 20s. The main networks include a phase dummy sortie followed by tasks for aircraft washing and ending with the phase entry node (SPLIT). The phase network follows after the last main network task. It starts with the phase network entry node and an E probability split into the various phases. The examples in Figure 33 show the main network portion, the beginning of the phase network, the beginning of the phase 3 portion, and the 424X0 work in Phase 3.

In coding phase tasks, type task is 3 (scheduled) and priority is 2. The organizational maintenance personnel dedicated to phase are coded 431P1. The recommended task and node naming convention is P action code followed by a sequential task number for inspection tasks, and UNS in columns 12 - 14 followed by a sequential task number for corrective actions. J node numbers may be used, provided that they are a different series than are used in any of the main networks. In the Figure 33 example, numbers under J1000 were used for other main networks, so J1000 and over were reserved for phase.

Unscheduled maintenance can be entered as a single task for each AFSC. This task represents all the corrective work done by that AFSC in one phase. Tasks in flight line unscheduled maintenance networks described in the previous chapter had to be broken out by action type and work unit code to correctly simulate the job frequencies and dispatch

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```
*****  424X  *****

WUC= 11D    CREW= 1    ELAP =  .8HRS.    1. M ACTS    94.3 MMHS    .36 MMH/
WUC= 11D    CREW= 2    ELAP = 2.3HRS.   16. M ACTS
WUC= 11D    CREW= 3    ELAP = 3.4HRS.    2. M ACTS
        .36 MMH/NO. OF PHASES    .07 1A/NO. OF PHASES                FOR
WUC= 46A    CREW= 2    ELAP = 2.0HRS.    2. R ACTS    53.8 MMHS    .13 MMH/
WUC= 46A    CREW= 4    ELAP = 6.5HRS.    1. R ACTS
        .13 MMH/NO. OF PHASES    .01 1A/NO. OF PHASES                FOR
WUC= 46B    CREW= 1    ELAP = 1.0HRS.    2. M ACTS    71.3 MMHS    .27 MMH/
WUC= 46B    CREW= 2    ELAP = 1.7HRS.    9. M ACTS
WUC= 46B    CREW= 3    ELAP = 8.3HRS.    1. M ACTS
WUC= 46B    CREW= 4    ELAP = 5.3HRS.    1. M ACTS
WUC= 46B    CREW= 1    ELAP = 1.0HRS.    2. R ACTS    15.6 MMHS    .06 MMH/
WUC= 46B    CREW= 2    ELAF = 1.4HRS.    5. R ACTS
WUC= 46B    CREW= 1    ELAP = 1.0HRS.    1. V ACTS     3.0 MMHS    .01 MMH/
WUC= 46B    CREW= 2    ELAP = 1.0HRS.    1. V ACTS
WUC= 46B    CREW= 2    ELAP = 1.4HRS.    2. T ACTS     5.6 MMHS    .02 MMH/
        .37 MMH/NO. OF PHASES    .08 1A/NO. OF PHASES                FOR
WUC= 46E    CREW= 2    ELAP = 4.4HRS.    2. M ACTS    17.6 MMHS    .07 MMH/
WUC= 46E    CREW= 2    ELAF = 4.1HRS.    2. R ACTS    27.8 MMHS    .11 MMH/
WUC= 46E    CREW= 3    ELAP = 3.8HRS.    1. R ACTS
WUC= 46E    CREW= 2    ELAF = 3.1HRS.    5. V ACTS    31.4 MMHS    .12 MMH/
        .30 MMH/NC. OF PHASES    .02 MA/NO. OF PHASES                FOR
       0.00 MMH/NC. OF PHASES   0.00 MA/NO. OF PHASES                FOR
        1.15 MMH/NO. OF PHASES    .13 MA/NO. OF PHASES    6.4 MMH/MA  FOR AFSC =

