MARINE CORPS AIRCREW SEAT RATIO METHODOLOGY

Naval Warfare Research Center

Final Report

Apr[redacted]78

By: ROBERT S. GARNERO
KENNETH R. AUSICH

Prepared for:

COMMANDANT OF THE MARINE CORPS
HEADQUARTERS MARINE CORPS
WASHINGTON, D.C. 20380
AND
OFFICE OF NAVAL RESEARCH (CODE 230)
DEPARTMENT OF THE NAVY
ARLINGTON, VIRGINIA 22217

CONTRACT N00014-76-C-0963

SRI Project 5411-5

333 Ravenswood Ave.
Menlo Park, California 94025
(415) 326-6200
Cable: STANRES, Menlo Park
TWX: 910-373-1246

SRI International

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
WASHINGTON, D.C. 20380

IN REPLY REFER TO

ASA-22-ibs
3930
1 AUG 1978

From: Commandant of the Marine Corps
To: Distribution List

Subj: Marine Corps Aircrew Seat Ratio Methodology Study

Encl: (1) Study report corrections

1. The subject study was conducted to develop a methodology that analytically produces aircrew seat ratios for use in determining squadron manning for Marine Corps tactical aircraft. Enclosure (1) are corrections to be made to the study report.

2. The objectives of the study were accomplished.

3. The model developed, called CREWMAN, is operational on the Headquarters Marine Corps computer and is utilized by the Department of Aviation (Code ASA).

4. A copy of this letter will be affixed inside the front cover of each of the subject study prior to its distribution.

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DDC (20)
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CMC (Code ASA) (20)
OP-59 (2)

ASA-22-ibs
3930
1 AUG 1978

Subj: Marine Corps Aircrew Seat Ratio Methodology Study Report

Corrections

o page 9 line 10, replace, "maintenance hours per flight hour", with "mean time to repair", lines 13, 17, 20, 26, 27, replace, "MHPFH" with "MTTR"

o page 10 line 4 and 5, replace "MHPFH" with "MTTR" and "maintenance hours per flight hour" with "mean time to repair", lines 8, 12, 13, replace "MHPFH" with "MTTR"

o page 62 line 3, replace "MAINT HR/FLIGHT HR" with "MTTR"

o page B-15, line 18, replace "MAINT HR/FLIGHT HR" with "MTTR"

Enclosure (1)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MARINE CORPS AIRCREW SEAT RATIO METHODOLOGY		5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. S. Garnero and K. R. Ausich		8. CONTRACT OR GRANT NUMBER(s) N00014-76-C-0963
9. PERFORMING ORGANIZATION NAME AND ADDRESS SRI International 333 Ravenswood Avenue Menlo Park, California 94025		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research (Code 230) Department of the Navy Arlington, Virginia 22217		12. REPORT DATE: April 1978 13. NO. OF PAGES: 134
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
14. MONITORING AGENCY NAME & ADDRESS (if diff. from Controlling Office)		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

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)

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

Aircrew Planning	Aircraft Availability
Pilot/Seat Ratio	Aircrew Availability
Air Operations Policy	Sensitivity Analysis

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

This report describes and presents operating instructions for an aircrew management model (CREWMAN). CREWMAN was developed to provide the USMC a methodology that analytically produces aircrew seat ratios for use in determining squadron manning for tactical aircraft. It is constructed so that important parameters affecting the ratio can be examined explicitly and subjected to sensitivity analysis. Aircraft and crew utilization and mission activity are modelled.

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PREFACE

This document is the final report of SRI Research Project No. 5411-5, entitled "Marine Corps Aircrew Seat Ratio Methodology." SRI initiated this four-month study in September 1977 for Headquarters, U.S. Marine Corps under Contract No. N00014-76-C-0963 from the Office of Naval Research. HQMC project management was provided by DC/S for Aviation.

The study followed the approach described in the SRI Research Proposal No. EGU 77-123(R), dated 22 June 1977.

Final results of the SRI research are contained in this document. Included among those results is a complete description and operating instructions for a computer model that was developed as an automated aid for present and future Marine Corps aircrew appropriation planning. That model was delivered to HQMC and exercised on the HQMC computer as part of the study. It is intended for continued use by Marine Corps planners as factors significant to aircrew appropriation change.

I INTRODUCTION

A. Background

In this study, SRI analyzed the factors affecting the numeric allocation of aircrews to Marine Corps squadrons, and developed a computerized simulation model as a planning aid that interrelated those factors. The research was undertaken to improve the effectiveness of previously used methods of estimation, as well as to provide a consistent, easily used, and easily updated computer tool. The model that was generated can be used for each type of fixed- and rotary-wing aircraft squadron in the Marine Corps inventory.

An important consideration in the development of the planning aid was the identification of those factors that have the greatest effect on the aircrew seat ratios. Previous analyses were consulted, and SRI performed additional sensitivity analyses using the newly developed simulation.

Another important consideration was the usability of the computer tool for Marine Corps analysts. It was especially desirable not to have large data input requirements or off-line analysis in support of the tool. Close cooperation was maintained with the Marine Corps sponsor throughout the research to accommodate these objectives.

Following an iterative process, the most relevant parameters were established in the model logic of a computer simulation, called the Crew Management (CREWMAN) Model. The main purpose of the simulation is to provide a consistent routine for estimating operational requirements for aircrew appropriation to effectively man aircraft of various types. The aircrew seat ratio is then defined within the context of the scenario in the simulation as the effective number of aircrews that are required to carry out the postulated missions for given aircraft numbers. Numerous scenario factors and aircrew assignment policy issues are imbedded within the simulation to closely represent actual operations.

This report presents the description of the CREWMAN model and its operating instructions. Section II contains a description of the logic underlying the CREWMAN formulation. Definitions are presented and major logic artifices are introduced. Sections III and IV present user-oriented information for using and interpreting the simulation model by describing the simulation inputs and outputs.

Two appendices complete this report. The first contains a discussion on some of the practicalities and subtleties of using the model that SRI discovered during its test. The second appendix contains a detailed definition of the model structure, program variables, and subroutines. It also contains a complete program listing.

B. Development Philosophy

The CREWMAN model was developed to provide Marine Aviation with a methodology that analytically estimates aircrew seat ratios for all tactical fixed- and rotary-wing aircraft squadrons. It is constructed so that the most important parameters affecting the aircrew seat ratio can be examined explicitly and subjected to sensitivity analyses.

By means of computer simulation, CREWMAN depicts air mission activity, aircraft availability and utilization, and aircrew assignment and utilization in a fashion designed to closely represent actual operations. As developed, CREWMAN provides a flexible, rapid and well-documented analytic estimation technique, but it is not so large or so complex that users are overly burdened with input requirements or difficulties in interpreting results. In fact, ease of use has been stressed at every opportunity where it does not jeopardize the credibility of the results.

CREWMAN simulates the activities of Marine Aviation squadron during a 30-day scenario. Based on a user-defined level of operational activity, air missions are randomly scheduled during day and night periods. Aircrew availability is monitored for assignment to scheduled air missions. Aircraft and aircrew availability is determined on the basis of flight kinematics, management policy regarding assignment of aircrews, and constraints on the availability of aircraft caused by aircraft maintenance and turnaround requirements.

CREWMAN is an event-step simulation. A mission-scheduling algorithm provides the initiating operational activity during each simulated day. To capture the dynamics of both aircraft and aircrew utilization, CREWMAN treats aircraft and aircrews as separate entities. Each is modeled through a description of possible states and events that determine the instantaneous status of any aircraft or aircrew in the scenario. By monitoring these states, the model aggregates activity to provide the summary statistics at the end of the computer exercise.

Use of the CREWMAN model requires a nominal input requirement. The input parameters provide a description of the squadron being examined, the scenario properties, the operations doctrine and the simulation control data. The squadron attributes include a description of squadron unit equipped (U/E) aircraft and maintenance hours per flight hour for both normal and surge conditions. Additional parameters describe whether or not the aircraft is multi-piloted, whether or not the aircraft is pressurized and whether or not the aircraft has an ejection seat. These last three are used in applying OPNAVINST recommendations for maximum flight hours. The scenario properties detail the number of surge, and non-flying days to be included in the analysis and describes an aircraft resupply rate. Attrition variables are created for both aircrew and aircraft. The operations doctine allows a specification of the length of a duty day for an aircrew, brief times, and the density of missions. Specification of mission density allows breakout for daylight and night, and for both air and ground alert classes of missions. The simulation control data include the number of replications desired, a starting random number, and a cutoff figure for crew total flight hours. Crews falling below this cutoff figure are not included in the summary statistics.

Based on the simulation of scenario operations, results are automatically collected and printed as computer output. The output parameters are composed of daily parameters, scenario totals, and multiple run statistics. The daily parameters include an accounting of each day's missions met and missed, each day's loss of aircrews due to combat and administrative policy, and daily aircrew statistics such as average and maximum flight hours and average miscellaneous duty hours. The scenario totals data include an aircrew seat ratio for the scenario, aircrew sorties flown, aircrew total flight hours, and aircrew miscellaneous duty hours. The multiple run statistics include probability distribution information on aircrew ratio and sortie rate for multiple replications of the same scenario.

C. Hardware and Software Requirements

CREWMAN is written in the special purpose simulation language, SIMSCRIPT II.5. This is a versatile programming language designed specifically for discrete-event simulation applications such as CREWMAN. Its special attributes reduce the total time required to design, program, and test simulation models. SIMSCRIPT II.5 is a free-form and English-like programming language, and it provides a number of useful debugging aids.

SIMSCRIPT II.5 is a proprietary language owned by CACI, Inc., Los Angeles, California. For details of its attributes and use, the reader is referred to available literature, especially "SIMSCRIPT II.5 Programming Language" by Kiviat et al.

The minimum hardware requirements to utilize the CREWMAN model include a general purpose computer with a card reader and line printer. The general purpose computer must be able to support a SIMSCRIPT II.5 compiler. Computers currently in this class include the IBM S/360-370, the Honeywell 600/6000, and the CDC 6000 series.

Provided with the compiler by CACI, Inc. is a set of job control procedures that facilitate the use of the model. These procedures are documented in user manuals. Users of CREWMAN will need access to the manual appropriate to his computer system. The use of such a manual in conjunction with a knowledge of the operating system of his computer center will enable the user to execute the CREWMAN model.

D. Purpose of the CREWMAN Description and Operating Instructions

The purpose of this document is to provide all relevant information required to properly exercise the CREWMAN model, in a form that maximizes the utility of this document to a user. The contents of this document satisfy the intent of DoD Instruction 5233.1A of June 1973 concerning documentation of computer programs. All requirements set forth in this instruction that are relevant to the development of CREWMAN, a research activity, have been fulfilled.

Since this document is written for Marine Corps analysts, it is assumed that the user has a thorough understanding of the Marine Corps aviation systems, procedures, terminology, and requirements in the amphibious planning environment. Use of this document does not require a technical data processing background. However, a general knowledge of the basic principles of data processing is most desirable.

In this document, a general framework for the model is first developed along with the identification of concepts that will be referred to throughout the text. Next, a section is devoted to describing each major subroutine utilized by CREWMAN. These subroutines are called events, and represent discrete points in time at which the state of a given aircraft or aircrew changes. A look at each of these events should illuminate all the salient features of the model and the logic used in interleaving the basic simulated activities. Macro flowcharts accompany each of these descriptions.

Next, each of the inputs to CREWMAN is defined and instructions for preparing input data are provided. Finally, the simulation results are discussed.

For the user interested in a precise description of the model, Appendix B has been produced to define explicitly the model structure, list the program variables and subroutines, and provide a complete program listing.

II SIMULATION MODEL LOGIC DESCRIPTION

A. General Framework

Combat air operations performed by Marine Corps squadrons involve a complex and dynamic set of activities. These activities include mission scheduling, aircraft assignment, aircraft maintenance policy, aircrew duty, aircrew flight scheduling, aircrew rest policy, and so on. The complexity of these activities results from strong interactions among them, as well as from significant interactions with the combat environment.

SRI's research to develop an aircrew seat ratio methodology was faced, therefore, with the problem of modeling these activities in a logical and tractable manner. Several abstractions of real-world activity, along with some simplifying assumptions, were required to achieve this objective. An understanding of these artifacts is essential for comprehending the approach of the CREWMAN simulation, so they have been addressed in the remainder of this subsection.

Modeling abstractions have been particularly important in four areas of the CREWMAN formulation:

- Mission designation and scheduling
- Aircraft availability
- Aircrew availability and assignment
- Squadron operations and policy.

Each area is discussed in the following paragraphs.

1. Mission Designation and Scheduling

To avoid excessive user input burdens and the complexity of individually treating each of numerous Marine Corps air missions, the CREWMAN formulation calls for the specification of only two types of missions during each simulation. These are generic missions--one being an air mission and one being a ground alert mission--that are meant to stand for actual missions such as close air support, combat air patrol, interdiction, ground loiter, strip alert, and so on.

As an example, a Marine Corps fighter squadron might be assigned combat air patrol, strike escort, deep interdiction, and strip-launched intercept missions. Under the CREWMAN formulation, these would be compressed into generic air missions and generic ground alert missions. The parameters for the air mission (mission time, number of missions, attrition rate) would be a compromise between parameters associated with the combat air patrol, strike escort, and deep interdiction missions. The parameters for the ground alert mission would, however, closely follow the parameters of the strip-launched intercept mission, since it is the only alert mission considered.

It was judged that this compromise offered substantial benefits for reduced data entry, and it also reduced the difficulty of interpreting simulation results without greatly reducing the effectivness of the CREWMAN model for estimating aircrew seat ratios.

Another simplification used in CREWMAN was the use of a random process to schedule missions during the day. This action was taken to relieve the user from the tedious business of acting as a mission scheduler for the entire scenario. The random process distributes in time a designated number of missions during a designated period (day or night). While the number of requested missions is restricted to be the same each day in the CREWMAN formulation, the occurrence of these missions during the simulation period will differ each day due to the random effect.

Missions may be scheduled in CREWMAN to occur during a daylight period or a night period. In the CREWMAN model each period consists of 12 hours and together these two periods comprise a simulation day. Thirty days complete one simulation exercise.

2. Aircraft Availability

Aircraft availability in the CREWMAN concept is constrained by the number of aircraft that the user specifies as the squadron U/E and by simulated aircraft downtimes. During aircraft downtime an aircraft is unavailable for missions. Aircraft downtime is based on three factors: (1) mission time, (2) maintenance hours per flight hour, and (3) rearm and refuel time. This downtime is applied following each air or ground alert mission. The formulation of this concept is contained in the equation:

$$DT = MT * MHPFH + RR \qquad (1)$$

where

DT = aircraft downtime (hrs)
MT = mission time (hrs)
MHPFH = maintenance hours per flight hour
RR = rearm and refule time (hrs).

During surge conditions (i.e., intense air operations of a short duration) the MHPFH parameter reflects the reduction of preventive maintenance and is allowed to be smaller than that which would occur during normal operations. However, the difference between the parameters is used to create a maintenance backlog, which must be completed at the first opportunity after the surge. To be precise, CREWMAN uses the following two equations for computing downtime for normal and surge conditions, respectively.

$$DT = MT * MHPFH_N + RR + BACKLOG \qquad (2)$$

$$DT = MT * MHPFH_S + RR$$

where

DT = aircraft downtime
MT = mission time
$MHPFH_N$ = normal maintenance hours per flight hour
$MHPFH_S$ = surge maintenance hours per flight hour
RR = rearm and refuel time.

and

$$BACKLOG = MT * (MHPFH_N - MHPFN_S) * \text{number of surge sorties.}$$

A numerical example will help solidify this concept.

Assume:

MT = 1.5 hrs
$MHPFH_N$ = 2.0 hrs
$MHPFH_S$ = 1.0 hrs
RR = 2.0 hrs

During a surge, each sortie will generate a DT = 1.5 * 1.0 + 2.0 = 3.5 and a BACKLOG = 1.5 * (2.0 - 1.0) = 1.5. After, say, three sorties during surge conditions, assume normal operations resume. A backlog of 4.5 hours will have accumulated for the aircraft. After its fourth sortie it will have a DT = 1.5 * 2.0 + 2.0 + 4.5 = 9.5. Every sortie thereafter will have a DT = 1.5 * 2.0 + 2.0 = 5.0. In a modeling sense, a recovery period of reduced air operations will be thus associated with a surge period.

3. Aircrew Availability and Assignment

The number of aircrews that become involved in a CREWMAN simulation is constrained only by the availability of aircrews that have previously been introduced into the scenario. In contrast to the formulation of aircraft availability, the nonavailability of aircrews to meet a requested mission for which an aircraft is ready does not force cancellation of that mission. Rather, at this point, another aircrew is introduced into the scenario, and it remains for the duration of the scenario for subsequent assignment as the situation dictates. In this respect, the aircrews may be thought of as dependent variables whose total number is the subject of study.

Within the scenario itself, aircrews are available for mission assignment only for a certain period each day. This period is referred to as the duty day, or duty hours, and its length is a variable that may be changed by the user. The remainder of the simulation day (24 hours) that is not designated as the on-duty period is taken to represent the length of normal rest that the aircrew is provided.

The duty day consists either of miscellaneous duty (an abstraction of training, administration, or other tasks undertaken by Marine Corps aircrews) or mission assignment. With every mission assignment, there is a pre-mission brief and a post-mission debrief. Aircrews begin their duty day in miscellaneous duty, and are selected for missions as they occur. Since there is no actual mission scheduler, the selection of aircrews to fulfill a given mission is provided for by an algorithm in CREWMAN. The algorithm determines which aircrews are on-duty; which aircrews of those on-duty have sufficient duty time remaining to completely conduct the requested mission; and, finally, which aircrew of those having sufficient duty time remaining is closest to going off-duty.

The latter criteria are intended to maximize the use of the total aircrew resource pool for meeting missions without introducing a new aircrew into the simulation.

Aircrew availability is further influenced by administrative policy regarding the number of flight hours aircrews may be assigned over various periods of time. The basis of the CREWMAN formulation of this aspect of aircrew use is contained in the recommendations of OPNAVINST 3710.7J. These recommendations are summarized in Table 1. CREWMAN invokes these recommendations in the form of a filter that determines the appropriate standard to apply to a particular aircrew based on its flight-time history.

Table 1

FLIGHT TIME ADMINISTRATIVE POLICY

Time Period	Maximum Recommended Individual Flying Time			Maximum Recommended Number of Flights		
	Single-Piloted Aircraft	Multi-Piloted Non-Pressurized Aircraft	Multi-Piloted Pressurized Aircraft	Single-Piloted Aircraft	Multi-Piloted Non-Pressurized Aircraft	Multi-Piloted Pressurized Aircraft
Day (24 hours)	6.5 hr	12 hr	12 hr	2	3	3
Week* (7 days)	30 hr	50 hr	50 hr	---	---	---
Month (30 days)	65 hr	100 hr	120 hr†	---	---	---

*Flight personnel should not be assigned flight duties on more than 6 consecutive days.

†If multi-piloted pressurized aircraft has an ejection seat, this standard is 80 hr.

Source: OPNAVINST 3710.7J

4. Squadron Operations and Policy

Since the purpose of the CREWMAN development was to estimate aircrew seat ratios as the basis for establishing squadron manning requirements, several squadron operational assumptions were incorporated into the methodology. The first is rather obvious from the formulation of the simulation model. That is, the aircrew seat ratios for Marine Corps squadrons are determined through consideration of combat conditions. On the basis of this assumption, such factors as aircraft and aircrew attrition rates were included, as were operational procedures such as surge condicions.

A second major decision concerning the influence of squadron policy on the estimation of aircrew seat ratios was the decision not to consider overhead aircrews, as had at least one other previous major study of the subject. (Overhead aircrews are extra aircrews within the squadron, air group, or wing command structure that have only limited availability for flight assignment because of the requirements of their command-type functions.) The decision not to consider overhead aircrew concepts was based on the fact that overhead aircrews might not always be available since the Marine Corps often would be called on to deploy with less than a full wing structure. In essence, the aircrew requirement must be established for the more demanding cases in which the presence of overhead aircrews could not be guaranteed.

The effect of not considering overhead aircrews is also minimized by the CREWMAN formulation since a portion of the simulation results describe how much each aircrew was used during the scenario. Aircrews that only experience small use during the scenario could be considered as representing the effect of overhead aircrews. A fuller discussion of this aspect of CREWMAN is contained in Appendix A.

B. Simulation Program Framework

The program algorithm framework that exerts an executive control over the activities of the simulated CREWMAN scenario is shown in the form of a flowchart in Figure 1. By means of this framework, data input by the model user is read and interpreted to serve the needs of event schedulers and statistics counters.

C. Model Events

Discussions of the CREWMAN events are presented in the following paragraphs, along with descriptive flowcharts. The integration of these events with allowable aircraft and aircrew states provides the essence of the conceptual logic of the CREWMAN model. Figures 2 and 3 are an overview of that integration.

As shown in Figure 2, the potential aircraft states are defined as:

IDLE	A state in which aircraft are available for mission assignment (that is, they are not down for maintenance and turnaround), but are not as yet assigned to a specific mission
ASSIGNMENT	A state in which aircraft are committed to a specific mission--the duration of that commitment dictated by the mission time
NOT AVAILABLE	A state in which aircraft are unavailable for mission assignment, due to the requirement for maintenance and turnaround following a completed mission

These aircraft states are integrated (along with input/output factors) by the CREWMAN events: NEW.DAY, MISSION, READY, and END.SORTIE.