**************
```

Figure 32. Data bank printout of AFSC 424X0 unscheduled maintenance in phase.

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Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Dist. Type	N AFSC/AGE	N AFSC/AGE
J1000	Z	Z00000	J1001	H		00010	0			WASH	BEFORE		PHASE	
J1001	JT	JTØWAC	J1002	S		00010	0		11					
J1002	JT	JPREP1	J1003	D		00010	0	32		4	29L	543	/1x/	1TUG
J1003	JT	JWASH1	J1004	D		00010	0	32		10	29L	143	/1x/	1WRACK
J1004	JT	JTØWAC	SPLIT	D		00010	0	32		30	29L	343	/1x/	
				H		PHASE				100	HR	PHASED	INSPECTION	
SPLIT	PT	PT1000	PHAS1	E	.34	PHASE	E	32						
SPLIT	PT	PT1001	PHAS2	E	.33	PHASE	E	32						
SPLIT	PT	PT1002	PHAS3	E	.33	PHASE	E	32						
				H		PHASE				PHASE	3	JACKING &	INV CHK	
PHAS3	P0	P00300	J13000	D		PHASE		32		PHASE	40L	29L	4431P11	3JACK

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Figure 33. Phase network example.

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT	WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	% VAR	Dist. Type	N AFSC/AGE	N AFSC/AGE	Continuation
J1300	P	00301	J1301	D		PHASE	E		32	10		29L	1423x0 3JACK	2B4	
				H		PHASE				PHASE	3	DEPANNEL ACFT			
J1301	P	00302	J1302	D		PHASE	E		32	35		29L	4431 PI 1D60		
				H		PHASE				PHASE	3	WEAPONS RLSE INSP			
J1302	P	00303	J1303	D		PHASE	E		32	30		29L	3462Y0		
J1303	U	NS0012		A	14	PHASE	E		32						
										PHASE	3	ELECT & FUELS INS			
J1302	P	00309	J1315	D	12	PHASE	E		32	10		29L	1423x0 1424x0		
J1315	U	NS007		A	54	PHASE	E		32						
J1315	U	NS0018	J1316	A		PHASE	E		32	32		29L	2424x0		
J1316	S	HØP	SD6A00	A	16	PHASE			32						

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Figure 33. Phase network example (continued).

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of crews to the flight line. This is not necessary for phase since most of the corrective work is generally done by the same dispatched crew in conjunction with their inspection. The corrective maintenance task is shown with an A probability following the inspection. Most phase repairs are on aircraft fixes, but if something does go to the shop, a SHOP dummy task is shown with another A probability.

Assuming all the subsystems listed for the 424X0 fuel specialists in Figure 32 are comparable, a corrective action is required every 18 phases. It takes an average 6.4 manhours, which is equivalent to an average 3.2 hours elapsed time by the typical crew of two indicated in the data. If there were a fuels inspection task in each of the three phases, the corrective maintenance task would follow each 424X0 inspection with an A selection mode and .18 probability. Resources would only be listed to define the task in the first of these three entries. If there were no fuels inspection, it would be shown once from the phase entry node, also with an A selection mode and .18 probability. In this instance, the only fuels inspection is in Phase 3. The corrective task is networked following this task. Since it can never occur on Phases 1 and 2, the appropriate A selection mode parameter is the average number of actions in three phases, or three times .18. Figure 33 shows the task with a .54 probability of occurrence in the third phase.

Most phase corrective actions are on aircraft repairs. The data bank run shows only one in-phase removal rate by 424X0s that is even marginally significant. They reported seven in-phase unscheduled removal actions against subsystem 46B in the 14,386 sortie sample. This is .14 of the 47 total 424X0 in-phase R and M corrective actions. Figure 33 shows a dummy shop task with an A selection mode probability of .14 going into the 46A shop entry node in the unscheduled maintenance networks. The same tasks apply for shop processing regardless of where the item was removed from the aircraft. Scheduled removals in phase that are processed in-shop are networked in a similar manner. The ejection seat an filters are typical examples.

Corrective actions by 431P1s are generally minor repair of seals, gaskets, etc., and are an inherent part of their disassembly, inspection, and reassembly tasks. It is probably more accurate to get a total job estimate from experienced technicians that covers all inspection and repair than to try and break out corrective work with MDC data.

Other Scheduled Inspections and Time Change Items

The lists of 04 inspections in the work unit code manuals, the data bank runs on these inspections, and the data bank runs for scheduled removals should be carefully reviewed for all comparable aircraft. A list of inspections and time changes applicable to the new aircraft must be developed, using these data as a starting point but adjusting for differences in design and maintenance concepts. Contractor recommendations can be helpful if available, but should be verified by Air Force engineers and technicians.

Inspections that occur at calendar intervals may be scheduled on the
Form 20s. Examples are the 45-day corrossion wash for fighter aircraft
of the annual teardown and inspection of the M-61 gatling gun on the A7D.
Only major inspection that tie up an aircraft for half a day or more should
be handled this way. The network does not include a failure clock. It
is entered through a dummy mission in the main network, in the same manner
as shown above for phase.

There are many other scheduled inspections that are done in conjunction
with postflight when they come due. Section III included an example of
gun inspections entered with E probabilities in a main network. This method
is cumbersome except where the inspection is only done after certain kinds
of missions. The more general way is to use scheduled inspection networks
with failure clocks based on the inspection interval. These clocks are
only decremented and interrogated on missions going to postflight. Coding
is similar to unscheduled maintenance networks except that task type is
three, the work unit codes and clock numbers have an S in the last position,
and nodes are six digits starting with X. These conventions avoid any
unintended duplication of nodes or tasks used in unscheduled maintenance.
Two example networks from an A7D model are shown in Figure 34.

Every 50 flight hours the water collection bag on the air conditioner
must be emptied. This is done in 100 hour phase and during a postflight,
half way between phases. The 422X1 technician must remove the water
separater (41AAL) to do this. The whole job is generally coded in MDC as
a removal for access. The postflight check is shown in the network as a
scheduled check every 36 postflights (100 flying hours at 1.8 sortie length
and 50% average successful aircraft turnaround).

The cabin pressure regulator (41BCA) and pressure valve (41BCC) are
replaced every four years (every 550 sorties at peacetime flying rates).
The job requires radar swing-out by 322X1, access removal of armor plate
(11AAL) by a 431X1 crew chief, and a pressure check after the components
are replaced.

The postflight clock values on scheduled tasks must be adjusted when
scenario assumptions are changed.

VI.   BUILDING A DATA BASE

Data Base Processing

The steps in building simulation input files are shown in Figure 35.
In step 1, the extended Forms 11 are keypunched, and after careful checking
to correct coding or key punch errors, they are run into a computer file
called DBASE. These cards and the corresponding DBASE file are the basic
maintenance data base for a system, with all the data pertaining to a single

INPUT No. 2
EXTENDED FORM 11

Prior Node	ACT / WUC	Next Node	Sel. Mode	MSBF or Probability	NCLOK Clock No.	Release	Type Task	Priority	HOURS (Tenths)	*YAR	Distr. Type	N AFSC/AGE
XD1AA0	F41AAS	XD1AA1	H	36	41AAS							
XD1AA1	V41AAS		F		41AAS		31	31	AIR COND	27	29L	WATER COLL CHECK 2422X1
			D		41AAS		31	31				
			H	550	41BCS				CABIN		PRESS	REG, VALVE TC
XD1BC0	F41BCS	XD1BC1	F		41BCS		31	31			29L	
XD1BC1	X41B1S	XD1BC2	D		41BCS		31	31		7	29L	2431X1
XD1BC2	X41B2S	XD1BC3	D		41BCS		31	31		18	29L	2322X1
XD1BC3	R41BCS	XD1BC4	D		41BCS		31	31		25	29L	2422X1
XD1BC4	V41B1S	XD1BC5	D		41BCS		31	31		30	29L	2422X1
XD1BC5	V41B2S		D		41BCS		31	31		240	OC	

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Figure 34. Scheduled maintenance examples.

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Figure 35. Five steps in processing a simulation data base.

1.) EXTENDED FORMS II → DBS → DBASE UPDATE FILE CY=1 → DATA BASE LISTING

2.) EXTENDED FORM II MODS → MOD. DBASE UPDATE FILE CY=1 → P1 → PHASE I DIAGNOSTIC PRINTOUT / MOD DATA BASE LISTING

3.) MOD. DBASE UPDATE FILE CY=1 → P1 → NTWKB COMMON (TEMP) FILE → P2 → FDATA UPDATE FILE CY=2 / AFSC/AGE TASK AND CREW LISTING / LCOM FORMS LISTING / LCOM FORMS 10,13,16 FOR MEN, AGE

4.) ADDITIONAL LCOM FORMS AND/OR MODS → MOD. FDATA UPDATE FILE CY=2 → ZAP WITH LCOM INPUT PROC → LCOM MAINT. INPUT CY=3 / LCOM INP. PROC. DIAGNOSTIC

5.) LCOM FORMS 20 → 20S LCOM INPUT PROC → LCOM OPS INPUT CY=4

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task contained in one record. Once on file they can be readily updated using either a computer terminal or the update procedure described in this section. The basic card deck should still be maintained and kept up to date as a control and backup even though faster computer update methods are used. After the extended Form 11 card deck and DBASE file listing has been checked again and all coding and keypunch errors identified, the corrections are run through the first part of the Phase I program. This is step 2 on Figure 35. The P1 program provides a number of useful diagnostics which may detect additional errors. The procedure of updating the deck and checking diagnostics is repeated until a clean result is obtained.

In step 3 the corrected DBASE file is run through both parts of the Phase I program; programs P1 and P2 translate the extended Form 11 file into LCOM formats and place the translated data an update file called FDATA. P2 also prints out resource data needed to make further additions to the FDATA File.

In step 4 the FDATA file, along with certain additional LCOM input cards and any corrections, is run through the LCOM input processor program. This ZAP run sets up the maintenance data input file for simulation and/or provides further diagnostics. The process of correcting the file, rerunning, and rechecking diagnostics is repeated again until a clean run and output file is obtained. The last step is to run the operations data through the LCOM input processor and check the resulting output file. The form 20 deck is corrected and the process reported until a clean set of operations data is on file.

The programs used in these runs are maintained on "permanent" CDC 6600 system disk files at the ASD Computer Center. They are accessed by the DBS, P1, P2, ZAP, and 206 control decks referred to in Figure 35. Authorized users can obtain these decks from a designated programmer in the ASD Computer Center. The first card of each deck will contain the deck name in Columns 3 - 4 or 3 - 5. The user must also establish a CDC 6600 permanent file location name. This provides for the five cycles in disk storage needed to process the data base and simulation output. The following sections explain the procedures for steps 1 through 5 in detail.

Debugging with Phase I

The extended Form 11 data base may be set up on either an UPDATE permanent file and updated with change cards or be set up on an ordinary permanent file and updated directly from a remote terminal keyboard using EDIT mode. A slightly different version of the P1 deck is required in each case. The procedure described in this section presumes that the UPDATE mode for processing change cards is used.

Step 1 is to put the extended Form 11 card deck on file using the DBS control deck. The user must enter his file location and Cy=1 on the "catalog" control card. One run parameter card is also prepared for the entire run. The format is:

Cols 1-3	Any three digit number (used to identify run)
Cols 4-6	Aircraft (e.g., A-10)
Cols 7-12	Any six digit number (used for run data)
Cols 14-17	X001
Cols 23-24	Pre-flight Decrement (e.g., 04 to decrement .04 sortie)
Cols 29-30	Post-flight Decrement (e.g., 96 to decrement .96 sortie)
Col 32	"2" for constant time distributions, "1" for time distributions and standard deviations specified on extended Forms 11
Cols 34-36	Multiplier on G probabilities (e.g., 010 to increase the probability of a multiple occurrence 10 times over chance). The multiplier can be used to show the impact of sympathetic failure and/or reduce simulation run time.
Cols 38-39	Average time to get resupply from depot in days after NRTS action.

This run parameter card is entered immediately after the deck card, followed by all the extended Form 11 cards in this **sequence:**

    main networks
    phase networks
    scheduled maintenance networks
    corrective maintenance networks in ascending order of clock number

All networks must include appropriate header cards. Carefully check an 80 - 80 listing of the deck to be sure all data and keypunch errors are corrected before entering it into the computer. The DBS run will provide a listing showing each record on file and its DBASE identification number for update. Subsequent corrections and additions can be made through CDC 6600 update by referencing these numbers.

In step 2, the P1 test deck is used to obtain a diagnostic of the DBASE file. The attach and catalog cards in the P1 deck must specify the DBASE file location and Cy=1. The *ID card on the first run should specify MOD1.

The program provides the following error checks and warnings:

a.   Data must be in appropriate numeric format. The system will halt and print an error diagnostic if alpha data appears in any column designated as numeric format.

b.   Action and work unit code on a trailer card must match action and work unit code on the preceding card with C in column 80. If it does not, an error is printed and the record is not processed.

c.   Only selection modes A, B, C, D, E, F, G, S, or X are accepted. If selection mode is omitted, or any other letter used, an error message is printed and the record is not processed.

d.   An A, E, F, or G selection mode must have a non-blank MSBMA or probability value indicated or a warning message is printed.