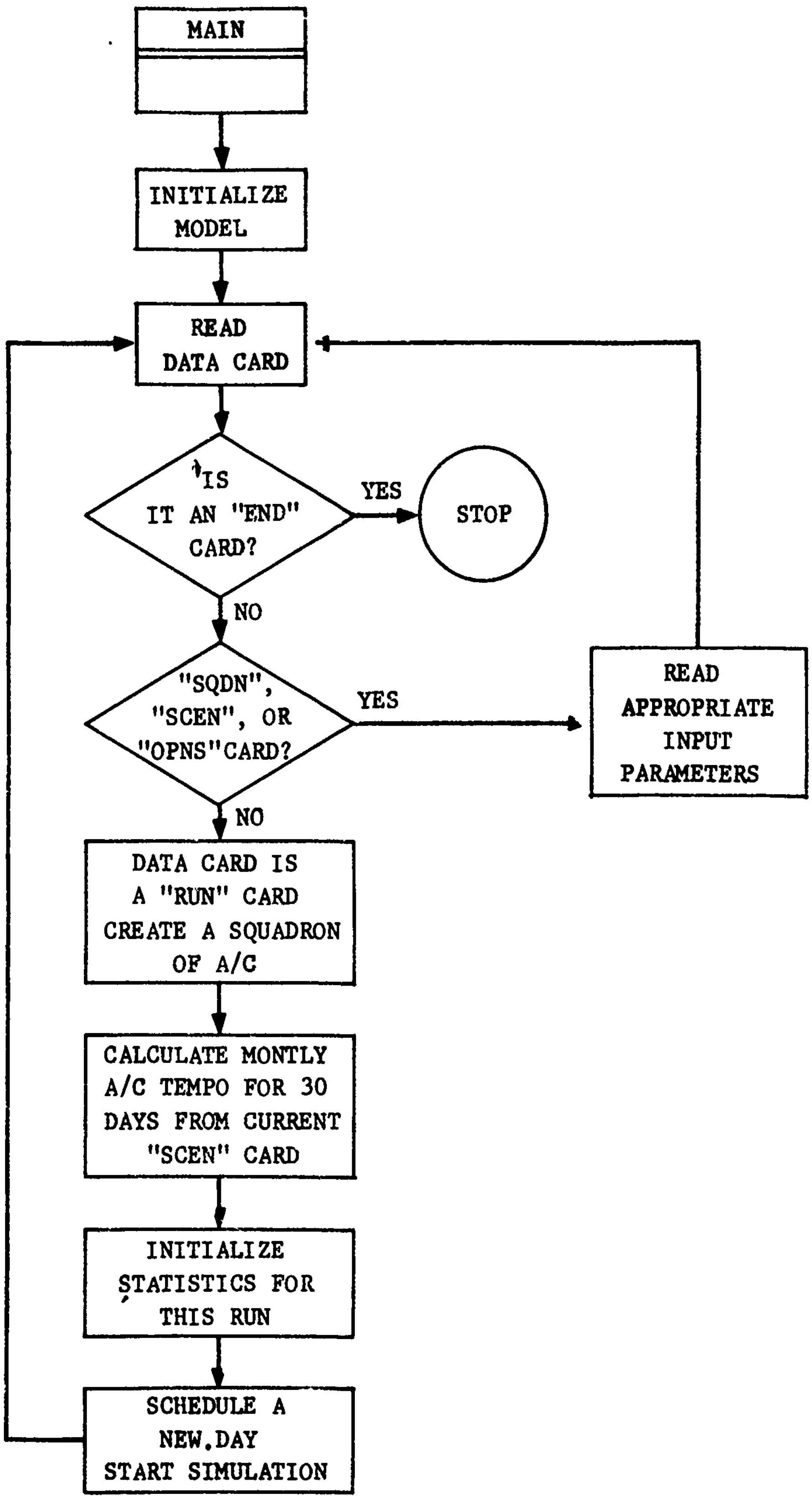

FIGURE 1 MAIN PROGRAM IN CREWMAN

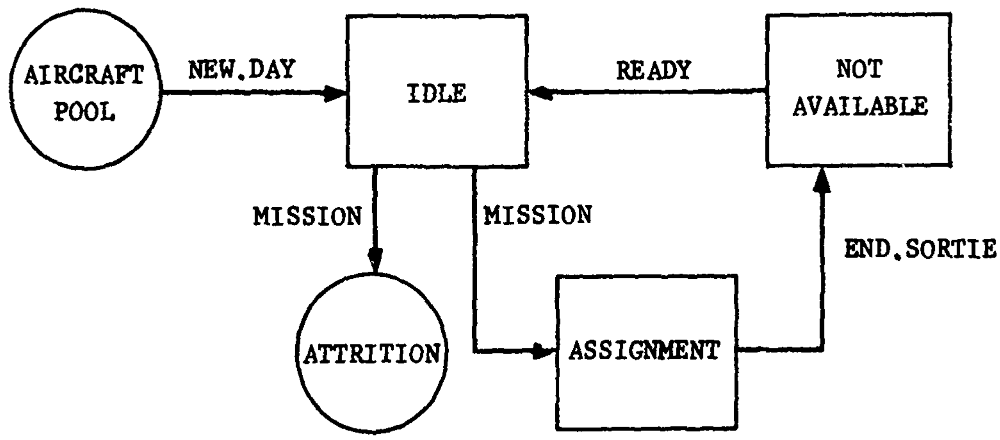

FIGURE 2 AIRCRAFT STATES AND EVENTS IN CREWMAN

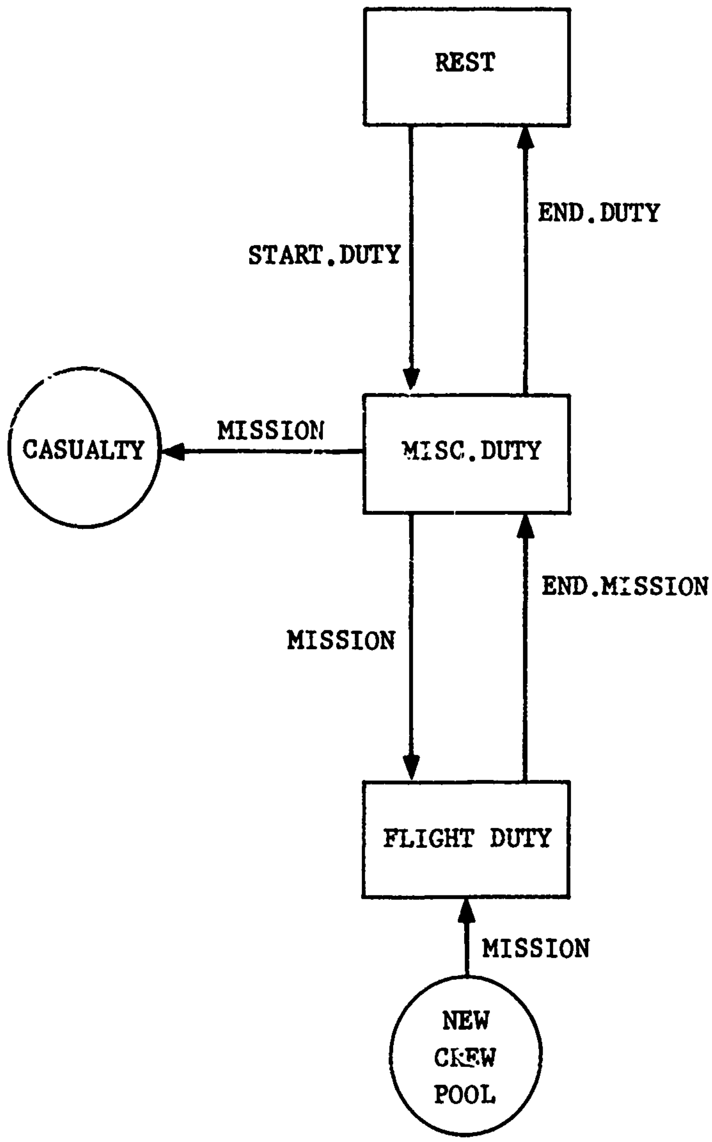

FIGURE 3 AIRCREW STATES AND EVENTS IN CREWMAN

As shown in Figure 3, the potential aircrew states are defined as:

REST	A state in which aircrews are unavailable for assignment to a mission because they are not on-duty
MISC.DUTY	A state in which aircrews are available for assignment to a mission because they are on-duty and because they are not already committed to a specific mission
FLIGHT DUTY	A state in which aircrews are committed to a specific mission--the duration of that commitment dictated by the mission time

These aircraft states are integrated (along with input/output factors) by the CREWMAN events: START.DUTY, END.MISSION, MISSION, and END.DUTY.

1. END.DUTY Event

The END.DUTY event in the simulation logic causes an on-duty aircrew (residing in the MISC.DUTY state) to go off-duty (enter the REST state). This action is based on the concept of a "duty day" that the CREWMAN logic concept embraces. Under this formulation, each aircrew is assigned a regular duty day during which that aircrew is available for a mission assignment or miscellaneous duty. The duty day is a consecutive period of time, and it is followed by another consecutive period of time that coincides with aircrew rest (during which no mission assignments may be accepted).

Practically speaking, the logic of the END.DUTY event causes four actions to be carried out as shown in Figure 4:

- Update aircrew's accumulated miscellaneous duty time
- Apply Naval regulations (Table 1) to determine the extent of rest due the aircrew

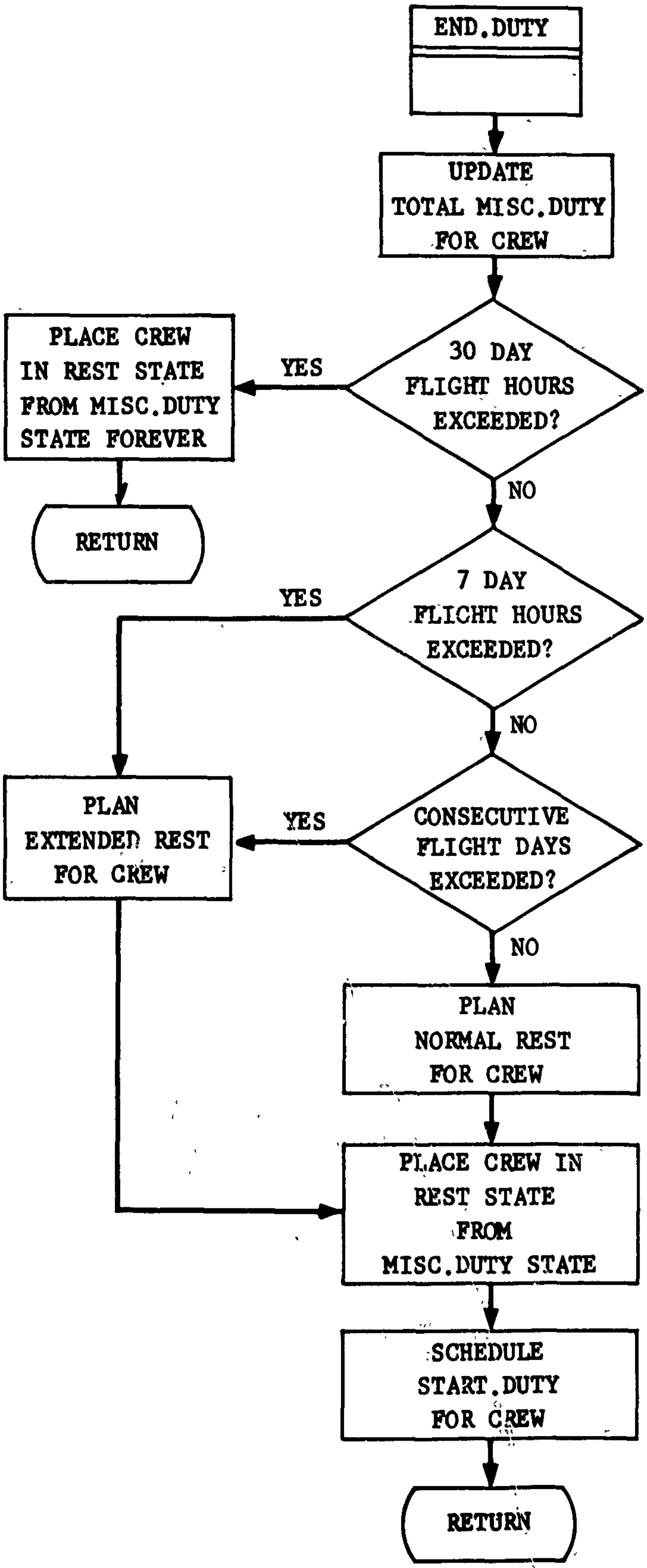

FIGURE 4 END.DUTY EVENT MACRO FLOWCHART

- Place the aircrew in the appropriate rest status
- Schedule the next duty day for the aircrew.

Accumulated miscellaneous duty time is calculated as the total amount of time of non-flight and non-briefing duty time accumulated from the time the aircrew initially entered the scenario (this could be Day 1 or Day 30, depending on the number of aircrews required to meet the mission demand throughout the scenario).

Navy regulations prescribe standards for the amount of flight time that an aircrew can accumulate over varying periods of time. These standards have been summarized in Table 1 previously, and they are contained in the CREWMAN logic in the form of a filter that determines which standards, if any, are applicable--based on the aircrew's previous history.

Once the amount of rest due to an aircrew is determined, the END.DUTY event places that aircrew in the REST state. The REST state contains two components: normal rest and extended rest. Normal rest is taken to mean the amount of time in the aircrew's 24-hour day that is not "on-duty" time. It is applied normally when no other standards are violated. Extended rest is taken to mean the amount of time equal to the normal rest period plus an additional 24 hours. It is applied when appropriate weekly Navy flight standards are violated. When a crew accumulates its maximum monthly flight hours, it is put in rest indefinitely.

The aircrew's next duty day is scheduled by determining when the REST state ends, based on the type of rest status in which the aircrew has been placed.

2. <u>END.MISSION Event</u>

The END.MISSION event in the simulation logic causes an aircrew to transition from a FLIGHT DUTY state to a MISC.DUTY state following completion of the air (or ground alert) mission and its subsequent post-mission debrief. It is a straightforward logic construct as shown in Figure 5.

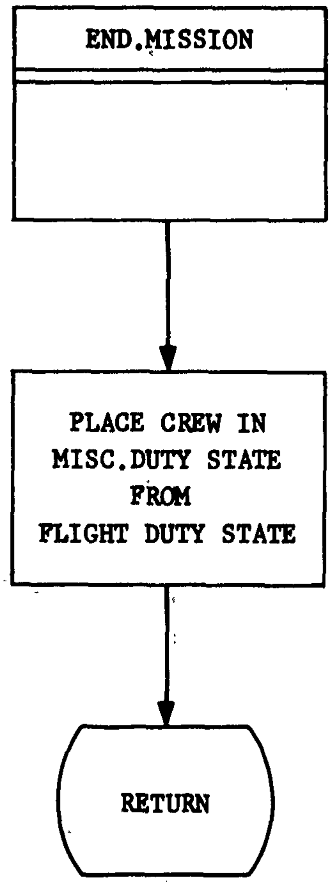

FIGURE 5 END.MISSION EVENT MACRO FLOWCHART

3. END.SORTIE Event

The END.SORTIE event in the simulation logic causes an aircraft to transition from the ASSIGNMENT state to the NOT AVAILABLE state following completion of an air mission. Based on the downtime assigned to the aircraft (see discussion of aircraft availability in Part II.A2), this event also generates a READY event for the aircraft's return to a status capable of accepting another mission. It is a straightforward logic construct as shown in Figure 6.

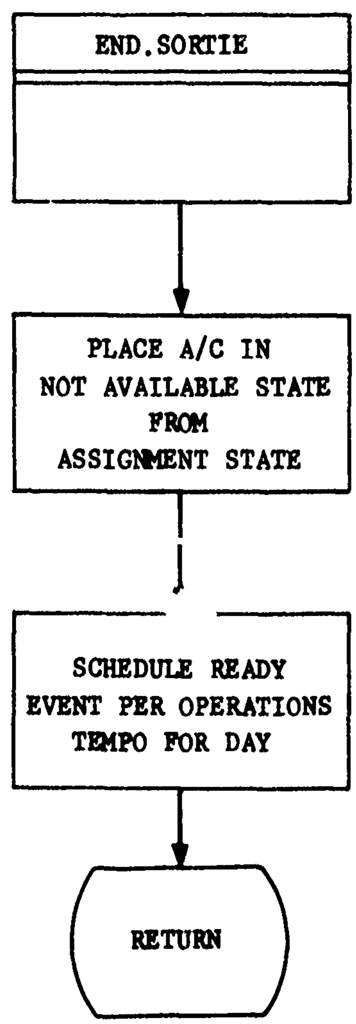

FIGURE 6 END.SORTIE EVENT MACRO FLOWCHART

4. READY Event

The READY event in the simulation logic causes an aircraft to transition from a NOT AVAILABLE state to an IDLE state following completion of the maintenance and turnaround downtime that the aircraft incurred following its last mission. It is a straightforward logic construct as shown in Figure 7.

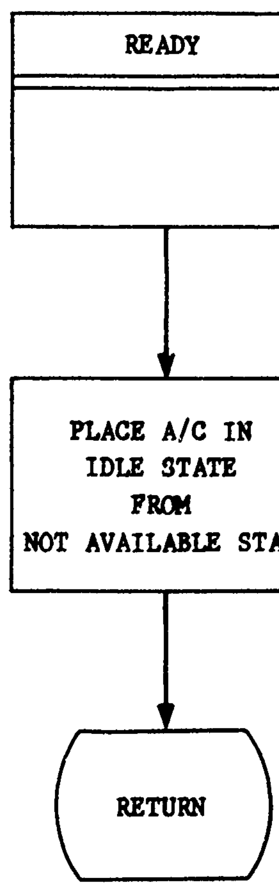

FIGURE 7 READY EVENT MACRO FLOWCHART

5. START.DUTY Event

The START.DUTY event in the simulation logic causes an aircrew to transition from a REST state to a MISC.DUTY state following completion of the required rest period that the aircrew was assigned after its last duty day. On the basis of the time at which the new duty day is initiated and the length of the duty day (defined by the simulation user), a time for ending the duty day is calculated and the transition to a subsequent REST state is scheduled. It is a straightforward logic construct as shown in Figure 8.

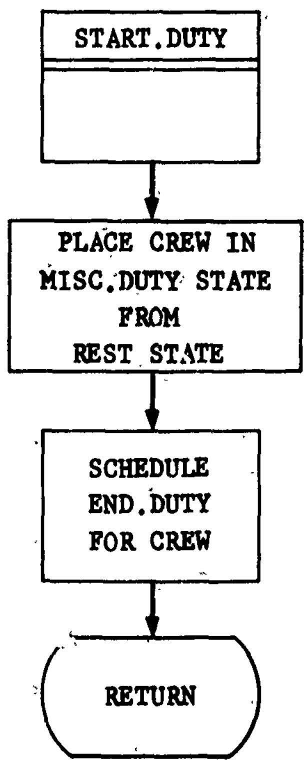

FIGURE 8 START.DUTY EVENT MACRO FLOWCHART

6. MISSION Event

The MISSION event in the simulation logic finds and brings together the aircraft and aircrew resources necessary to fill a mission in the scenario. If an aircraft is not available, the mission is not undertaken, and that fact is recorded as a missed mission in the computer output. If an aircrew is not available, a new aircrew if formed; therefore, a mission is never missed because an aircrew if not available. (In other words, aircrews are treated as dependent variables whose value is driven by the circumstances of the scenario.) The logic of the MISSION event is shown in Figure 9.

In selecting the aircrew for assignment to a mission, the simulation logic performs a sorting function that determines the "most eligible aircrew." The concept of the most eligible aircrew is based on finding an aircrew that has flight capability left in its duty day (that is, one that will not violate its recommended flight hours or sorties by accepting another flight); an aircrew that has enough time left in its duty day to fulfill the requested mission prior to going off-duty; and, finally, of those aircrews still eligible, the one that is closest to going off-duty.

The MISSION event also accounts for both aircraft and aircrew losses due to combat attrition, and it updates flight statistics for air missions. Aircrew and aircraft losses are computed independently by CREWMAN, which can give rise to the anomoly of a crew being lost without the aircraft being lost. Given the structure of the model, this is not critical, however, because average availabilities of both aircrews and aircraft are of first order importance. Over a 30-day scenario, the losses will approach the average loss parameters that were input.

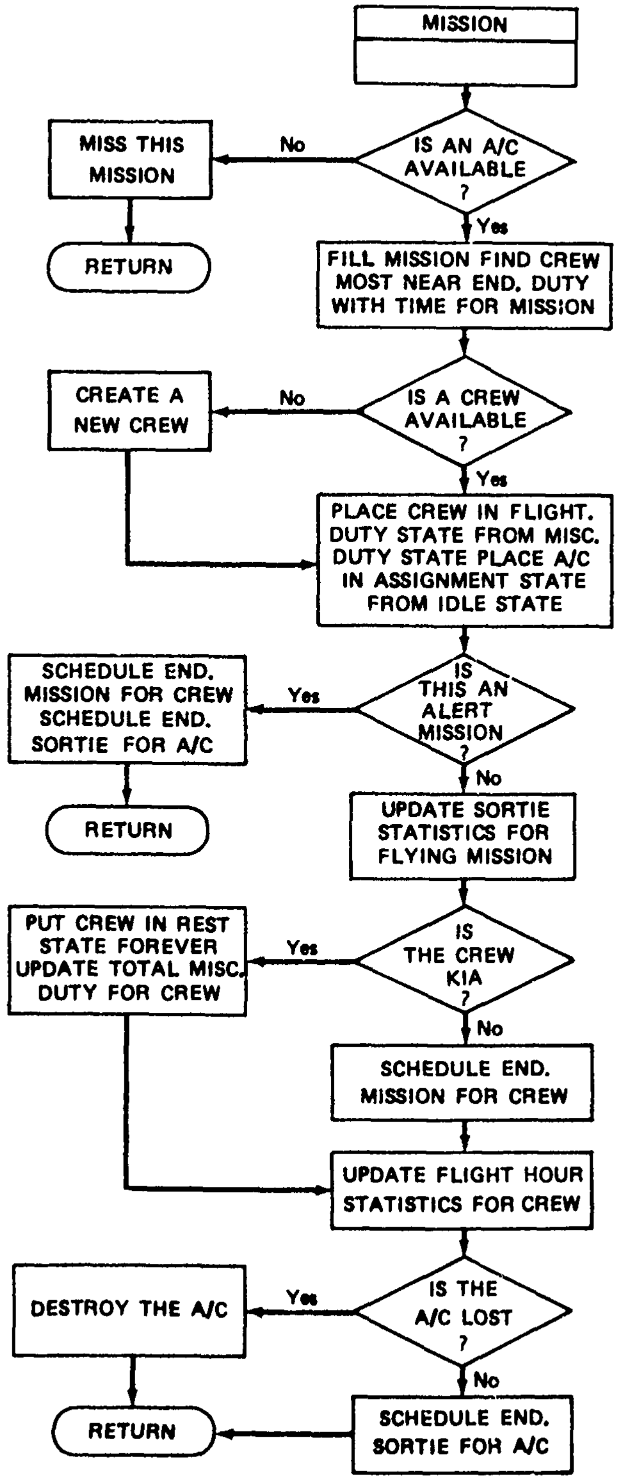

FIGURE 9 MISSION EVENT MACRO FLOWCHART

7. NEW.DAY Event

The NEW.DAY event in the simulation logic is the modeling artifact for translating the scenario input into the action sequence required to simulate a Marine Corps squadron performing air operations over a 30-day scenario. It is also the breakpoint within the simulation for gathering interim (daily) statistics covering the actions taken and the resources used.

The logic of the NEW.DAY event is as shown in Figure 10. Daily statistics are accumulated for the previous day's operations and printed out in the daily summary portion of the simulation results. Appropriate summaries that are to be presented in the scenario totals portion of the simulation results are also generated.

In terms of actions critical to the simulation, this event provides the mechanism for replacing lost aircraft. This procedure is accomplished on the basis of the two user inputs, aircraft resupply delay and aircraft resupply allotment. For CREWMAN these parameters are meant to mean the number of aircraft that can be supplied within a certain period of time.

For example, suppose the aircraft resupply delay is taken to be 4 days and the aircraft resupply allotment is taken to be 4 aircraft. The concept of resupply in CREWMAN, under this example, will tend to supply 4 aircraft replacements in every 4-day period when they are needed. If 4 aircraft were lost on Day 1 and 4 more were lost on Day 2, CREWMAN would resupply 4 aircraft on Day 5 and 4 more on Day 9, rather than 4 on Day 5 and 4 on Day 6.

Another action that NEW.DAY provides is the mission schedule for each day's simulation of air operations. The number of missions is a user input, and it is the same for each day of the scenario. The time at which these missions appear each day varies, however, according to a random draw from a uniform probability distribution. In this formulation, day missions

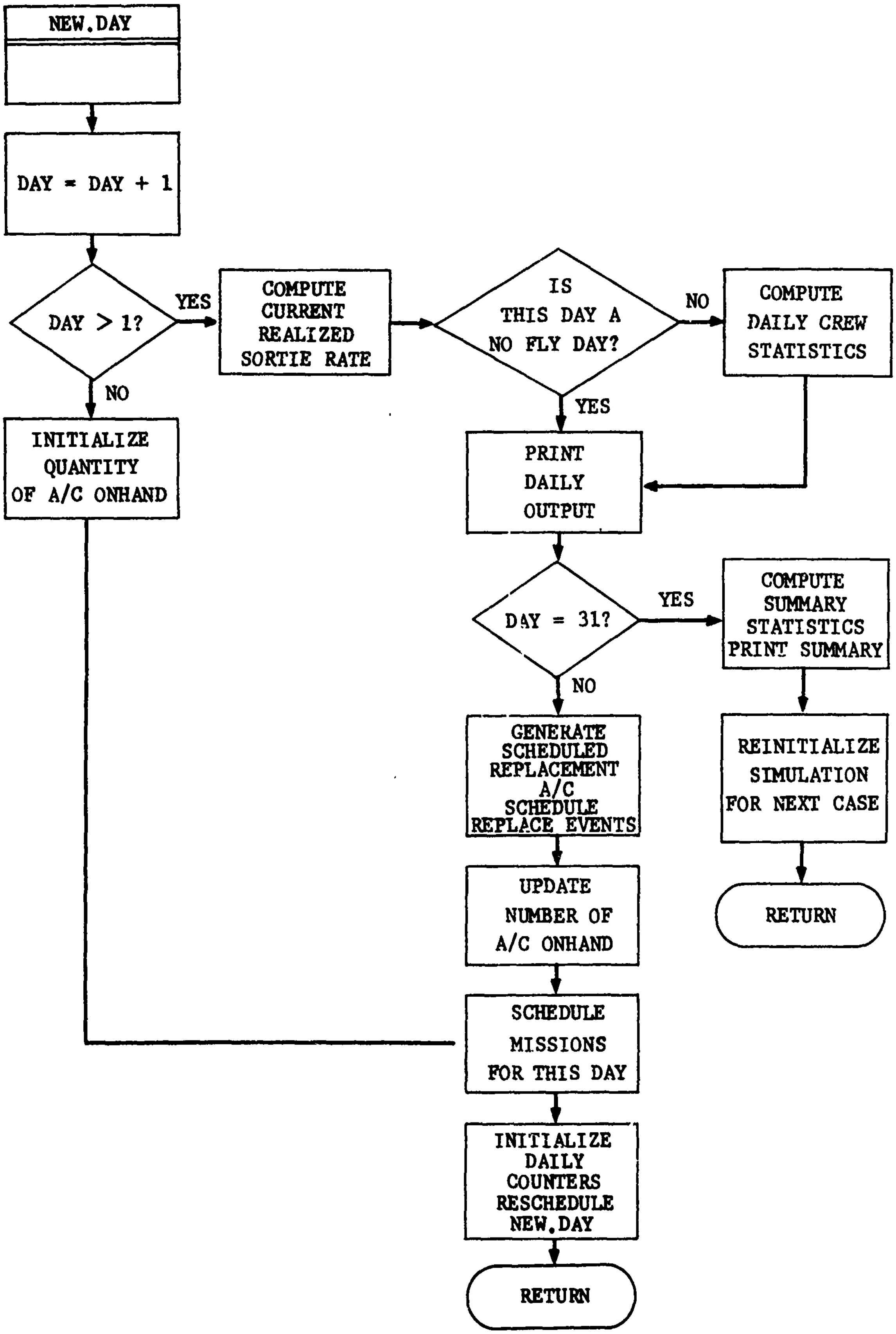

FIGURE 10 NEW.DAY EVENT MACRO FLOWCHART

are equally likely to occur at any time during the 12-hour day period, and night missions are equally likely to occur at any time during the 12-hour night period.