e.   If a record has an F selection mode, work unit code and clock number must match. If not, an error is printed and the record is not processed.

f.   If the input record specifies any time or resources when repeating a previously defined task, the program prints a warning. This usually indicates that the same task name was inadvertently used to define two distinctly different tasks.

g.   If an asterisk is not found in column 39 for a task with action code W, K, or N the program prints a warning. This does not necessarily indicate an error. There are situations where an N, W, or K card should not have the asterisk, such as bench check on return from depot. The message is a warning to double check and be sure that the omission was intentional.

h.   If sequentially encountered E probabilities in the same network segment do not sum to 1.00, the program prints a warning. This is not necessarily an error. If H cards for nomenclature are inserted within a sequence of E probability tasks it will upset the computer's tally and produce this message. However, any time the message appears the preceding E probabilities should be double checked.

When corrections for all the errors have been determined, the correction cards must be keypunched and entered in another run of the P1 program. This time the *ID card number will be MOD2. Each update run must carry a new ID MOD number. CDC 6600 update allows the user to delete and/or replace individual records in the file without having to reenter the entire card deck. This is done with delete control cards. A delete control card is made up as follows:

Col 1-2   *D
Col 4-   DBASE. XXXX
where XXX is the left justified DBASE identification number of
the record to be deleted.

The replacement card or cards, if any, follow right after the delete control card. A series of adjacent records may be deleted with one control card specifying the first and last numbers of the sequence. For example, the control card to delete records 95, 96, 97, 98, 99, 100, and 101 would be:

*D DBASE.95, DBASE.101

It would be followed by any replacement cards. Cards can be added to the fil without any deletions by specifying *I instead of *D on the control card and indicating the number of the record the insertion is to follow.

Each P1 run produces a revised listing of the file. Changes are identified with MOD numbers instead of DBASE numbers. If an error was made in MOD2 and it was to be fixed in the MOD3 run, the delete control card in the MOD3 run would be:

*D MOD2.XX
where: XX is the indicated MOD2 identification number.

The corrected record would be placed in the P1 deck immediately after this control card. An example setup of P1 control cards and changes is shown in Figure 36.

The P1 run is repeated with change cards and a new MOD number until the diagnostic output and careful checking of the deck show no further corrections are required.

Translation into LCOM

When the P1 output is free of errors, the full Phase I can be processed (step 3). The P1 and P2 decks are submitted together as a dependency run and the COMMON card is included in the P1 deck. The P1 deck also requires a new MOD number even though no change cards are entered. The catalog card in P2 must specify the file location and CY=2 for the FDATA file that will be created. Outputs from this run include a listing of the new FDATA file or records translated into LCOM format and a sorted list of all AFSCs and AGE identifying crew sizes and the tasks they perform. A complete LCOM input processor file must contain the following kinds of records in the order listed:

LCOM 10 cards specifying report column headings for the simulation output
LCOM 13 cards specifying the number and type of aircraft, types of AFSCs, types and quantities of AGE, types and initial stock of spares, and all failure clock distributions
LCOM 12 cards defining each task
LCOM 11 cards defining network sequence
LCOM 14 cards defining which failure clocks are advanced by which DCRMT tasks and the amount of advance
LCOM 16 cards giving shift policy and shift manning by AFSC
LCOM 18 cards giving priority and decision rule parameters
99999 card to signify the end of input

All of these data are not included on the initial FDATA file produced from the Phase I program, as indicated in Figure 37. The FDATA file will have LCOM 10 cards specifying the first 99 LRUs as report column headings and placing the rest in "other"; LCOM 13 cards for all clocks and spares, with an initial spare level of 100; LCOM 12 cards for each unique task; LCOM 11 cards for each DBASE extended Form 11 task entry; and three sets of 14 cards specifying clock decrement values taken from the DBASE run parameter

PUNCH CARD TRANSCRIPT

1-5	columns		
*ID	MØD3		
*D	DBASE.4		
*D	J0001 CALLL3 J0002 C	00010 31	
*I	DBASE.7		
	CALLL3 HCØDES D	00010 31	02 29L 2328X0
*D	DBASE.985,DBASE.1012		
*D	DBASE.2103		
	G4A04 X74ACO G4A11 D	11 74A00 21	12 29L 3462X0
	G4A11 R74AEO G4A12 E	74A00 21	17 29L 3462X0
	G4A12 SHØP D	74A00 21	

Figure 36. Sample DBASE corrections using update.

REQUIRED FOR INPUT PROCESSOR	PRODUCED BY PHASE I	SUPPLEMENTED IN ZAP RUN
LCOM Forms 10	Forms 10 for Spares	Forms 10 for Reports, Missions, Aircraft, AFSCS*, AGE*
LCOM Forms 13	Forms 13 for Spares and Clocks	Forms 13 for Aircraft, AFSCS*, AGE*
LCOM Forms 12	All	—
LCOM Forms 11	All, with every unscheduled maintenance network connected to CALLS1	Modifications to reconnect unscheduled maintenance networks to be called from main network tasks other than CALLS1
LCOM Forms 14	Three sets with decrementing task not specified	Modifications to specify decrementing task and delete records not needed
LCOM Forms 16	—	All*
LCOM Forms 17	—	All
LCOM Forms 18	—	All
9999 End Card	—	Yes

* Cards that can be used for supplementing are produced in Phase I

Figure 37. LCOM input processor file.

99

card. The exact translations performed by the Phase I program detailed in AFHRL-TR-74-97(IV). The LCOM forms are described in detail in the LCOM users guide (Drake et el., 1970).

Building an LCOM Input File

The supplemental LCOM inputs are set up in update format and entered into FDATA with the ZAP control deck. The update control cards are prepared as shown in paragraph above, except that FDATA numbers are specified instead of DBASE. The changes are described as follows in their order of entry in the ZAP deck. Sample entries are illustrated in Figure 38. Format for the LCOM 10 series cards is shown in Figure 39. The required entries are:

10 01   Card giving the initial report cycle and summary report frequency. Enter 30D in columns 8 - 10 and 4 in column 14. These parameters can be changed later through the simulation run control deck.

10 02   Card specifying the number of mission names listed on the Forms 17. (Form 17 preparation was explained earlier in Section II of this report.)

10 03   Card(s) specifying all the mission names listed on the Forms 17. Each mission name must be entered in the report column heading field that was indicated for it in columns 12 - 13 of the Form 17. Dummy missions are included. If more than ten names need to be entered, a second card is prepared in the same format but represents report column headings 11 - 20. A third card would be used to enter report column headings 21 - 30, etc.

10 04   Card specifying the number of aircraft types (usually 1)

10 05   Card specifying the aircraft name in columns 7 - 12.

10 06   Card listing the number of different AFSCs found on the AFSC/AGE printout from step 3. This card is punched out by the P2 program.

10 07   Card(s) naming each AFSC found on the AFSC/AGE printout from step 3. Additional cards in the same format can be used for entries under column headings 11 - 20, 21 - 30, etc. These cards are punched out by the P2 program but the user may want to alter the order in which AFSCs appear.

The 10 08 and 10 09 cards are already in the FDATA deck. Only the first 99 LRUs are listed and the rest covered under "other." If different LRUs are to be displayed, appropriate changes should be made with *D cards at this point. Comparable changes must then be made in the 13 cards discussed later in this section.

The rest of the 10 cards are entered after the last 10 09 card in FDATA using a *I UPDATE control card. They are:

100

THE REPORTING CYCLE TIME IS [07|08|09|10]. EVERY [13|14] CYCLES, A SUMMARY REPORT IS PRODUCED.

[04|05] [0|1]

IN THE OPERATIONS AREA, MISSIONS ARE IN [07|08] CATEGORIES.

[04|05] [0|2]

THE COLUMN HEADINGS FOR EACH CATEGORY ARE:

[04|05] [0|3]

FOR AIRCRAFT, THERE ARE [07|08] GROUPS.

[04|05] [0|4]

THE APPROPRIATE COLUMN HEADINGS ARE:

[04|05] [0|5]

IN THE MAINTENANCE AREA, SHOPS ARE IN [07|08] GROUPS.

[04|05] [0|6]

THE COLUMN HEADINGS FOR THE RESPECTIVE GROUPS ARE:

[04|05] [0|7]

SUPPLY STATISTICS ARE ACCUMULATED IN [07|08] CATEGORIES.

[04|05] [0|8]

COLUMN HEADINGS FOR THESE CATEGORIES ARE:

[04|05] [0|9]

EQUIPMENT ITEMS ARE DIVIDED INTO [07|08] CATEGORIES.

[04|05] [1|0]

THE APPROPRIATE COLUMN HEADINGS ARE:

[04|05] [1|1]

Figure 38. Format for LCOM 10 cards.

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PUNCH CARD TRANSCRIPT

1 2 3	4 5 6	7 8 9 10	11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 ...
*ID	MØD	-1	
*I	FDATA	.R	
	1001	30D	4
	1002	9	
	1003	DCM3	AGAT3BFCAS4〰 AGAT4 TRNG4 PRFLT PHASECCWAS:HHANGAR
*I	FDATA	.-14	
	13	A7D	I 〰 72 1
*D	FDATA	.2838	B3AD00 F
	11	CALLS9	
*D	FDATA	.4484,	FDATA.4559
	14	DCRMT3	C F74A00 1.00

AF FORM 1530
FEB 67

PREVIOUS EDITIONS OF THIS FORM WILL BE USED
UNTIL STOCK IS EXHAUSTED.

AFLC–WPAFB–JAN 74 500

Figure 39. Sample update entries to supplement an FDATA file.

10 10　　Card specifying the number of different AGE items found on the AFSC/AGE printout from step 3. This card is punched out by the P2 program.

10 11　　Card(s) naming each type of AGE equipment found on the AFSC/AGE printout from step 3. Additional cards in the same format can be used for entries under column headings 11 - 20, 21 - 30, etc. These cards are punched out by the P2 program.

The 13 cards defining resource variables for aircraft, men, and AGE are entered immediately after the 13 header card in the FDATA run, using a *I UPDATE control card.

A 13 card must be entered for the aircraft. Column 12 is I, and the aircraft name is specified in field 5 - 10 exactly as it was entered on the Forms 20. The number of aircraft in the simulated organization is entered in field 24 - 27. This may be modified later in the simulation run.

A 13 card must be entered for each AFSC listed in the AFSC/AGE print-out from step 3. The AFSC is entered in columns 06 - 10, column 12 resource type is M, and the report column heading set up in the Forms 10 07 above is entered in columns 14 - 15. The rest of the card is normally left blank. However, if one AFSC can always substitute for another it can be entered in columns 30 - 34. Substitute resources should be used with caution. A set of cards without substitute resources is punched out by the P2 program.

A 13 card must be entered for each AGE type listed on the AFSC/AGE printout from step 3. The AGE title is entered in field 06 - 10 exactly as it appears on the listing from step 3. Resource type in column 12 is A, report column in columns 14 - 15 is as specified on the Form 10 above. A set of cards with authorized quantity initially set at 100 in columns 32 - 34 is punched out by the P2 program. Resource quantities can be adjusted later in the simulation run deck.

The FDATA file already contains 13 cards for the clocks (C cards) and LRU spares (P cards). The P cards should be changed for duplication, and any duplicate eliminated with a *D UPDATE control card. If the LRU report columns in the Form 10 were changed above, comparable changes must be made in the Form 13 P decks using *D UPDATE control cards. The initial spare levels are automatically set to 100, but these can be adjusted later in the simulation run deck.

The next modifications that may be required are in the LCOM 11 cards. The Phase I program automatically chains all F tasks back to CALLS1 through a three digit numeric dummy mode. In some situations, call tasks other than CALLS1 may have been set up in the networks to handle conflicting maintenance contingencies. In the examples shown in Section III, CALLS9 and CALLS 8 represented the CALL tasks for engine maintenance and for landing

gear maintenance requiring jacking. The F tasks that are to be called from these specific CALL tasks must have the connecting 11 card that was created by Phase I deleted, and a card connecting it to the correct CALL section substituted. The record to be deleted will show a three digit number in columns 8 - 10, columns 11 - 18 will blank, and the prior node of the F task that needs to be reconnected will appear in columns 20 - 24. The record is deleted with a *D update control card and an 11 card in the following format entered in its place:

Col 2 - 3   11
Col 5 - 10   Name of call task desired
Col 20 - 24   Prior node of the F task to be called from the call task
               specified in columns 5 - 10
Col 26   F

A connecting card change must be made for every clock that is to be called from a main network call section other than CALLS1.

The next set of changes is made to the LCOM 14 cards. These cards specify which clocks are to be advanced and by how much of a sortie each is to be advanced when a specific DCRMT task is processed in a main network. These 14 cards are grouped by DCRMT task. The first 14 card in a group lists the DCRMT task name, a clock it advances, and it is followed by a card for every other clock advanced by the same DCRMT task. These cards specify clock number and advance but do not list the DCRMT task name. After all clocks advanced by the first DCRMT task are listed, the 14 cards for clocks advanced by the second DCRMT task are entered in a similar manner.