III SIMULATION MODEL INPUT

The SIMSCRIPT II.5 programming language was selected for CREWMAN, in part, because of the ease by which data can be entered in simulation applications. The SIMSCRIPT II.5 attribute most responsible for this facility is the "free-form read" characteristic. Briefly, the free-form nature of the language relieves the burden of constantly monitoring format constraints in terms of column-associated entries; therefore, data need only be separated by a blank to satisfy the SIMSCRIPT II.5 data entry requirements. It is essential, however, that all data fields be filled by either numeric or alphanumeric characters, and that all alphanumeric words be expressed in four or fewer characters.

Data input requirements for CREWMAN are not extensive. Each exercise of the CREWMAN model requires only a small data set (5 or more 80-column computer cards, or the equivalent amount of lines on a terminal entry device). With the appropriate data set, CREWMAN can be instructed to produce a single scenario simulation or multiple scenario simulations during a single job submission to the computer. Each scenario run may also be replicated one or more times for sensitivity analyses of the stochastic parameters.

The CREWMAN data set consists of two types of information. The first embraces those parameters that are necessary to completely describe the circumstances and resources of the Marine Corps aviation squadron activity that is being simulated. The information requirement for this calls for three computer cards that contain: (1) squadron data, (2) scenario data, and (3) operations data.

The second type of information consists of user-initiated control data that specify computer instructions for use of the model. The information requirement for this calls for two computer cards that contain: (1) simulation control data, and (2) simulation termination data.

All of these data types are described in following subsections. Each description includes specifications for the data entry formats required by the CREWMAN model. A final subsection contains a discussion on how the different data card types may be structured to set up single and multiple simulation runs of various types.

A. Squadron Data

1. Information Description

Squadron data required by CREWMAN describes the physical and operational characteristics of the aircraft flown by the Marine Corps squadron whose operations are being simulated. These characteristics are:

- Squadron type--designated by generic Marine Corps aircraft and aircraft usage, such as VMA, VMFA, HMH, HML, and so on.
- Aircraft type--aircraft model assigned to a Marine Corps squadron.
- Squadron unit equipped (U/E) aircraft--number of aircraft assigned to a Marine Corps squadron.
- Normal maintenance time--amount of time spent on aircraft maintenance for each hour of flight time during normal operations.
- Surge maintenance time--amount of time spent on aircraft maintenance for each hour of flight time during surge operations.
- Rearm and refuel time--amount of time spent on rearming and refueling an aircraft after every mission.
- Multi-piloted--whether or not the aircraft is multi-piloted.
- Pressurization--whether or not the aircraft is pressurized.
- Ejection seat--whether or not the aircraft has an ejection seat.

In the following paragraphs each element of scenario data is addressed to identify: (1) the nature of its potential numeric value or alphanumeric word, (2) its use in the CREWMAN model, and (3) potential sources for determining it.

a. Squadron Type

The squadron type may be any one of the Marine Corps fixed- or rotary-wing squadrons or a component detachment thereof. The sole modeling artifact of the CREWMAN model is that the squadron or squadron detachment contain only one aircraft type. The squadron type data are provided in an alphanumeric word of 4 characters or less. The selection of characters is up to the user (subject to the 4-character constraint), but the following list has been provided as an example of potential identifiers based on current Marine Corps squadron types:

Squadron Type	Potential Identifier
VMA	VMA
VMA(AW)	VMAW
VMFA	VMFA
VMA(V)	VMAV
VMO	VMO
VMAQ	VMAQ
VMFP	VMFP
VMGR	VMGR
HMH	HMH
HMM	HMM
HML	HML
HMA	HMA

The squadron type information is not used in the simulation algorithm, but it is output with the results of the computer run as an identifier to the analyst of the problem being simulated.

A definitive source of squadron type information is FMFM 5-1, Marine Aviation.

b. Aircraft Type

The aircraft type may be any one of the Marine Corps fixed- or rotary-wing aircraft. The aircraft type data are provided in an alphanumeric word of 4 characters or less. The selection of characters is up to the user (subject to the 4-character constraint), but the following list has been provided as an example of potential identifiers based on current Marine Corps aircraft inventories:

Aircraft Type	Potential Identifier
A-4	A4
A-6A	A6A
F-4J	F4J
AV-8A	AV8A
OV-10A	OV10
EA-6B	EA6B
RF-4B	RF4B
KC-130	C130
CH-53D	CH53
CH-46F	CH46
UH-1N	UH1N
AH-1J	AH1J

The aircraft type information is not used in the simulation algorithm, but it is output with the results of the computer run as an identifier to the analyst of the problem being simulated.

A definitive source of aircraft type information is the Effective Fleet Marine Force Table of Equipment (T/E) series.

c. Squadron U/E Aircraft

The squadron U/E aircraft represents the pre-scenario allocation of aircraft available to the squadron whose operations are being simulated. Squadron U/E data are provided to CREWMAN by an integer value.

Squadron U/E data are used in the simulation algorithm to define the number of initial aircraft available to conduct air and ground alert missions. It provides the upper bound on the number of aircraft that are present at any one time in the scenario, and it is used in the determination of the aircrew seat ratio.

The definitive source of squadron U/E aircraft information is the Effective Fleet Marine Force Tables of Equipment (T/E) series.

d. Normal Maintenance Time

The normal maintenance time provides information on the average amount of time an aircraft is down due to maintenance during normal sustained combat operations. Normal maintenance time is provided to CREWMAN by a real numeric value that describes the amount of time (hours) spent in maintenance for each flight hour.

This parameter is a primary contributor to the determination of aircraft availability in the model. Its specification is a particularly complex undertaking due to the number of factors involved--including the interaction and scheduling of the squadron maintenance activity, and the basic reliability and maintainability of the aircraft. Actual operational experience is, perhaps, the best source of information, but extrapolations and models can be used to provide representative values. Normal maintenance time can also be estimated from the maintenance and supply records of such systems as the Naval Maintenance Data Collection System (3M).

This parameter might be artificially reduced if the user can assume a certain amount of maintenance is done during idle hours, such as might occur if a squadron only flies during one-half of a day.

e. Surge Maintenance Time

The surge maintenance time provides information on the average amount of time an aircraft is down due to maintenance during temporary surge combat operations. Surge maintenance time is provided to CREWMAN by a real numeric value that describes the amount of time (hours) spent in maintenance for each flight hour.

This parameter is a primary contributor to the determination of aircraft availability in the model. Its specification is a particularly complex undertaking due to the number of factors involved--including the interaction and scheduling of the squadron maintenance activity, and the basic reliability and maintainability of the aircraft. Actual operational experience is, perhaps, the best source of information, but extrapolations and models can be used to provide representative values. Surge maintenance time can also be estimated from the maintenance and supply records of such systems as the Naval Maintenance Data Collection System (3M).

This parameter might be artificially reduced if the user can assume a certain amount of maintenance is done during idle hours, such as might occur if a squadron only flies during one-half of a day.

f. Rearm and Refuel Time

The rearm and refuel time provides information concerning the amount of time an aircraft is down due to rearming and refueling after every flight. Rearm and refuel time data are provided to CREWMAN by a real numeric value that describes the above parameter in hours.

Actual operational experience is, perhaps, the best source of information, but extrapolations and models can be used to provide representative values.

g. Multi-Piloted

Multi-pilot information reflects the number of aviators required to fly an aircraft of a particular type. This parameter is used as a factor in establishing flight-hour ceilings for aircrews according to the recommendations of OPNAVINST 3710.7J, as summarized previously in Table 1. Multi-pilot information data are provided to CREWMAN through an alphanumeric code having two possible alternatives. If the aircraft requires more than one pilot, the alphanumeric word "YES" is entered, and if the aircraft requires one pilot, the alphanumeric word "NO" is entered.

Multi-pilot data are used in the simulation algorithm to help determine the appropriate policy to apply with regard to the number of flight hours a particular aircrew will be allowed to accumulate over various periods of time; therefore, the specification of the number of aviators allows CREWMAN to effect administrative policy regulating aircrew flight hours.

A definitive source of multi-pilot information is the NATOPS Flight Manual for the aircraft under consideration.

h. Pressurization

Aircraft pressurization information reflects the flight environment of aircrews flying different aircraft. This environment is used as a factor in establish flight-hour ceilings for aircrews according to the recommendations of OPNAVINST 3710.7J, as summarized previously in Table 1. Aircraft pressurization information data are provided to CREWMAN through an alphanumeric code having two possible alternatives. If the aircraft is pressurized, the alphanumeric word "YES" is entered, and if the aircraft is not pressurized, the alphanumeric word "NO" is entered.

Aircraft pressurization data are used in the simulation algorithm to help determine the appropriate policy to apply with regard to the number of flight hours a particular aircrew will be allowed to accumulate over various periods of time; hence, the specification of the aircraft pressurization allows CREWMAN to effect administrative policy regulating aircrew flight hours.

A definitive source of aircraft pressurization information is the NATOPS Flight Manual for the aircraft under consideration.

i. Ejection Seat

Ejection seat information reflects the presence of an ejection seat in a particular aircraft. This parameter is used as a factor in establishing flight-hour ceilings for aircrews according to the recommendations of OPNAVINST 3710.7J, as summarized previously in Table 1. Ejection seat information data are provided to CREWMAN through an alphanumeric code having two possible alternatives. If the aircraft has an ejection seat, the alphanumeric word "YES" is entered, and if the aircraft does not, the alphanumeric word "NO" is entered.

Ejection seat data are used in the simulation algorithm to help determine the appropriate policy to apply with regard to the number of flight hours a particular aircrew will be allowed to accumulate over various periods of time; hence, the specification of the presence of an ejection seat allows CREWMAN to effect administrative policy regulating aircrew flight hours.

A definitive source of ejection seat information is the NATOPS Flight Manual for the aircraft under consideration.