The Phase I program creates three series of 14 cards. Each series lists every clock. Two lists have the preflight and postflight decrement advances that were specified on the DBASE run control card, and the third series has a decrement advance of 1.00. The user must enter which main network DCRMT tasks are to advance which clocks, and delete the 14 cards that do not belong with a particular decrement advance. Also, the first 14 card in each list of clock advances must specify that DCRMT task that triggers the advance. The mechanics of the change are to delete the first applicable 14 card in each list and substitute a similar 14 card with the DCRMT task tame added in columns 5 - 10 exactly as it appeared in columns 12 - 17 on the main network extended Form 11.

The procedure is best explained with a specific example. The main network for a ground attack mission shown in Chapter III had a DCRMT1 task for unscheduled maintenance before the sortie, a DCRMT2 task for unscheduled maintenance after the sortie, a DCRMT4 task for scheduled maintenance in postflight, and a DCRMT3 task for unscheduled gun maintenance after a gun mission. If the specified preflight clock advance was .03 and the post-flight advance .97, FDATA will initially show a series of 14 cards with

.03 in columns 24 - 26 for every clock, followed by a series of 14 cards for with .97 in columns 24 - 26 for every clock, followed by a series of 14 cards with 1.00 in columns 23 - 26 for every clock. The *D UPDATE control cards are used to delete all scheduled maintenance and gun clocks from the .03 list. The first unscheduled maintenance clock in the .03 list is also deleted with a *D card and a similar card substituted that has DCRMT2 entered in columns 5 - 10.

The same thing is done with the .97 list, except the new card for the first unscheduled maintenance clock has DCRMT2 in columns 5 - 10. The 1.00 list applies only to the gun and to scheduled maintenance. The 14 card for the first scheduled maintenance task is deleted with a *D card and a similar card substituted that has DCRMT4 entered in columns 5 - 10. The 14 card for all unscheduled maintenance clocks in the 1.00 list are deleted with *D UPDATE control cards. The gun clock 14 card is reentered with DCRMT3 in columns 5 - 10. The end result of the deletions should be a set of 14 cards with clock advance values .03, .97, and 1.00 still in ascending order. A card specifying each DCRMT task is followed by cards for all the clocks decremented by that task.

The optional "PM" program may be used to determine the probability of a maintenance action before and after flight for various values of clock advance. The 13 cards are read from the FDATA file and run through the PM program. A control card specifies five trial clock advance values. The program may be run for the whole aircraft or for individual subsystems. Another optional program is available to read and repunch the 14 cards with new clock advance values. The old 14 cards would then be deleted and new cards entered in a ZAP UPDATE run. The probability decrement value change programs are not usually required, so are not shown in Figure 35. They will be described in a future AFHRL TR.

The final step in building an LCOM simulation input deck is to enter the LCOM 16, 17, 18, and 99999 cards. These follow the last 14 card in the deck and may be entered in a block using a single *I card.

The first LCOM 16 cards specify shift policies. The rest give the initial unconstrained manning for each AFSC entered on a 13 card above. The 16 card entries are as follows:

A header card with 16 in columns 2 - 3
A shift definition card with * in column 5 and the number of hours in each shift starting at midnight. Three eight-hour shifts would be entered with eight in column 17, eight in column 21, and eight in column 25. Two twelve-hour shifts running 0600-1800 would be entered with six in column 17, twelve in columns 20 - 21, and six in column 25. Entry of more complex shift patterns is described in the LCOM Users Guide (Drake et al., 1970, pp 8-15).
A card with R in column 5 and seven in column 25 for a seven day work week.

A card for each AFSC that was listed on a 13 card, giving very high values for totally unconstrained shift manning. The format is AFSC in columns 8 - 12 and number of people in columns 15 - 17, 19 - 21, and 23 - 25. A set of cards with 200 people per shift is punched out by the P2 program.

The LCOM 17 cards were described in Section II. A header card with 17 in columns 2 - 3 and all the 17 cards are inserted at this point.

The LCOM 18 cards specify various simulation parameters. Their correct values are difficult to estimate but they can have subtle but significant effects on the result. When in doubt, the best approach is to render them inoperative. Suggested entries are as follows:

18 header card with 18 in columns 2 - 3

18 04 card with two in column 7, one in column 13, and 0 in column 19. This limits preemptions (stopping a job to task resources for a higher priority job) to two per task for the flightline and one per task for phase.

18 06 card with .48 in columns 7 - 9, 13 - 15, and 19 - 21. This limits maximum overtime at the end of a shift to just under half an hours. If it is a half hour or more, it distorts the matrix output discussed in the next chapter.

18 07 card with 50 in columns 8 - 9, 100 in columns 13 - 15, and 100 in columns 19 - 21. These values practically nullify the LCOM option of increasing priority in proportion to delay, and force the program to follow the established AFM 66-1 priorities.

18 08 card with .99 in columns 7 - 9. This practically nullifies the LCOM option of shortening task times when delays occur.

The final card entered in the ZAP UPDATE run in an LCOM end card with 99999 in columns 1 - 5. The ZAP control deck must specify the file location name and CY=2 on the UPDATE attach and catalog cards and the file location name and CY=3 on the "TAPE9" catalog card for the LCOM input processor.

The P1 and P2 programs are undergoing continual improvement to produce more of the LCOM input processor deck on the initial FDATA file. Changes to include all 13 and 16 cards in FDATA may be operations in the near future simplifying the above procedure.

Debugging the Input Processor

The LCOM input processor printout from the ZAP run contains several additional diagnostic checks that were not made in Phase I. The first step in checking out the results is to see if the output cataloged in Cycle 3. Then check whether the run ends with the statement, "initialization tape produced." If the tape was not produced, it means the program detected a fatal error. Go through the run, find the diagnostic, and make the necessary corrections.

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Check the listing of deletions and inserts at the beginning of the run to verify that the modifications were made as intended. The printout starts with a listing of input cards. The next list show all records deleted indicated by D on the far right side of the page and the records added indicated by I.

Carefully check each page of the following output for error messages and entries that look out of place. Producing an initialization tape is no guarantee that the data base is completely error free. Some diagnostic messages are not fatal in the input processor but warn of entries that might cause problems in the simulation.

Some SIMSCRIPT initialization data follows the data on changes. This need not be checked. Next are listings of the "Report Specifications" (LCOM 10 cards), "Resource Definitions" (LCOM 13 cards), "Task Resource Requirements" (LCOM 12 cards), and "Task Network-Input Data" (LCOM 11 cards) Some useful diagnostics follow that should be thoroughly checked. The first is titled, "The Following Nodes are Network Entry Points." The list under this heading should contain all the entry nodes listed on the Form 17, plus the call tasks, but nothing else. Any other node listed indicates a networking error. Check the DBASE listing and find why the task record leading to such a node was incorrectly entered in the run. Frequently the cause will be a keypunch error in the node number, such as a letter O instead of zero.

The output, "The Following Nodes are Undefined," lists nodes entered as next nodes on an extended 11, but never as the beginning node of any following tasks. Check the DBASE listing and find out why. Such next nodes are either unnecessary or should be leading to something.

"The Following Nodes are Multiply Referenced," is followed by a list of all the nodes that have more than one task leading to them. There is nothing wrong with this, but a careful check of each one in DBASE will often disclose an unintended error. They should at least be checked out in the first ZAP run.

No tasks should appear under, "The Following Tasks are Constrained." This refers to use of the B selection mode not previously mentioned in this report. The B was not recommended because it can only be used in restricted situations without introducing errors. Both B selection mode and call sections handle parallel task constraints, but the call sections are more generally applicable.

All the nodes leading to more than one task are listed after the heading, "The Following Nodes are Multiply Defined." Multiple definition is common in networking logic and does not indicate any error. The listing of "Resource Clock Decrements" (LCOM 14 cards) should be checked to see that each DCRMT task is listed once and is followed by the list of the clocks it advances and correct amount of advance. After listings of "Shift Policies," (LCOM 16 cards), "Mission Entry Points-Classes," (LCOM

17 cards), and "Priority Specifications" (LCOM 18 cards), there is a list of "Resources Never Referenced," this should only contain the aircraft name. Check anything else in the AFSC/AGE list produced by the P2 program to trace the error.

The next heading is, "The Following Tasks were Not in the Task Network." Anything appearing here other than call tasks indicates an error made in the ZAP UPDATE control cards. After a meaningless list of cost values there are various tables and indexes used in the simulation program; the numbers assigned in the "Resources" list will be an important reference when setting up the simulation run decks. Any resource level changes made at that time must refer to the resource numbers in this index list.

If the input processor contained any errors, go back to step 3 and rerun Phase I with the necessary DBASE correction cards. The part 2 control deck must now include a purge card for CY=2. Most of the same ZAP change cards will be used in rerunning step 4, except that the UPDATE control cards must refer to FDATA identification numbers on the new FDATA run. This same procedure (rerunning steps 3 and 4) is followed for all. UPDATING changes to the data base. The DBASE file serves as the master control deck of maintenance input and model configuration.

Establishing the Operations File

Form 20s are run through the LCOM input processor using the 20s deck with a catalog card specifying the file location and CY-4. The input data preparation was covered in Section II. These data are entered in the following order:

LCOM 15 header card, with 15 in columns 2 - 3 (use only if Form 15 is required)
LCOM Form 15, if required to specify alert mission distributions
LCOM 20 header card, with 20 in columns 2 - 3
LCOM list card, with list in columns 1 - 4, the number of days of operations data to be generated on file specified in columns 5 - 7, and a scenario title starting in column 9.
LCOM Form 20, ordered by day and take-off time within day. Alert missions with a distribution number in the takeoff column are placed at the end of the indicated day. Ordering the Form 20 card input by day is essential or missions will be missed.

A summary table should appear at the end of the 20S LCOM input processor run. It gives missions, sorties, and flying hour totals (including dummies) and breakouts by mission type. Be sure the totals for 20S real missions match the intended program and scenario, and that the proper number of dummies are included. If the Form 20s need to be updated and rerun, a purge card for CY=4 must be included in the 20S deck.

VII. TESTING AND OPERATING THE SIMULATION

LCOM Run Parameters

Before proceeding with this section, it might be useful for the reader to go back and briefly review Section I on how the LCOM program works.

The LCOM simulation control deck MM must include appropriate attach cards to access the maintenance and operations files. The attach TAPE7 card must specify the location and cycle of the operations data file, and the attach TAPE9 card must specify the location cycle of the maintenance input file. If data is to be stored for a matrix program run, the deck must also include a catalog Tape 11 card specifying the location and cycle of an empty output file.

The LCOM parameter cards are placed behind the SIMSCRIPT initialization cards at the end of the control card deck. Formats for all the cards normally required are shown in Figure 40. Additional options are described in the LCOM USERs guide (Drake et al., 1970, pp 8-34).

The RFREQ card specifies the interval in simulated days between performance summary outputs. The RCYC card gives the number of successive reports to be included in an overall summary report. The STOP card specifies the run length in simulated days, plus one tenth. The extra tenth assures that the last day is completed and included in statistical outputs. The SWICH 101 card as shown must always be included in runs with the ASD CDC 6600 LCOM program. The PCT card specifies the factor for increasing the remaining time on a job interrupted for a shift change or a higher priority preemption. Experience with in running several LCOM simulations shows that results can be highly sensitive to this value. The PCT card must be included in every run with a parameter value no greater than 1.05 and no less than 1.00. The 45 card indicates the cutoff time, in hours to takeoff, for starting to process an unprepared aircraft for a mission. Experience indicates that one hour is a reasonable value when simulating operations with tactical fighter bombers. It might be wise to recheck the sensitivity of this parameter if a different kind of aircraft is being simulated. The 47 card releases all ready spare aircraft at the specified interval of days. Ready spares are held for the next mission of the same substitution class. Normally, this parameter should be set to equal or exceed the simulation run length so that it is inoperative. It may be set to release spares at break points where the scenario shifts to a different mission mix. A 47 card must be included in every run.

The AUTH and 46 cards are used to change resource quantities for each iteration of the constraining process. The AUTH card is used to change the number of aircraft, spares, or AGE. The 46 card changes manning by shift. The resource ID number found in the ZAP input processor is used to identify the resource to be changed. The SWICH 123 card turns on output to the matrix tape at the specified time and SWICH 120 turns it off. The manpower and backorder matrices are important tools for the contraining process discussed in Section VIII.

PARAMETER NAME LEFT JUSTIF COLS 1-6	INTEGER VALUE RIGHT JUSTIF COLS 7-12	DECIMAL VALUE DEC PT IN 19 COLS 13-21	ALPHA VALUE COLS 26-31	INTEGER VALUE RIGHT JUSTIF 35-37
RFREQ		INTERVAL		
RCYC	FREQUENCY			
RUN			NAME	
STOP		TIME*		
SWICH	101	0.1		
PCT		1.05		
45		1.0		
47		INTERVAL		
AUTH	RESOURCE ID NO	QUANTITY		
46	RESOURCE ID NO	SHIFT NO		QUANTITY
SWICH	123	TIME*		
SWICH	120	TIME*		
MNSTAT		TIME*		
BOSTAT		TIME*		
ITEM		TIME*		
ISEED	1	SEED		
ISEED	2	SEED		
ISEED	3	SEED		

*TIME entries are in decimal days. The fourth day at 0600 hrs would be entered as 4.25 in Cols 18-21

Figure 40. LCOM run parameters.

The rest of the parameters listed in Figure 40 are only used for debugging, checkout, and **sensitivity tests**. MNSTAT, BOSTAT, and ITEM give detailed "snapshots" of what is going on in the simulation at the specified point in time. MNSTAT provides a mission status output, BOSTAT displays delayed jobs, and ITEM gives the status of all resources. The three seed cards are used with any different numbers between 1 and 99 to alter the sequence of random numbers drawn during model processing.

Test Deck Setup and Checkout

Sections II through VI explained how to develop and check out the individual elements in the simulation data base. These must now be checked out together before proceding with the full simulation runs. A 30 day form 20 file is constructed for the first test. The Form 20 cards up to Day 30 are duplicated with 30 inserted in place of any number of 30 in columns 71 - 73. The 20S deck is then run with these test Form 20s, using a list card specifying 35 days, and set to catalog the file in CY=5. This will put a 37 day schedule on file with scenario missions for 30 days followed by five days with no missions at all.

A 35-day simulation with diagnostics is then run against this schedule. The LCOM control card deck is set up with:

    run time approximately 1,000 seconds
    attach TAPE7 card specifying the file location and CY=5 for the
        test LCOM operations input file
    attach TAPE9 card specifying the file location and CY=3 for the LCOM
        maintenance input file
    no catalog TAPE11 card

The LCOM run parameter cards are set up as shown in Figure 41. This gives a 35 day unconstrained run with reports every five days, a 30 day summary at the end of the flying schedule, mission, resource, and backorder diagnostics on day 21, and again at the end of the last nonflying day.

The operations output on the LCOM performance summary should show at least 98% of all real sorties accomplished and 100% accomplishment of all phases and scheduled inspections. Mission accomplishments should approach 100% for this unconstrained run. Preflights and hangar dummies may have a lower percent accomplished since they are affected by the number of aircraft tied up in long repairs. If these rates are not achieved look at the pattern across each five day period. If the percentages are approximately constant after the first five days, it indicates an operations data problem. If they continue to decline, it indicates a problem in the maintenance input.

The MNSTAT diagnostics are helpful in debugging an operations data problem. Data are shown for each mission in preparation at the time of the report. The type column indicates the aircraft resource ID number. If it is negative, no aircraft is yet available to start processing. Status is 0 if the aircraft is still being prepared and 1 when it is

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PARAMETER NAME LEFT JUSTIF COLS 1-6	INTEGER VALUE RIGHT JUSTIF COLS 7-12	DECIMAL VALUE DEC PT IN 19 COLS 13-21	ALPHA VALUE COLS 26-31
RFREQ	0	5.00	
RCYC	6	0.00	
SWICH	101	0.10	
45	0	1.00	
47	0	36.00	
MNSTAT	0	21.20	
MNSTAT	0	21.30	
MNSTAT	0	21.40	
MNSTAT	0	21.45	
MNSTAT	0	21.55	
MNSTAT	0	21.60	
MNSTAT	0	21.65	
MNSTAT	0	21.65	
ITEM	0	21.75	
ITEM	0	21.45	
BOSTAT	0	21.75	
MNSTAT	0	34.95	
ITEM	0	34.95	
BOSTAT	0	34.95	
PCT	0	1.05	
RUN	0	0.00	TEST
STOP	0	35.10	

Figure 41. Example LCOM test run parameter cards.

ready to takeoff. If aircraft appear to be available and the performance report shows a high percentage of missions but not sorties accomplished, the Form 20 leadtime is probably too short. If aircraft quantity on the 13 card is correct and mission computations check out but aircraft are not available, the schedule may not allow enough time between first flights and turnaround flights.

The resource status and backorder status outputs are useful in debugging network problems. The resource status report shows the number authorized (AUTH), available for assignment (OH), out on jobs (DIB), and needed but not available (DOB). Resources are identified by ID number listed in the ZAP input processor output. The backorder status report shows the resource ID numbers and quantities required for delayed jobs. The job number shown can be traced to a task through the task index in the ZAP input processor output. If a problem is traced to a particular resource and the available quantity (13 card input) is correct, the AFSC/AGE list output from Phase I may be useful to help trace the network tasks causing the problem.

In addition to showing high percentages of sortie accomplishment, the performance summary should not show any unsatisfied demands for personnel or there is a network error. The number of reparable generations for each item in the shop repair summary should equal the number of units demanded for the same item in the supply summary. If not, there is an error in the equivalent relationship required between Q tasks and asterisked W,K, and N tasks for that item. The number of items in repair and backlogged should not show any continuing pattern of increase after the first five days. There should not be any cannibalizations, supply backorders, or unsatisfied supply demands. Any unsatisfied demands for equipment, indicate that an AGE 13 card or network task is in error. The diagnostics for the last day of no flying should show no missions, no resources working or needed, and no jobs delayed in backorder. Anything else indicates a data error.

When all the problems have been analyzed and corrections identified, go back to the DBASE file or supplement to FDATA, as necessary, to make the needed changes. Make sure that any Form 20 changes are made to both the full operations file and 30 day test file. Repeat the process of data base building and simulation checkout from the point corrections were made and get another test run. Continue debugging until an unconstrained simulation is obtained that checks out perfectly in all respects.

Establishing Run Length

Simulation runs must be long enough that results clearly measure the long run effects of input conditions, and not change occurrence of random fluctuations. If the model is rerun with the same input but different random seeds, the conclusions should still be the same. An example of criteria for run length would be that sorties accomplished will vary less then 1%; total wing manhours will vary less than 3%, and manhours for any single work center will not deviate by more than 5% (or by the equivalent

of one man if under 20 people). Run lengths can be shorter if less precision is satisfactory for the specific questions to be answered with the simulation run.

Adequate run length is different for each scenario and maintenance model. It is more a function of processed and sorties flown than simulated days. To compound matters, it can also depend on the degree of constraint. A reasonable procedure is to make an initial unconstrained test to approximate an adequate run length (in simulated days) for running a new LCOM model. Use this length for the first simulation study. When final results are obtained, redo the run length test with the final constrained manning and different random seeds. If the approximated run length was too small, the recheck will provide enough data to correct the results and also establish a better fix on run lengths for subsequent simulations of the same aircraft.

Factor this run length by an inverse ratio of total sorties scheduled when simulating different scenarios or unit sizes. The run length in days for simulating a 24 aircraft squadron must be three times the run length for simulating a 72 aircraft wing flying the same sortie rate.

Run length for the initial unconstrained run length test is estimated by:

$$\text{Run length (days)} = \frac{27,000,000}{\text{Jobs Processed in 30 Days}}$$

The number of jobs processed in 30 days is shown on the last page of the LCOM performance summary from the 30 day test run. The test Form 20s can now be purged and the original deck (with 999 in columns 71 – 73 where appropriate) cataloged in its place using a list card specifying the number of days required for the run length test. The simulation control deck is set up with:

Attached TAPE7 specifying the run length test Form 20 file location **and cycle**
Attach TAPE9 card specifying the LCOM maintenance input file location **and cycle**
· Not catalog TAPE11 card

The LCOM parameter cards are set for:

A performance report every 30 days
A summary every third report
SWICH 101 card
45 card
47 card equal to run length to nearest 30 days
No diagnostics
PCT card
Run name = length
Stop at run length to nearest 30 days plus .1

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Sorties and manhours by AFSC are representative run length criteria. A 30-day whole man equivalent is the number of manhours per month available for direct productive work (e.g., 85.2 in peacetime, 144 in wartime). Any difference less than 144 manhours per month would be less than a man in a wartime scenario. The results from the performance summary are transcribed to a table similar to Figure 42. The differences between various combinations of 30-day periods, 60-day periods, 90-day periods, etc. are calculated. The smallest time period that shows all differences within their respective criteria is selected. Thirty days are added to allow stabilization before taking data. This estimate can then be used to set run length for the first simulation study.

In the example (Constrained run final check) shown in Figure 42, all measured except engine shop manning were within criteria at 90 days. Engine manhour variability is 6% slightly less than or two equivalent men. It was decided that improving precision by one man in one shop was not worth the cost of simulating another 30-day period on each run, so run length was set at 120 days (30 day stabilization + 90 days accumulating data).

Full Simulation with Matrix Output

Figure 43 shows the run sequence for a full simulation. The LCOM program is run for the number of days determined in the run length test. A catalog TAPE11 card specifying a file location and empty cycle is included in the control deck to produce a matrix data file. LCOM parameter cards SWICH 123 and SWICH 120 are used to specify the days matrix data output is turned on and off. These should match the periods of performance summary data that will be analyzed, discarding the first month of data for stabilization. The report frequency specified in the LCOM run deck is the number of work days in a calendar month. Normally, this is equivalent to the number of flying days. For combat simulations, there are 30 days in every month but there may be only 23 work days per month in peacetime.

The MX control deck is run with an ATTACH card specifying the location and cycle of the cataloged matrix file. The program prints matrices show demands and backorders for each AFSC by time of day. These matrices are used in determining manning levels by the methods described in the next section.

The first parameter card at the end of the MX deck is set up as follows:

Cols 2 - 4   Total number of AFSCs as specified on the LCOM 10 06
              card in the input processor file
Cols 5 - 7   Start day of matrix, as indicated on the SWICH 123 card
              in the LCOM simulation run deck. Entered as the nearest
              whole number, right justified, no decimal
Cols 8 - 10   Stop day of matrix, as indicated on the SWICH 120
              card in the LCOM simulation run deck

The rest of the parameter cards for the MX run specify the AFSCs and report columns in the order entered on the LCOM 13 cards. They are entered in eight column block across the entire card. The first five columns of each block give the AFSC and the last two specify report column. For example:

	PERIODS	SCHEDULED SORTIES % FLOWN	TOTAL MAN HRS.	431X1 MAN HRS.	432S0 MAN HRS.	421X2 MAN HRS.	WHOLE MAN EQUIV.
30 DAY PERIODS	1	97.8	106,532	19537	2688	2982	
	2	98.2	100,702	19834	3306	3196	
	3	98.4	103,142	19445	2889	2894	
	4	97.5	105,463	19683	2937	3092	
	5	98.3	105,283	19685	3325	3030	
	6	98.1	107,602	19761	3214	3138	
30 DAY DIFFERENCES	2-1	0.4	5,830	297	618	214	144
	4-3	0.9	2,321	238	48	98	144
	6-5	0.2	2,319	76	111	108	144
60 DAY DIFFERENCES	(65)-(12)		5,651	75	545	10	288
	(65)-(34)		4,280	318	713	182	288
	(34)-(12)		1,371	243	168	192	288
90 DAY DIFFERENCES	(456)-(123)			313	613		432
	(246)-(135)			591	555		432
	(136)-(245)			459	777		432
		WITHIN 1%	WITHIN 3%	WITHIN 5%	* 6%	WITHIN 1 MAN	

Figure 42. Representative extracts from an analysis of run length test data.
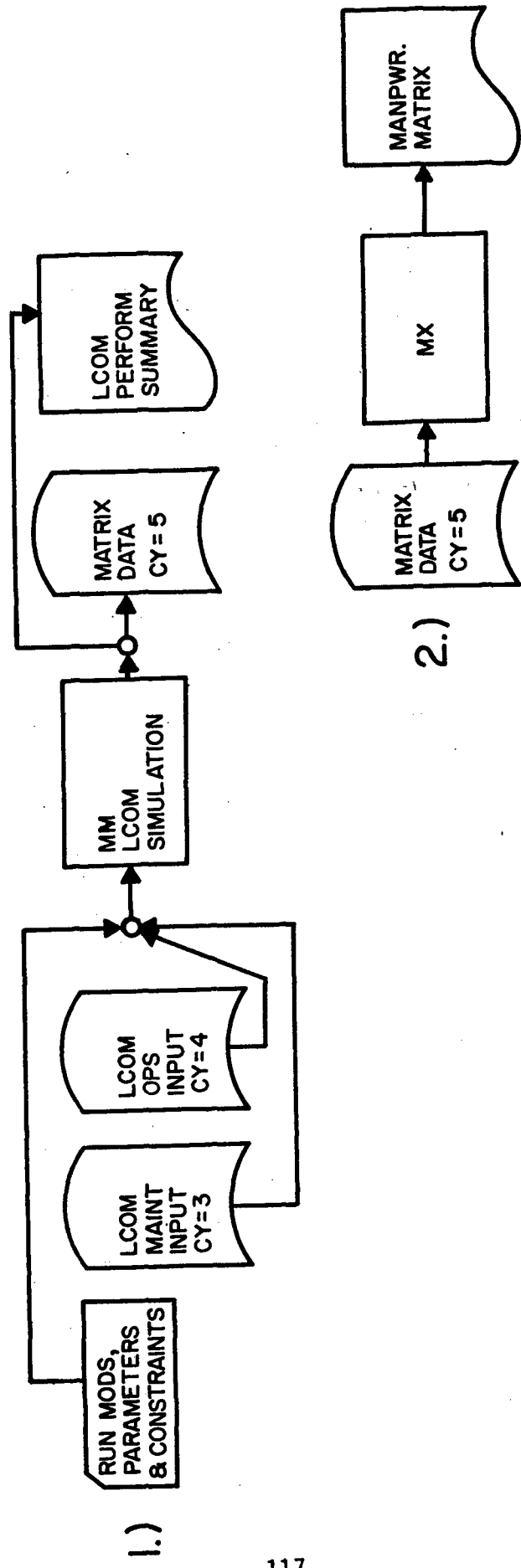
Figure 43. Simulation run sequence.

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```
Cols 1 - 5      First AFSC
Cols 7 - 8      01
Cols 9 - 13     Second AFSC
Cols 15 - 16    02
Etc.
```