2. Input Card Format

One 80-column computer card is required to enter the squadron data (described above) necessary to run the CREWMAN model. In accordance with the SIMSCRIPT II.5 facility for free-form data entry, it is not necessary that strict column formats be specified. It is necessary, however, that 19 fields of data be supplied, and that each field be separated by a "blank". It is also necessary that any alphanumeric field not exceed 4 characters. The following tabulation describes the content and sequence of the 19 required fields:

Field Number	Data Entry	Field Description
1	"SQDN"	Required data card identification
2	Alphanumeric designation	Identifies following field as squadron type data
3	Alphanumeric designation	Squadron type mnemonic
4	Alphanumeric designation	Identifies following field as aircraft type data
5	Alphanumeric designation	Aircraft type mnemonic
6	Alphanumeric designation	Identifies following field as squadron U/E aircraft data
7	Integer value	Number of aircraft assigned to the squadron

Field Number	Data Entry	Field Description
8	Alphanumeric designation	Identifies following field as normal maintenance time data
9	Real value	Amount of time (hours) spent on aircraft maintenance for each flight hour during normal operations
10	Alphanumeric designation	Identifies following field as surge maintenance time data
11	Real value	Amount of time (hours) spend on aircraft maintenance for each flight hour during surge operations
12	Alphanumeric designation	Identifies following field as rearm and refuel time
13	Real value	Amount of time (hours) spent on rearming and refueling an aircraft after every mission
14	Alphanumeric designation	Identifies following field as multi-piloted data
15	"YES" or "NO"	Whether or not aircraft is multi-piloted
16	Alphanumeric designation	Identifies following field as pressurization data
17	"YES" or "NO"	Whether or not aircraft is pressurized
18	Alphanumeric designation	Identifies following field as ejection seat data
19	"YES" or "NO"	Whether or not aircraft has an ejection seat

B. Scenario Data

1. Information Description

Scenario data required by CREWMAN describe the physical and operational environment in which the selected squadron is being simulated. That environment is described by the following:

- Aircraft attrition--estimated number of aircraft lost in combat per sortie flown
- Aircrew attrition--estimated number of aircrews lost in combat per sortie flown
- Non-flying days--number of days of no air operations during the 30-day scenario (for example, due to poor weather)
- Surge days--number of days of projected intense combat operations beginning the 30-day scenario
- Aircraft resupply delay--number of days required to replace U/E aircraft lost in combat
- Aircraft resupply allotment--maximum number of aircraft that can be replaced within the period of the aircraft resupply delay.

In the following paragraphs each element of scenario data is addressed to identify: (1) its potential numeric value or alphanumeric word, (2) its use in the CREWMAN model, and (3) potential sources for determining it.

a. Aircraft Attrition

The aircraft attrition parameter provides information on the average expected loss of aircraft in combat during the 30-day scenario. This parameter is commonly specified as a rate--describing the number of expected losses per 1000 sorties of the aircraft. Aircraft attrition data are provided to CREWMAN by a real numeric value that describes the expected number of losses per single sortie (for example, 0.010 losses per sortie).

Aircraft attrition data are used in the simulation algorithm to determine randomly those air missions that will result in the loss of aircraft. A random number stream is sampled during each mission to see if criteria for loss of the aircraft are met. The process is based on a random sampling technique, and successive runs of the simulation may not yield the same results.

Aircraft attrition rates are a function of such factors as the weapon capability of the enemy, the density of enemy weapons, and operations policy, as well as the vulnerability of the aircraft. Such rates, therefore, could vary widely over several scenarios. The best sources of estimation are based on combat experience and aircraft vulnerability test information.

b. Aircrew Attrition

The aircrew attrition parameter provides information on the average expected loss of aircrews in combat during the 30-day scenario. As for aircraft attrition, aircrew attrition is provided to CREWMAN by a real numeric value that describes the expected number of losses per sortie (for example, 0.007 losses per sortie).

Aircrew attrition data are used in the simulation algorithm to determine randomly those air missions that will result in the loss of aircrews. This is an independent determination from the aircraft attrition determination, but it is done in the same random manner. As a modeling artifact, CREWMAN treats aircraft and aircrew attrition as being independent, so that aircrews may be lost on air missions that do not lose aircraft (or vice versa). In any case, the losses for both will tend toward the value specified by the user according to the laws of probability.

The factors affecting aircrew attrition are basically the same as those affecting aircraft attrition. The best sources of estimation are based on combat experience and aircraft vulnerability test information.

c. Non-Flying Days

The specification of a number of non-flying days in the 30-day scenario is included to account for the possible effect of poor weather that would restrict air operations on those days. Non-flying days data are provided to CREWMAN by an integer value that specifies the total number of days in the scenario during which no air operations will be conducted.

Non-flying days data are used in the simulation algorithm to determine those days that will be designated as having no air operations. The process is based on an random sampling technique, and successive runs of the simulation may not yield the same results.

User judgment of scenario weather conditions is the usual source of information for the specification of non-flying days.

d. Surge Days

The surge days parameter provides information on the number of days beginning the 30-day scenario that will be designated for high fulfillment of air missions due to a short-duration air operations policy. Surge data are provided to CREWMAN by an integer value that indicates the desired number of days to be included in the surge period.

Surge days data are used in the simulation algorithm to specify those scenario days during which aircraft availability (as determined by its downtime) will be at the high value associated with its surge sortie rate. As a modeling artifact, the surge period is always a consecutive number of days that occurs at the beginning of the 30-day scenario.

User judgment is the source of information for the specification of this parameter. It is possible to have no surge conditions by specifying zero days of surge.

e. Aircraft Resupply Data

The aircraft resupply delay parameter provides information on the period of time between the loss of an aircraft in combat and the availability of a new aircraft in the scenario as its replacement. Aircraft resupply delay data are provided to CREWMAN by an integer value that indicates the length of the delay in days.

Aircraft resupply delay data are used in the simulation algorithm to schedule replacement aircraft in the scenario.

Aircraft resupply delays are commonly a function of aircraft type, the scenario, and Marine Corps operating policy. User judgment is the source of information for the specification of this parameter.

f. Aircraft Resupply Allotment

The aircraft resupply allotment parameter provides information concerning the maximum number of aircraft that could be expected to be available to replace aircraft lost in combat during a specified interval of time. Aircraft resupply allotment data are provided to CREWMAN by an integer value that indicates the maximum number of aircraft that are available to replace lost aircraft within the time period of the aircraft resupply delay.

Aircraft resupply allotment data are used in the simulation algorithm to bound the supply of aircraft that may be replaced within the space of the resupply delay.

The aircraft resupply allotment parameter must be specified always in conjunction with the aircraft resupply delay parameter. Sources of this type of information are the same as those stated for the resupply delay.

2. <u>Input Card Format</u>

One 80-column computer card is required to enter the scenario data (described above) necessary to run the CREWMAN model. In accordance with the SIMSCRIPT II.5 facility for free-form data entry, it is not necessary that strict column formats be specified. It is necessary, however, that 13 fields of data be supplied, and that each field be separated by a "blank". It is also necessary that any alphanumeric field not exceed 4 characters. The following tabulation describes the content and sequence of the 13 required fields:

Field Number	Data Entry	Field Description
1	"SCEN"	Required data card identification
2	Alphanumeric designation	Identifies following field as aircraft attrition data
3	Real value	Number of aircraft lost per sortie flown
4	Alphanumeric designation	Identifies following field as aircrew attrition data
5	Real value	Number of aircrews lost per sortie flown
6	Alphanumeric designation	Identifies following field as non-flying days data
7	Integer value	Number of non-flying days in scenario
8	Alphanumeric designation	Identifies following field as surge days data
9	Integer value	Number of surge days beginning the scenario
10	Alphanumeric designation	Identifies following field as aircraft resupply delay data
11	Integer value	Number of days delay before aircraft lost in combat can be replaced

Field Number	Data Entry	Field Description
12	Alphanumeric designation	Identifies following field as aircraft resupply allotment data
13	Integer value	Maximum number of aircraft that can replace combat lost U/E aircraft within the period of the aircraft resupply delay

C. Operations Data

1. Information Description

Operations data required by CREWMAN describe the framework of the simulated squadron's activity in the scenario. As such, it sets the level, appropriation, and duration of aircraft/aircrew resource commitment in the scenario. This framework contains the following items:

- Aircrew daily duty hours--the assigned amount of time each day during which aircrews are available for mission assignment.
- Air mission requests (day)--the number of air missions requested during a 12-hour daylight period each day.
- Air mission requests (night)--the number of air missions requested during a 12-hour night period each day.
- Ground alert mission requests (day)--the number of alert missions requested during a 12-hour daylight period each day.
- Ground alert mission requests (night)--the number of alert missions requested during a 12-hour night period each day.
- Air mission time--the projected flight time required to accomplish assigned air missions.
- Ground alert mission time--the projected alert time required to fulfill assigned alert missions.
- Briefing times--the amount of time allocated to pre-mission briefs and to post-mission debriefs.

In the following paragraphs each element of operations data is addressed to identify: (1) the nature of its potential numeric value or alphanumeric word, (2) its use in the CREWMAN model, and (3) potential sources for determining it.

a. Aircrew Daily Duty Hours

The aircrew daily duty hours information defines the consecutive hours in one day that each aircrew is on-duty (that is, available to accept a mission assignment). While each aircrew is on-duty the same length of time, their starting and ending times are randomly dispersed throughout the day (and/or night) depending on when they accepted their first mission in the scenario--that being the start of their first duty day. Aircrew daily duty hours data are provided to CREWMAN by a real numeric value that specifies the number of hours in an aircrew's duty day.

Aircrew daily duty hours data are used in the simulation algorithm as one of the mechanisms by which aircrews are able to accept or reject mission requests. The daily duty hours are one component of a daily cycle that also includes a normal rest period (the remainder of the 24-hour day that is not part of the daily duty hours).

User judgment and normal squadron operations procedures are usual sources of this type of data.

b. Air Mission Requests (Day)

Air missions in the CREWMAN formulation are those that actually involve flight time. Depending on the type of squadron involved, the air mission might be close air support, interdiction, reconnaissance, troop transport, and so on. The CREWMAN model makes no distinction as to the type of air mission, and each air mission for a particular squadron has the same characteristics with regard to mission time, briefing times, attrition rates, and so on.

Air missions requests (day) information is the user-defined number of air missions that will be scheduled during the 12-hour daylight period of each day. (This number does not change during the 30-day scenario.) Air mission request data are provided to CREWMAN by an integer value that reflects the total number of air mission of this type for each day in the scenario.

Air mission requests (day) data are used in the simulation algorithm to establish a mission schedule for the daylight period. Under the assumption that missions are equally likely to occur at any time during that period, a random process is used to construct a daily schedule, so that even though the same number of missions occur each day, they appear at different times on different days.

User judgment and combat experience are sources for estimating air mission request information. While theoretically any number of requests may be made, the number of missions that can be met is practicably tied to the number of aircraft used in the scenario and their effective daily sortie rate.

c. Air Mission Requests (Night)

Air mission requests (night) correspond exactly in their formulation to that discussed directly above for day mission requests, with the exception that these missions occur during the 12-hour period of darkness during each scenario day.

d. Ground Alert Mission Requests (Day)

Ground alert missions in the CREWMAN formulation are those that do not involve flight time. Depending on the type of squadron involved, the ground alert mission might be strip-launched intercept, ground loiter, and so on. The CREWMAN model makes no distinction as to the type of ground alert mission, and each ground alert mission for a particular squadron has the same characteristics with regard to mission time, briefing times, and so on.

Ground alert mission requests (day) information is the user-defined number of ground alert missions that will be scheduled during the 12-hour daylight period of each day. (This number does not change during the 30-day scenario.) Ground alert mission request data are provided to CREWMAN by an integer value that reflects the total number of ground alert missions of this type for each day in the scenario.

Ground alert mission requests (day) data are used in the simulation algorithm to establish a mission schedule for the daylight period. Under the assumption that missions are equally likely to occur at any time during that period, a random process is used to construct a daily schedule, so that even though the same number of missions occur each day, they appear at different times on different days.

User judgment and combat experience are sources for estimating ground alert mission request information.

e. Ground Alert Mission Requests (Night)

Ground alert mission requests (night) correspond exactly in their formulation to that discussed directly above for day ground alert mission requests, with the exception that these missions occur during the 12-hour period of darkness during each scenario day.

f. Air Mission Time

The air mission time represents the length of time that an aircraft is airborne during a mission. These data are provided to the CREWMAN by a real numeric value that reflects the air mission time in hours.

Air mission time is diversely used in the simulation algorithm. It represents the time (along with the briefing times) during which an assigned aircrew in the middle of its duty day cannot accept another mission. In conjunction with the sortie rate, it is used in determining the downtime associated with each aircraft following a mission. It is also accounted against each aircrew's flight hour ceilings following each mission.

User judgement and combat experience are the sources for information of this type.

g. Ground Alert Mission Time

The ground alert mission time represents the length of time that an aircraft is on station while carrying out a ground alert mission. These data are provided to the CREWMAN model by a real numeric value that reflects the ground alert mission time in hours.