additional cards follow specifying report columns 11 - 20, 21 - 30, etc, as needed.

An appropriate version of the matrix program must be used to provide summaries for the assumed shift pattern. The designated ASD programmer can provide a deck to give summaries at 0800, 1600, and 2400 (for eight hour shifts) or at 0600 and 1800 (for 12-hour shifts).

VIII. ITERATIONS TO CONSTRAIN DIRECT MANNING

General Concept and Method

Manning for certain work centers is determined by existing command standards rather than by the simulation. Examples are work centers such as the crash recovery crew, the machine shop, and the personnel equipment shop. These are treated as an overhead requirement in the Moody manpower program (Section IX).

The simulation is used to determine daily manning requirements for those AFSCs and work centers whose workload is generated by aircraft flying, and who report their work against aircraft work unit codes in MDC. This covers the majority of the field and organizational maintenance AFSCs and includes all those with large manning requirements. The daily manning requirement in these work centers is the greater of:

Manning dedicated to fixed posts, such as runway checkers, alert pad crew chiefs, and engine test cell operators. They must spend a full shift at their assigned posts regardless of workload, and are not available for assignment to any other work during that time. They are included in the simulation rather than treated as fixed overhead since their work directly constrains aircraft availability.

Manning to accomplish the number of direct hours of work required on the aircraft and equipment removed from the aircraft.

Manning to cover the minimum crew sizes for every shift on the flight line and at least one shift per day in the shop. For example, if it takes four 432X0s to change an engine, the engine flight line dispatch crew must have at least four people on each active shift.

Manning to meet peak workloads that are essential to accomplish the required flying program.

The sortie rate determines which of the above factors drives the manning requirement for each AFSC under a given maintenance model and set

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of operations and maintenance assumptions. This relationship is illustrated in Figure 44. Post or minimum crew manning must be provided to fly and do the required maintenance at all. It is shown as a horizontal line representing the fixed portion of the manning requirements.

Another independent curve represents the manning equivalent of the direct labor required to service and maintain aircraft. This is a nearly linear function of sorties flown. The increasing slope at high sortie rate represents a certain amount of rework on jobs preempted by higher priority demands. This "PCT" factor was discussed in Section XII. The likelihood of such interference increases with sortie rate.

The third independent curve in Figure 44 represents manning required to meet peak demands for people working at the same time, which if not met will prevent accomplishment of the required flying program. This depends on a number of interacting factors. Indirect work is assumed to be deferable (i.e., can be done in slack periods), and if adequate spares are available, shop work is deferable also. Under an AFM 66-1 concept where flight line and shop work can be done by the same people as needed, these deferable manhours provide a buffer to cover all except the most severe flight line peak demands. The larger the organization, the more random demands average out and the larger the buffer available to absorb them. However, if the flying program is highly irregular with massed flights at particular times of the day; if there are few or no spare LRUs; if the indirect work allowance is small; or if the flight line and shop work are handled by separate cadres; more people may be needed to cover peak demands than are provided to cover the manhours of work at the assumed percentage of direct labor utilization. The slope and shape of this curve depends on the interaction of the various factors involved. It is entirely simulation determined, as discussed in the fourth paragraph of this section.

Computing Daily Requirements

As discussed above, the number of people required per day is the greater of the number needed for post manning, the minimum number needed to voer crew size requirements on each shift, the number needed to accomplish the manhours of work, or the number needed to meet peak workloads. In the initial computations peak workloads are ignored; they are only brought into consideration if manning based on the other factors proves insufficient.

Minimum crew sizes per shift are found on the AFSC/AGE printout that was produced on the Phase I Data Base Translation Run (Section VI). The largest crew required for a flight line task is usually put on every shift. The largest crew required for a shop task (action type N, W, or K) need only be put on one shift if spare LRUs are available and shop work is deferable. Some judgment is necessary in minimum crew assignment. If only one flight line task needs a large crew size, and it is very infrequent, it may be feasible to man only one shift with the large crew size.
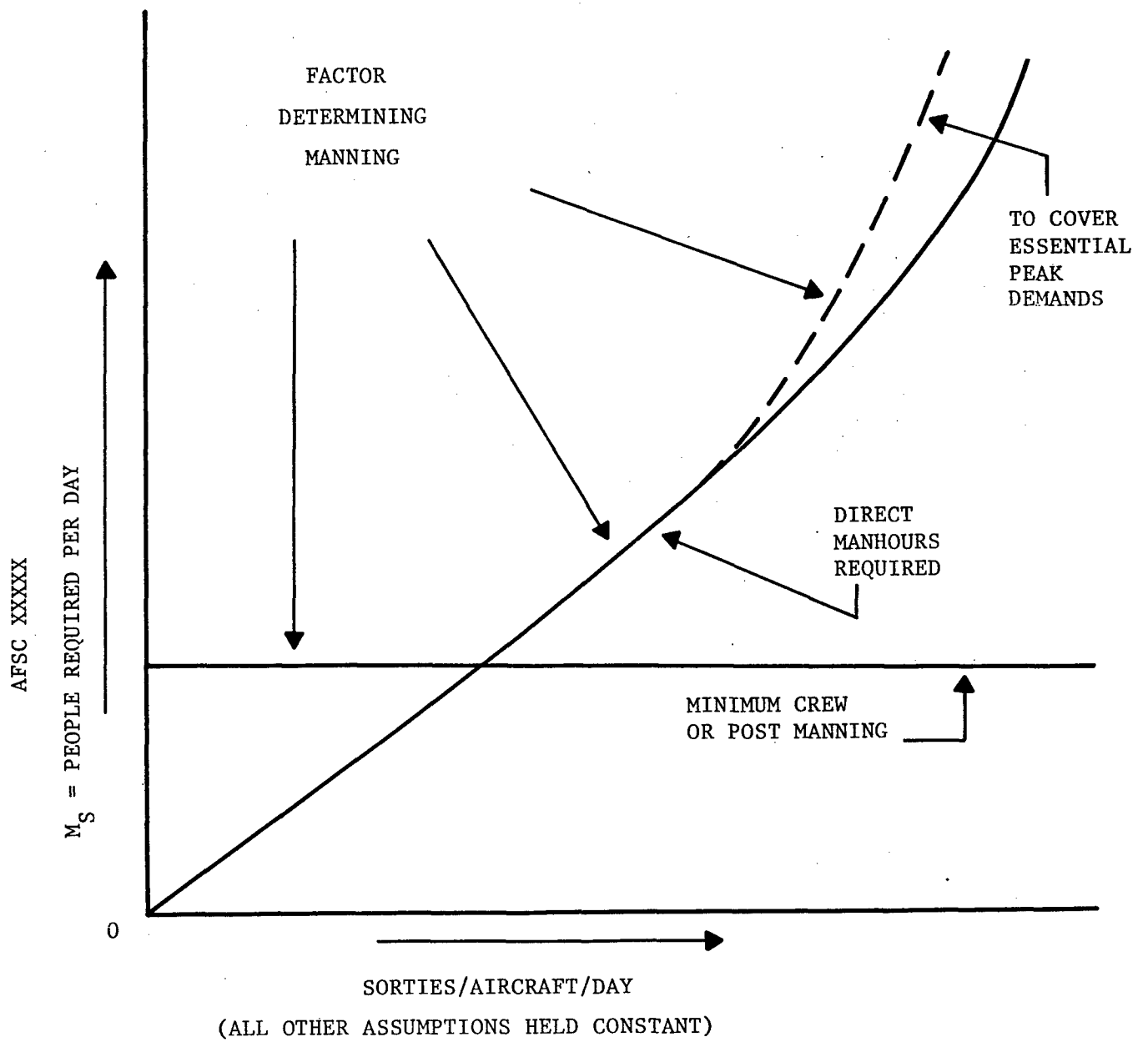
Figure 44. Factors determining daily direct manning requirements for an AFSC.

Post manning is determined by the operations and maintenance assumptions obtained from the using command. End of runway checkers and alert crew chiefs are typically dedicated to post manning. The pilot of the functional check flight may be assigned as post manning for daylight hours only as a way of modeling the constraint that test flights are not done at night.

The daily manning needed to accomplish the required manhours of work on the aircraft and equipment removed from the aircraft depends on the proportion of the maintenance man's available hours that can be used for direct work. Ideally, this is determined by measuring the actual requirement for indirect work and allocating the rest as direct. Lacking such data for new aircraft, the current Air Force AFM 26-3 standard of .60 direct utilization has generally been assumed, but the manning requirements determined can be quite sensitive to this assumption. The operations and maintenance concept obtained from the operating command must define the number of workdays per month and the number and length of shifts per day. The number of people by AFSC that are required per day across all workshifts is:

$$M_s = \frac{\text{Direct Manhours Required/Mo.}}{(\text{Direct Utilization}) \ (\text{Workdays/Mo.}) \ (\text{Shift Length})}$$

Where direct manhours required per month are obtained from the LCOM performance summary. This is the shift loading, not the total manning requirement.

Allocating Daily Manning to Shifts

Where the daily requirement is based on post manning or crew size, the shift allocation is already determined. However, where it is based on manhours of required work, the total number of people per day must be allocated to shifts. This is done with the aid of the work center matrices. These matrices show how the workload for an AFSC varies with the time of day. Separate matrices are provided for flight line and shop work.

The matrix displays the number of times during the simulated period that the number of people shown on the leftmost vertical axis were working at the time of day shown on the horizontal axis. The time is in half hour increments. The cumulative sum of these data over a workshift is shown in a vertical column at the start of that shift.

An example of a flight line matrix for three eight hours shifts is shown in Figure 45. It shows, for instance, that on 10 of the 90 simulated days there were 17 431X1s working at 1000 in the morning during the second shift (number of people working is indicated on the extreme left vertical axis). The greatest demand for 431X1s occurred at 0300 during the first shift. Once on the 90 days, 35 people were required at that time, and the fewest ever required were 15, which also occurred only once. On 12 of the 90 days, 24 431X1s were working at 0300.

$$\frac{(X\%)(No.\ of\ UE\ ACFT)(No.\ of\ 1/2\ Hrs/Day)(No.\ of\ Days)}{(No.\ of\ Work\ Centers)(No.\ of\ Shifts)}$$

$$\frac{(.05)(24)(48)(90)}{18\ \times\ 3} = \frac{5184}{54} = 96\ \text{Ticks Out.}$$

ON EQUIPMENT MANPOWER MATRIX FOR WORK CENTER 431X1   THIS MATRIX COVERS   90 DAYS OF SIMULATION DATA

HOUR OF THE DAY

Figure 45. Work center matrix

The concept for using data in this form was originally suggested by the RAND Corporation (Bell & Stucker, 1971, pp 227-229). The criterion of deferred demands per shift (X) is computed as a function of aircraft available hours using the equation shown on Figure 45. An example computation with x = .05 is illustrated. The closest value not exceeding this computed criterion is located in the summary column for each shift, and a horizontal line drawn below it. The shift **manning** for that criterion is indicated immediately below this line on the extreme left axis. For the example shown in Figure 45 the computed criterion is 96 demands or "ticks." The closest number in the first shift cumulative sum column that does not exceed 96 is 68. A line is drawn below 68 and carried over to the left axis. This indicates a relative shift manning of 26 431X1s.