Ground alert mission time is used in the simulation algorithm to represent the time (along with the briefing times) during which an assigned aircrew in the middle of its duty day cannot accept another mission. It also affects aircraft in the same way.

User judgment and combat experience are the sources for information of this type.

h. Briefing Times

Briefing time information reflects the amount of time that aircrews are engaged in preparation for a specific assigned mission, as well as the amount of time that aircrews are engaged in recording the results of a completed mission. In CREWMAN, the specification of briefing time applies equally to the pre-mission brief and the post-mission debrief. (That is, a simplifying assumption of the CREWMAN formulation is that the two times are equal.) Briefing time data are provided to CREWMAN through a real numeric value that represents the time in hours that an aircrew will be engaged prior to an assigned mission and following that mission.

Briefing time data are used in the simulation algorithm to represent the amount of time (in addition to the mission time) associated with each mission that an aircrew is unavailable for assignment to other missions. Briefing times are associated both with air missions and with ground alert missions in CREWMAN.

User judgment and standard squadron operational procedures are sources for estimating the duration of mission briefs.

2. Input Card Format

One 80-column computer card is required to enter the operations data (described above) necessary to run the CREWMAN model. In accordance with the SIMSCRIPT II.5 facility for free-form data entry, it is not necessary that strict column formats be specified. It is necessary, however, that 17 fields of data be supplied, and that each field be separated by a "blank". It is also necessary that any alphanumeric field not exceed 4 characters. The following tabulation describes the content and sequence of the 17 required fields:

Field Number	Data Entry	Field Description
1	"OPNS"	Required data card identification
2	Alphanumeric designation	Identifies following field as aircrew daily duty hours data
3	Real value	Length of aircrew daily duty in hours

Field Number	Data Entry	Field Description
4	Alphanumeric designation	Identifies following field as air mission request (day) data
5	Integer value	Number of requested air missions during 12-hour daylight period each day
6	Alphanumeric designation	Identifies following field as air mission request (night) data
7	Integer value	Number of requested air missions during 12-hour night period each day
8	Alphanumeric designation	Identifies following field as ground alert mission request (day) data
9	Integer value	Number of requested ground alert missions during 12-hour daylight period each day
10	Alphanumeric designation	Identifies following field as ground alert mission request (night) data
11	Integer	Number of requested ground alert missions during 12-hour night period each day
12	Alphanumeric designation	Identifies following field as air mission time data
13	Real value	Length of air missions in hours
14	Alphanumeric designation	Identifies following fields as ground alert mission time data
15	Real value	Length of ground alert missions in hours
16	Alphanumeric designation	Identifies following field as briefing time data
17	Real value	Length of aircrew pre-mission brief in hours (post-mission debrief automatically assumes the same value).

D. Simulation Control Data

1. Information Description

Simulation control data required by CREWMAN specify instructions that affect the replication of computer runs, the injection of random processes in the simulation, and the interpretation of simulation results. Those instructions are contained in the following data categories:

- Case replication--number of runs (during one job submission to the computer center) of the simulation using the same data set.
- Random number seed--number that specifies the starting point in a random number stream that is used to initiate stochastic events in the simulation.
- Aircrew minimum use cutoff--a specified number of flight hours accumulated by aircrews in the simulation; aircrews accumulating fewer flight hours than this cutoff are not considered in the calculation of the aircrew seat ratio and other results measuring scenario totals.

In the following paragraphs each element of simulation control data is addressed to identify: (1) the nature of its potential numeric value, (2) its use in the CREWMAN model, and (3) potential sources for determining it.

a. Case Replication

Case replication data are the user specification for the number of single case exercises (that is, having a constant data set) to be run consecutively during one job submission to the computer. Case replication data are provided to CREWMAN by an integer value that specifies the number of runs (initial run and subsequent replications) to be made.

Case replications are used to analyze the effect of the stochastic processes that are imbedded in the simulation algorithm. These processes generate events in the simulation that may vary from one simulation exercise to another (and hence cause a change in the calculated aircrew seat ratio). By averaging the effect of these processes on multiple runs, a representative aircrew seat ratio may be determined.

User judgment is used in specifying the number of case replications that should be conducted in support of a particular analysis that the user is undertaking.

b. Random Number Seed

Random number seed information is a user control for initiating the stochastic events (mission schedules, attrition, and so on) that take place in the simulation. Random number seed data are provided to CREWMAN by an integer value that specifies where in the random number stream the simulation is to begin sampling for a particular run. With that in mind, it is best to specify the seed with a relatively small (<100) number; otherwise, computer time is wasted.

The purpose of the random number seed information is to provide a means whereby the user of CREWMAN can cause the simulation to be the same as a previous one. To cause differences to occur between exercises, the random number seeds should be set differently for the two runs, but, to repeat a particular exercise, the random number seeds should be set the same for the two runs.

The user's purpose is the basis for determining which random number seed to use.

c. Minimum Aircrew Use Cutoff

Minimum aircrew use cutoff information is a user control for interpreting the results of a CREWMAN simulation. It is required because the abstraction of air operations in the CREWMAN formulation can cause spurious situations that unrealistically inflate the aircrew seat ratio determined by the simulation. These spurious situations result from the scheduling algorithms and the aircrew duty day concept. The effect is that some aircrews are introduced in the scenario, but their subsequent use is so little that their total flight hours in the scenario is relatively insignificant. Therefore, the minimum aircrew use cutoff data are used as a user-defined bound for significant flight time over the 30-day scenario. These data are provided to CREWMAN by a real numeric value that reflects the lower bound of significant flight hours for aircrews in the scenario.

CREWMAN uses the minimum aircrew use cutoff data to discount the scenario totals for aircrews whose flight hours fall short of the specified bound. The aircrew seat ratio, then, is based on calculations using only those aircrews that experienced significant use in the scenario, as defined by the value of the minimum aircrew use cutoff.

User experience and judgment are the source for this information. Since the maximum flight hours for any one aircrew in 30 days is known, it seems reasonable to determine the minimum cutoff on the basis of some percentage of the maximum (perhaps 10% for example). The effect of the cutoff need not be considered, however. This alternative is employed by specifying the cutoff as zero.

2. Input Card Format

One 80-column computer card is required to enter the simulation control data (described above) necessary to run the CREWMAN model. In accordance with the SIMSCRIPT II.5 facility for free-form data entry, it is not necessary that strict column formats be specified. It is necessary, however, that 4 fields of data be supplied, and that each field be separated by a "blank". The following tabulation describes the content and sequence of the 4 required fields:

Field Number	Data Entry	Field Description
1	"RUN"	Required data card identification
2	Integer value	Number of case replications to be run during this job submission
3	Integer value	Starting point for sampling of the computer generated random number stream (to determine the outcome of stochastic processes in the simulation)
4	Real value	Number of flight hours accumulated by aircrews in the simulation that will be considered as the cutoff for determining aircrews that performed a significant portion of the time in the scenario.

E. Simulation Termination Data

1. Information Description

Simulation termination data required by CREWMAN specify information to the computer that no further data exist on which to conduct simulations during that particular job submission, and that the job should be terminated and the results printed.

2. Input Card Format

One 80-column computer card is required to enter the simulation termination data (described above) necessary to run the CREWMAN model. This card has an extremely simple format containing only one field. Its content is described in the following tabulation:

Field Number	Data Entry	Field Description
1	"END"	Required data card identification.

F. Data Set Structure

As indicated above, the minimum data entry requirements for exercising the CREWMAN model are five computer cards (or lines) of information as follows:

- A card to enter squadron data ("SQDN card")
- A card to enter scenario data ("SCEN card")
- A card to enter operations data ("OPNS card")
- A card to enter simulation control data ("RUN card")
- A card to enter simulation termination data ("END card").

The use of these cards is somewhat flexible for providing single or replicated runs (using the same or different data), but certain rules must be observed.

The rules that govern the data set structure are as follows:

- The SQDN, SCEN, and OPNS cards may appear in any order, but in whatever order they appear they must be followed by at least one RUN card.
- An END card must appear once, and only once, and it must appear as the final card of the data set (following the last RUN card).

There are two cases that should be discussed with respect to these rules, and with respect to the different instructions that the job submission carries with it. One is described as the minimum case, and the other is described as the extended case.

The minimum case contains the following computer card sequence (or variation according to the data set rule above):

- SQDN card
- SCEN card
- OPNS card
- RUN card
- END card.

In this case, the RUN card causes the data contained in the SQDN, SCEN, and OPNS cards to be used in the simulation. Once the instructions of the RUN card have been carried out, the END card causes the job to be terminated and the results to be printed.

The extended case contains an extended card sequence, one example of which is provided by the following card sequence:

- SQDN card
- SCEN card
- OPNS card
- RUN card
- SCEN card
- RUN card
- END card.

In this case, the first RUN card causes the data contained in the first SQDN, SCEN, and OPNS cards to be used in the simulation. Once the instructions of the first RUN card have been carried out, the second SCEN card replaces the first SCEN card. The second RUN card then causes the data contained in the first SQDN and OPNS cards to be used with the data contained in the second SCEN card in another simulation. Once the instructions of this second RUN card have been carried out, the END card causes the job to terminate and the results of both RUN cards to be printed.

In a similar manner, multiple case runs changing any of the SQDN, SCEN, OPNS, or RUN cards may be accomplished. The rules to remember in these situations are:

- A new card of one of the following three types (SQDN, SCEN, or OPNS) changes the data formerly entered to correspond with that on the new card.
- Each RUN card operates with the most recent set of SQDN, SCEN, or OPNS cards.
- RUN cards may follow one another consecutively, in which case no changes occur in the data used in the simulation.
- Any number of RUN cards may be used (but there is a proviso that enough computer CPU time must be called for in the Job Control Language to accommodate large runs).

An example of a minimum case data set is shown in Figure 11.

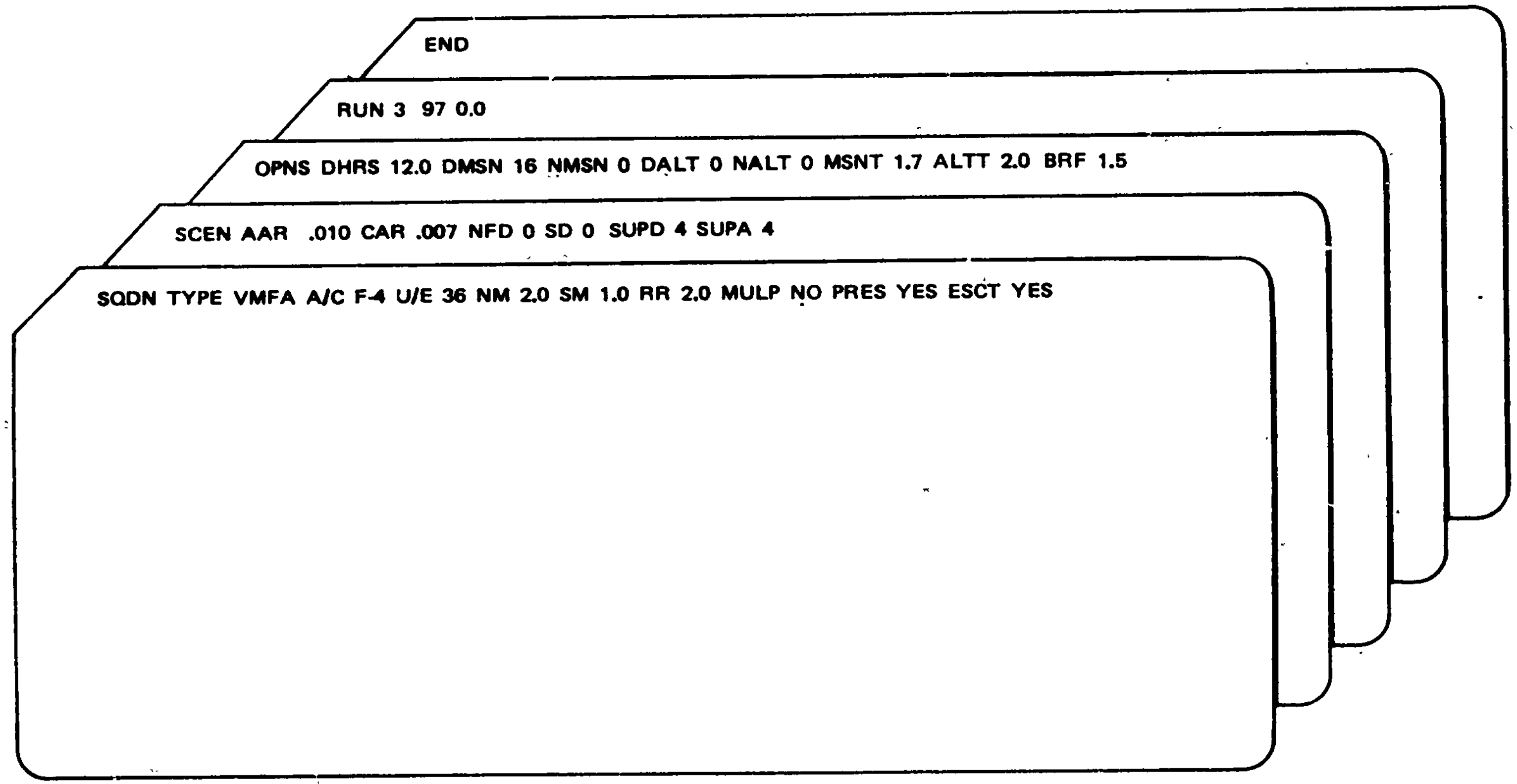

FIGURE 11 EXAMPLE CREWMAN DATA SET

IV SIMULATION MODEL OUTPUT

The computer output following each CREWMAN run provides the user with summary descriptions and totals of the activities that occurred during the simulation. Analysis may be performed on any of the various parameters that CREWMAN monitors by comparing the results of several different runs of the model.