These matrix results are used to determine the proportion of people to put on each shift. The total number of people to be assigned is determined from the direct manhours of work required, as described in paragraph 2 of this section. For the example shown in Figure 45, the number of 431X1s required per day would be multiplied by 26/65 to determine first shift manning. A little experimentation can often locate an X value that corresponds to the total manning to be allocated, and cuts down the amount of manual computation.

Procedure for Constraining Manning

The simulation is first run with no resource constraints, defaulting to the high resource levels originally set in the input processor on LCOM 13 and 16 cards (Section VI). Work center matrices and monthly manhour requirements are obtained from this run and used to compute the first daily manning constraint, as described in paragraph 3 of this section. These constrained levels of shift manning are punched on 46 cards (Section VII, paragraph 1).

The simulation is rerun with the 46 cards included in the run deck. This time the matrix output will include a set of backorder matrices showing the number of demands not satisfied by time of day. The performance summary from the constrained run is checked to see whether any AFSCs show a higher manhour utilization than the assumed utilization criteria for direct work. If so, the manning must be recalculated based on manhours shown, and the simulation rerun until utilization in all work centers falls within the utilization criteria assumed.

If the real sorties accomplished dropped more than 5% from the unconstrained run, additional people may have to be added in one or two bottleneck work centers to meet the required flying program. The bottleneck candidate is picked from an analysis of the backorder matrix, of percent demands unsatisfied from the performance summary, and the difference between the numbers shown on the matrix and actually manned on shifts during the initial shift allocation. Those work centers with the least buffer of indirect and

deferable shop work are the most likely to be the bottleneck. For a given "X%" criterion, they will show the greatest difference between flight line matrix determined manning and computed manning to accomplish required man-hours of work. The 431X1s are a likely bottleneck candidate since they do not do any shop work.

The bottleneck work center is constrained using the matrix figures rather than the Ms computation to determine daily manning requirements. The simulation is rerun with new 46 cards giving matrix manning for this work center. The other 46 cards are left as is. The process is repeated using different X values for the matrix manning computation until the sortie loss is close to but not exceeding 5% of the unconstrained run. The 46 utilization rate for the other AFSCs is checked and the simulation rerun for any "fine tuning" adjustment on the final manning constraint.

Computing Direct Manning

The number of direct authorizations necessary to provide the required daily shift manning that was determined by constraining the simulation depends on how many hours per month a man is available to work. Additional people may be necessary to provide full coverage of all shifts for the entire month.

The available hours per month to be assumed in manning computations are established by AFM 26-3 standards. Examples are 242 hours per month for sustained combat flying, or 144 hours per month in peacetime. The direct manning requirement for an AFSC is:

$$M = M_S \frac{(\text{Workdays/Mo.}) \ (\text{Shift Length})}{\text{Available Hours/Man/Mo.}}$$

Where Ms = required daily manning determined from the final constrained simulation run rounding off in these computations is done in accordance with AFM 25-5 criteria (1, P 7-8) shown in Figure 46.

Note that with eight hour shifts in a 30 day per month sustained combat situation where the standards are .6 direct work and 242 available hours per month, these factors will cancel out and:

$$M = M_S$$

This is a reasonable set of assumptions for many tactical combat scenarios, and eliminates one step in the manpower computation. However, if shifts are varied to match workload total requirements may change.

Authorized Manpower	Fractional Manpower Cutoff
1	1.077
2	2.154
3	3.231
4	4.308
5	5.385
6	6.462
7	7.539
8	8.616
9	9.693
10	10.770
11	11.847
12	12.924
13	13.999
Over 13	Authorized Manpower +.999

Figure 46. Criteria for rounding in manpower computations.

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Example of Manning Computations

A recommended format for recording and tabulating data is shown in Figure 47. The example illustrated is for a peacetime scenario in which there were 23 flying and maintenance workdays per month with three eight hour shifts per day. The direct utilization criterion was .60 and availability was 142 hours per man per month.

The first column of the tabulation lists the AFSC and the second column gives the resource ID number from the LCOM input processor. This number must appear on the "46" cards for each AFSC. The next three columns give the monthly manhours shown on the LCOM performance summary report for months two, three and four. Note that 23 day months were one of the assumptions of this scenario. Data from the first simulated month is always omitted. The three month manhours are summed and this total divided by 331.2 to get the daily requirement. This figure was obtained by:

$$M_S = \frac{(3 \text{ Mos. LCOM Manhours})}{(3 \text{ Mos.}) \ (.6) \ (23) \ (8)} = \frac{3 \text{ Mos. Manhours}}{331.2}$$

The next column gives the daily total of crew or post manning. The labor of the daily manning columns is used to allocate manning to the three shifts according to the proportion that were shown as an unconstrained matrix program run. Note that daily manning for AFSC 328X3 is determined by crew size rather than manhours.

The computation of direct manning required is:

$$M = M_S \frac{(8) \ (23)}{142} = 1.295 \ Ms$$

This would not normally be done until the final iteration. M_S values to two decimal places are used to avoid rounding twice with the AFM 25-5 criteria. The X column would be checked in the final tabulation if the AFSC were constrained by Matrix to meet peak demand and the M column would indicate the card number for **Moody manpower program input (Section IX).**

IX.   DETERMINING MANNING REQUIREMENTS

Integrating Simulation Results

Manning requirements should be determined with the simulation for three different sets of form 20s, holding everything constant except sortie rate and corresponding flying hours. The results of these runs are then combined in the regression program to produce manhour and/or matrix based manning equations for each work center. These equations are similar to the curves shown in Figure 44, except that the axes are direct manning requirements and flying hours per month. The conversion is equivalent since the manning assumptions and sortie length are held fixed for a given series of runs.

CONSTRAINT # 1

AFSC	Res. Id. No.	LCOM MAN HOURS Day 24-47	Day 47-69	Day 70-92	3 Mos. Total	Daily Manning 3 Mos. Tot. 331.2	Daily Post Manning or Min. Crew	Per Shift Post Manning or Min. Crew	Allocated/Shift 1	2	3	X	Direct= 1.295·Ms Man Hour	Post or Crew	M
322X1	2	4631	4583	4899	14113	(43)	6	2	4	12	27		(55)	8	
325X0	3	742	707	691	2140	(7)	6	2	2	2	3		(9)	8	
325X1	4	2040	2332	2303	6675	(20)	7	2/3	2	8	10		(26)	9	
328X0	5	957	915	841	2713	(8)	6	2	2	2	4		(10)	8	
328X1	6	1223	1066	1196	3485	(10)	6	2	2	4	4		(13)	8	
328X3	7	237	238	150	625	2	(6)	2	2	2	2		2	(8)	
328X4	8	2716	2935	2625	8276	(25)	6	2	2	8	15		(32)	8	

Figure 47. Example of manning constraint tabulation.

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Data from the simulation runs on three scenarios are entered in the following format, one card per AFSC:

Col 5	0
Cols 8-10	intercept (normally zero)
Cols 11-15	flying hrs/mo, scenario #1
Cols 18-20	final direct MHR/matrix manning scenario #1
Cols 21-25	flying hrs/mo, scenario #2
Cols 28-30	final direct MHR/matrix manning, scenario #2
Cols 31-35	flying hrs/mo, scenario #3
Cols 38-40	final direct MHR/matrix manning, scenario #3
Cols 45	0
Cols 48-50	intercept as entered in columns 8-10, normally zero
Cols 51-55	AFSC
Cols 59-60	FC
Cols 61-64	function code
Cols 69-70	minimum crew or post manning direct manning constant
Cols 75	card number for entry into Moody manpower program

The AFSCs entered on these cards are "real" AFSCs corresponding to the work centers defined by the operational command. LCOM AFSCs broken out to distinguish requirements for dedicated cadres or post manning must be combined back together to fit the operating command's function code structure. The minimum crew size requirements and manhour requirements must also be summed when LCOM AFSCs are combined.

If direct manning within any set of LCOM AFSCs being combined was determined on different bases, the post manning or minimum crew size determined direct manning must be added to the manhour determined direct manning, and this total entered as manhour determined direct manning. In this case, the post manning determined direct manning component is entered **instead** of zero as the intercept. For example, LCOM AFSCs 431A1, 431R1, and 431X1 must be combined as 431X1. The direct manning (431X1 manhours, 431R1 and 431A1 post manning) is all summed and entered as manhour determined direct manning for 431X1. The sum of the post manning determined fixed components for 431A1 and 431R1 is entered as the intercept in this case. The fixed component entered for 431X1 is the sum of minimum crew and post manning for 431X1, 431A1, and 431R1.

Parameters and data are put into the RGR control deck in the following order:

a card with zeros in columns 1 and 5
end of file card
data cards for each AFSC, entered in card number order

The regression outputs are a series of punched cards giving work center equations for input to the Moody manpower program, and a printout showing the degree and goodness of fit of these pylonomial regression equations. The run sequence is shown in Figure 48.

Producing a Basic Manpower Authorization Document

The direct manning determined in the various simulation runs and expressed as a regression equation is not a complete manning requirement. All the work centers are not covered by the simulation (Section VIII, paragraph 1). Only direct manning requirements are considered in the simulation but a maintenance organization must include provisions for shop supervision and an administrative staff. Finally, a complete manning document must consider grade levels. The LCOM data base described in this report identifies AFSC by specialty only.

The Moody manpower program is initially set up with standards for work centers not simulated, supervision rates, overhead organization requirements for various unit sizes, and grade spread criteria. This information is obtained from the operating command for the aircraft being simulated. AFHRL-TR-74-97(V) describes how standard data is structured and entered into the manpower program.

To run the Moody manpower program, the user must input a desired flying hour program and unit size, and a matching set of cards that were punched out by the regression program containing direct manning equations and fixed post or crew manning components for each work center. The Moody program then uses the greater of manning from the equation or fixed manning component in each work center, figured at the specified flying hours, as the direct work center manning. It adds in other work centers, at standard, and figures the necessary provision for supervision. After adding in the appropriate overhead structure for the unit size, it figures grade spread. The output is a complete basic authorization document for a maintenance organization, in printout and on punch cards.

The parameter card for a Moody manpower run is prepared in the following format:

Cols 2-6	Flying hours per month for which a manning document is desired (e.g., for a 72 aircraft unit flying a wartime program of 50 hrs/AC/MO, enter 3600)
Cols 7-8	Unit size (e.g., 72 aircraft)
Cols 9-11	AGE manning factor (e.g., 75 spaces per aircraft) as obtained from the operating command. This factor is not used if AGE maintenance is modeled and AGE work center manning is simulated.
Cols 12-13	A format control: +1 = print and punch, 00 = print
Cols 14-16	999
Cols 17-23	Alpha-numeric run title
Cols 24-25	Hours/aircraft/mo (if unclassified, otherwise 00)

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1.)

FLY HRS., DIRECT
MANNING, FIXED
MANNING, BY AFSC → RGR → GOODNESS
OF
FIT

2.)

REGRESSION
EQUATIONS AND
FIXED MANNING

MANNING STDS.
FOR OTHER
WORK CENTERS → MPW → BASIC
AUTHORIZA-
TION

SUPERVISION,
OVERHEAD,
GRADE SPREAD → BASIC
AUTHORIZATION
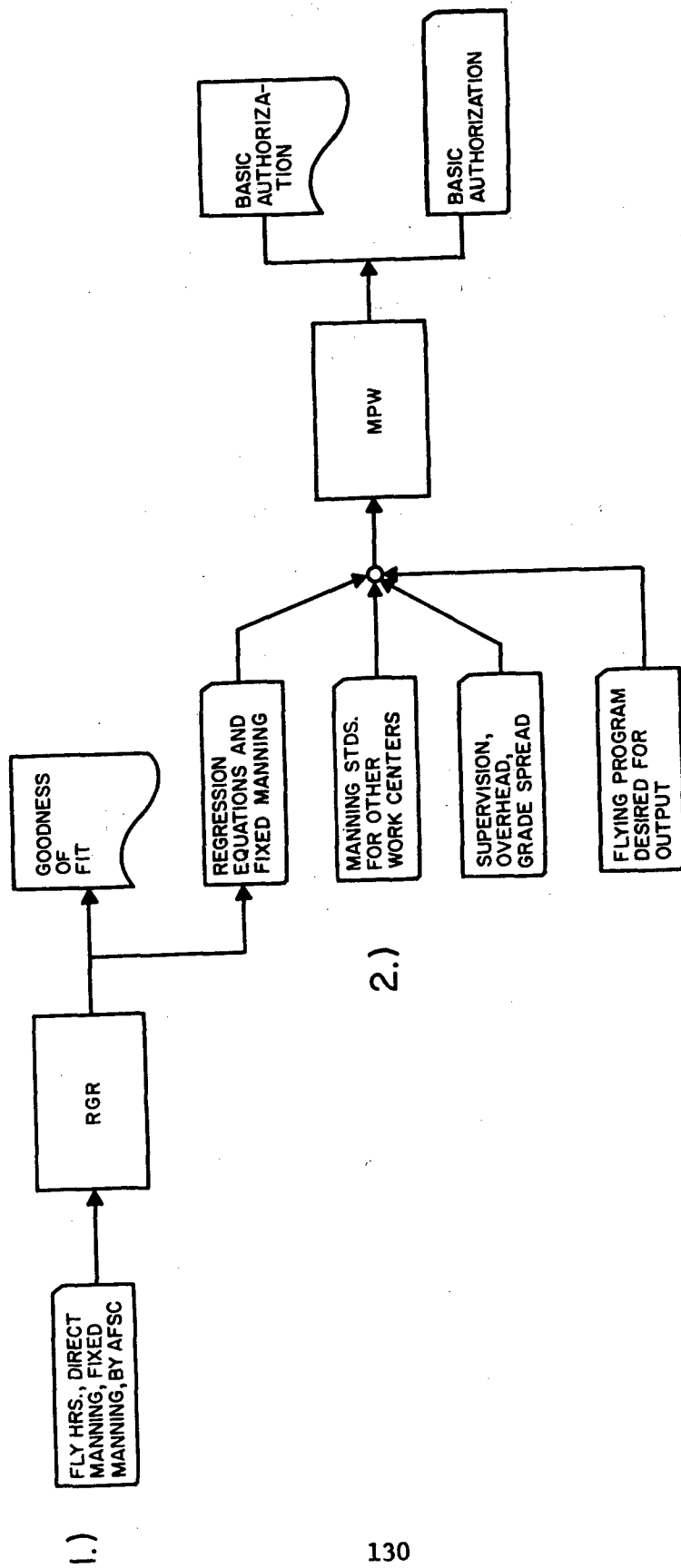
FLYING PROGRAM
DESIRED FOR
OUTPUT

Figure 48. Regression and Moody manpower programs.

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Cols 26-28   Sorties/aircraft/day (if unclassified, otherwise 00)
Cols 29-31   Average sortie length
Cols 31-34   Aircraft MDS

The parameter card is followed by the set of work center regression cards
for appropriate unit size.

To get a full complement of outputs for manpower planning, three flying
hour schedules for each of three different organization sizes should be
simulated. A set of regression cards would then be obtained for each unit
size.

Use of the regression and manpower programs permits manning for a
range of flying programs to be quickly obtained from the simulation of
three consistent points. The simulated hours scheduled or flown on any
of the three do not have to match the flying hour inquiry, but should be in
the same range. The procedure has the further advantage of assuring an
optimum scheduling. The answer for any given scenario can vary with the
percent of aircraft scheduled over and above the target flying program and
the simulation results seldom hit exactly on target. By redefining the
flying hours achieved as the scheduled program for regression program input,
overschedule becomes an output of LCOM and is consistent through the range
of the regression equations.

Variations and Updates

The regression and Moody manpower programs eliminate the need for many
additional expensive simulation runs to determine the impact of alternative
flying programs, provided other scenario assumptions remain constant. A
change in these assumptions does not necessarily require a complete rerun.
The regression program includes an option for proportionate shifting of
direct manning equations based on the simulation of one new point. The
curve continues to pass through the same origin, as shown in Figure 49.

The RGR deck setup for the curve shifting mode is as follows:

Card with 0 in column 1, and three or four in columns to indicate which
    field new data will appear in
Set of AFSC cards with regression equations that were punched out on
    original RGR program run
End of file
A set of AFSC input cards with the third (Columns 21-30) or fourth
    (31-40) data fields changed to show manning and flying hours for
    the new simulated points, as indicated on the first card above

The curve shifting feature is particularly useful for sensitivity
testing, since all results can be brought back to the same baseline. It is
applicable for most changes where manning is determined from the constant or
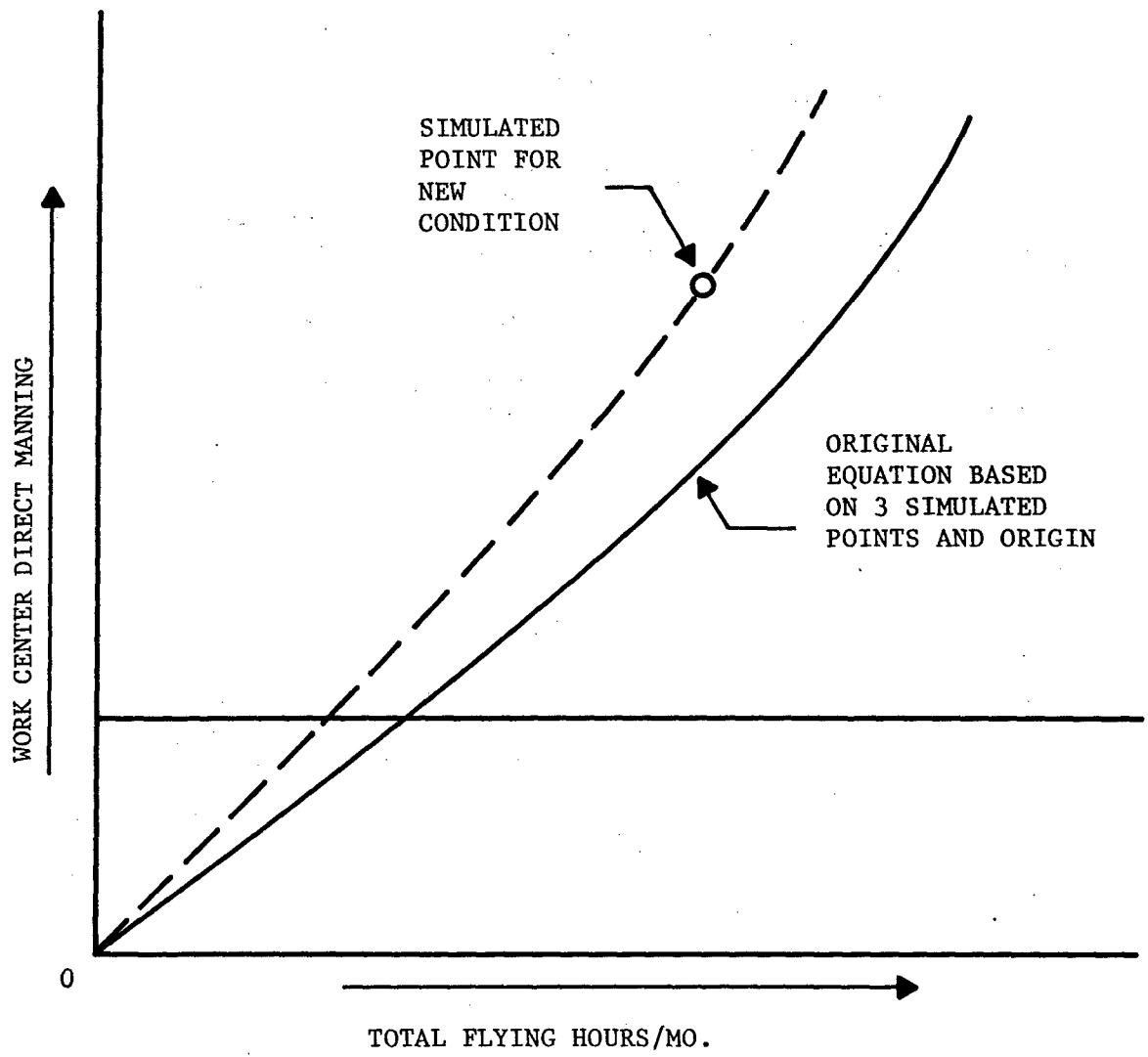manhour derived curves which are known to be nearly linear. It should be

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Figure 49. Curve shifting.

used with caution when extrapolating manning on portions of the curve that are matrix determined, since the general shape of peak demand functions is not yet well defined. Neither does this feature eliminate the need for periodic updates of the whole model.

The method of shifing curves in the regression program is explained in AFHRL-TR-74-97(V).

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LIST OF SYMBOLS AND CODES

LRU: Line replaceable unit

Main Network Types:

     Mode 1 - Preflight to thruflight

     Mode 2   Preflight to postflight

     Mode 3   Thruflight to thruflight

     Mode 4   Thruflight to postflight

Task Codes:

A - Obtain and set up powered AGE.

B - Loading or downloading.

C - CALL Section

D - Decrement failure clocks.

F - Failure clock.

G - Fueling or defueling.

H - Inspections, service, scheduled checks.

J - Aircraft handling and moving.

K - In-shop bench check of LRU, find it serviceable.

L - Dummy task for probabilistic determination of which LRU was removed from a failed subsystem.

M- On-aircraft repair not involving LRU removal.

N - In-shop bench check of LRU, find it broken determine repair can not be made at base level, prepare for shipment and order replacement form depot.

P - Dummy task representing time to obtain replacement LRU from depot.

Q - Draw LRU from base level stock.

R   On-aircraft remove replace of an LRU.

S   Dummy task representing shop entry point.

T   On-aircraft troubleshoot.

V   Inspect or functional check to verify on-aircraft repair.

W   In-shop, bench check and repair LRU.

X   On-aircraft gain access to subsystem and/or LRU.

Z   Fly sortie.

Selection Modes Specifying Network Processiing Logic:

A   Do the task when indicated by a random draw against the specified non-mutually exclusive probability.

C   Do all required task in the defind call section.

D   Do the task.

E   Do the task when indicated by a random draw against the specified mutually exclusive probability.

F   Do the task only when the indicated clock has failed.

G   Do the task when indicated by a random draw against the specified non-mutually exclusive probability, with such draws repeated until at least one task in the set has been selected.

X   Do the task when the following X or F task in the network sequence is to be done (clock within a subsequent call section has failed)

Type Resource Codes:

I - Aircraft

P - Parts

M - Men

A - AGE

Type Task Codes:

    1 - Sortie

    2 - Unscheduled maintenance

    3 - Scheduled maintenance

    4 - Depot repair

    5 - Other