The purpose of this section is to describe the several categories of output information from the CREWMAN model. There are two major categories in the CREWMAN output: (1) an INPUT SUMMARY and (2) a SIMULATION RESULTS. Each is addressed in the following subsections.

A. INPUT SUMMARY

The purpose of the INPUT SUMMARY in the CREWMAN output is to present in concisely and easily understood terminology the input data on which the simulation run is based.

An example of the CREWMAN output covering the INPUT SUMMARY is contained in Figure 12. As shown, this information is subdivided into four sections: (1) SQUADRON ATTRIBUTES, (2) SCENARIO PROPERTIES, (3) OPERATIONS DOCTRINE, and (4) RUN INFORMATION. These sections correspond to the input data categories described in Section III for squadron data, scenario data, operations data and simulation control data, respectively.

B. SIMULATION RESULTS

The purpose of the SIMULATION RESULTS in the CREWMAN output is to present in concise and easily understood terminology the most relevant information produced by the simulation exercise.

INPUT SUMMARY

SQUADRON ATTRIBUTES:

SQDN TYPE	A/C TYPE	SQDN U/E	MAINT HR/FLIGHT HR NORMAL	SURGE	REARM REFUEL	MULTI PILOT	PRESS URIZED	EJECT SEAT
VMFA	F-4	36	6.00	1.00	2.00	NO	YES	YES

SCENARIO PROPERTIES:

ATTRTN PER SORTIE A/C	CREW	NONFLY DAYS	SURGE DAYS	A/C RESUPPLY DELAY	ALLCTMNT
.0100	.0070	0	0	4	4

OPERATIONS DOCTRINE:

DAILY DUTY HRS	MISSION REQUESTS DAY	NITE	ALERT REQUESTS DAY	NITE	MISSION TIME NORMAL	ALERT	BRIEF TIMES
12.0	36	15	4	4	1.5	2.0	1.5

RUN INFORMATION:

NUMBER REPLICATIONS	RANDOM NO. SEED	FLIGHT HOUR CUT OFF
10	20	6.00

FIGURE 12 CREWMAN EXAMPLE OUTPUT (I)

The SIMULATION RESULTS component of the CREWMAN output is subdivided into three sections: (1) DAILY SUMMARIES, (2) SCENARIO TOTALS, and (3) MULTIPLE CASE STATISTICS. The first two subdivisions represent the interim and aggregate information produced by the simulated squadron activity in the 30-day scenario. In the situation where one or more replications of a case are being run, the third subdivision is present to aggregate information produced by the initial case and its replications. (In this situation, the DAILY SUMMARIES and SCENARIO TOTALS apply only to the first run of the replication set.)

1. DAILY SUMMARIES

Results contained in the DAILY SUMMARIES section of the SIMULATION RESULTS are shown for an example CREWMAN simulation in Figure 13. The following tabulation relates the mnemonics and abbreviations used in the computer output with the information collected by CREWMAN during the simulation:

Mnemonic or Abbreviation	Interpretation
DAY	Current day (in 30 day scenario)
CREW LOSS (ADMIN)	Aircrews lost to administrative policy
CREW LOSS (KIA)	Aircrews lost in combat
HI CREW	Highest number of aircrews used to current point in scenario
AVAIL A/C	Number of aircraft available on current day in scenario
CREW FLT.HR (AVE)	Average number of flight hours for each aircrew on current day in scenario
CREW FLT.HR (MAX)	Maximum number of flight hours achieved by any aircrew on current day in scenario

SIMULATION RESULTS

DAILY SUMMARIES (RUN NO. 1 IF CASE REPLICATED):

DAY	CREW LOSS ADMIN	CREW LOSS KIA	HI CREW	AVAIL A/C	CREW FLT.HR AVE	CREW FLT.HR MAX	CREW AVE MISC.DUTY	MISSION STATS MET	MISSION STATS MISSED
1	0	0	32	36	2.1	3.0	5.8	52	7
2	0	1	38	35	1.7	3.0	6.9	49	10
3	0	0	41	35	1.6	3.0	7.0	49	10
4	0	0	45	34	1.6	3.0	7.1	46	13
5	0	0	49	35	1.4	3.0	7.7	46	13
6	0	0	49	35	1.1	3.0	8.6	47	12
7	0	0	49	36	1.2	3.0	8.4	48	11
8	0	0	49	36	1.2	3.0	8.3	50	9
9	0	0	49	36	1.4	3.0	7.9	47	12
10	0	0	49	36	1.5	3.0	7.6	49	10
11	0	0	50	34	1.4	3.0	7.9	46	13
12	0	0	50	34	1.2	3.0	8.4	47	12
13	0	0	50	32	1.0	3.0	9.1	42	17
14	0	0	50	34	1.1	3.0	8.8	44	15
15	0	0	50	32	1.3	3.0	8.1	49	10
16	0	1	50	33	1.2	3.0	8.4	46	13
17	0	0	50	33	1.3	3.0	8.2	46	13
18	0	0	52	35	1.5	3.0	7.5	48	11
19	0	0	52	36	1.3	3.0	7.9	47	12
20	0	0	52	36	1.2	3.0	8.5	50	9
21	0	1	52	36	1.4	3.0	7.9	51	8
22	0	0	52	36	1.3	3.0	8.1	47	12
23	0	0	52	36	1.2	3.0	8.3	47	12
24	0	0	52	35	1.3	3.0	8.1	47	12
25	0	0	52	35	1.6	3.0	7.2	49	10
26	0	1	53	35	1.3	3.0	8.1	45	14
27	0	1	53	36	1.2	3.0	8.4	50	9
28	0	0	53	35	1.3	3.0	8.2	48	11
29	0	0	53	35	1.2	3.0	8.3	47	12
30	0	0	54	35	1.2	3.0	8.4	47	12

FIGURE 13 CREWMAN EXAMPLE OUTPUT (II)

Mnemonic or Abbreviation	Interpretation
CREW AVE MISC.DUTY	Average number of miscellaneous duty hours for each aircrew on current day in scenario
MISSION STATS (MET)	Number of air and ground alert missions met on current day in scenario
MISSION STATS (MISSED)	Number of air and ground alert missions missed on current day in scenario

2. SCENARIO TOTALS

Results contained in the SCENARIO TOTALS section of the SIMULATION RESULTS are shown for an example CREWMAN simulation in Figure 14. As indicated in Figure 14 by the statement "(STATISTICS REFLECT THOSE CREWS WITH TOTAL FLIGHT HRS GREATER THAN XX.)", a certain condition must exist before an aircrew in the simulation will be included in some of the summary statistics. The source of that condition is the minimum aircrew use cutoff value input by the user before the start of the simulation run (this is explained in Subsection III.D). Aircrews having total flight hours greater than the minimum aircrew use cutoff value will be considered for all statistics; aircrews having total flight hours less than the minimum aircrew use cutoff value will be excluded in the compilation of the following results: AIRCREW SEAT RATIO, CREW SORTIES FLOWN, CREW TTL FLIGHT HRS, and CREW TTL MISC.DUTY.

The following tabulation relates the mnemonics and abbreviations used in the computer output with the information collected by CREWMAN during the simulation:

SCENARIO TOTALS (RUN NO. 1 IF CASE REPLICATED):

(STATISTICS REFLECT THOSE CREWS WITH TOTAL FLIGHT HRS GREATER THAN 6.00)

AIRCREW SEAT RATIO
1.39

CREW SORTIES FLOWN				CREW TTL FLIGHT HRS				CREW LOSS		CREW
MEAN	STD.DEV	MAX	MIN	MEAN	STD.DEV	MAX	MIN	ADMIN	KIA	COUNT
24.2	6.7	42	8	36.3	10.1	63.0	12.0	0	5	50

CREW TTL MISC.DUTY				A/C	A/C SORTIE	MISSION STATS	
MEAN	STD.DEV	MAX	MIN	USED	RATE	MET	MISSED
179.3	46.5	276.0	48.0	46	1.33	1426	344

TOTAL FLIGHT HRS FOR EACH CREW (RUN NO. 1 IF CASE REPLICATED)

```
CREW NUMBER  1 HAS 60.00 TOT.FHRS
CREW NUMBER  2 HAS 48.00 TOT.FHRS
CREW NUMBER  3 HAS 37.50 TOT.FHRS
CREW NUMBER  4 HAS 43.50 TOT.FHRS
CREW NUMBER  5 HAS 42.00 TOT.FHRS
CREW NUMBER  6 HAS 49.50 TOT.FHRS
CREW NUMBER  7 HAS 37.50 TOT.FHRS
CREW NUMBER  8 HAS 48.00 TOT.FHRS
CREW NUMBER  9 HAS 39.00 TOT.FHRS
CREW NUMBER 10 HAS 49.50 TOT.FHRS
CREW NUMBER 11 HAS 39.00 TOT.FHRS
CREW NUMBER 12 HAS  3.75 TOT.FHRS
CREW NUMBER 13 HAS 34.50 TOT.FHRS
CREW NUMBER 14 HAS 34.50 TOT.FHRS
CREW NUMBER 15 HAS 30.00 TOT.FHRS
CREW NUMBER 16 HAS 25.50 TOT.FHRS
CREW NUMBER 17 HAS 16.50 TOT.FHRS
CREW NUMBER 18 HAS 15.00 TOT.FHRS
CREW NUMBER 19 HAS 12.00 TOT.FHRS
CREW NUMBER 20 HAS 39.00 TOT.FHRS
CREW NUMBER 21 HAS 30.00 TOT.FHRS
CREW NUMBER 22 HAS 33.00 TOT.FHRS
CREW NUMBER 23 HAS 34.50 TOT.FHRS
CREW NUMBER 24 HAS 36.00 TOT.FHRS
CREW NUMBER 25 HAS 31.50 TOT.FHRS
CREW NUMBER 26 HAS 28.50 TOT.FHRS
CREW NUMBER 27 HAS 33.00 TOT.FHRS
CREW NUMBER 28 HAS 34.50 TOT.FHRS
CREW NUMBER 29 HAS 31.50 TOT.FHRS
CREW NUMBER 30 HAS 28.50 TOT.FHRS
CREW NUMBER 31 HAS 34.50 TOT.FHRS
CREW NUMBER 32 HAS 36.00 TOT.FHRS
CREW NUMBER 33 HAS 63.00 TOT.FHRS
CREW NUMBER 34 HAS 43.50 TOT.FHRS
CREW NUMBER 35 HAS 33.00 TOT.FHRS
CREW NUMBER 36 HAS 37.50 TOT.FHRS
CREW NUMBER 37 HAS 31.50 TOT.FHRS
CREW NUMBER 38 HAS 31.50 TOT.FHRS
CREW NUMBER 39 HAS 22.50 TOT.FHRS
CREW NUMBER 40 HAS 42.00 TOT.FHRS
CREW NUMBER 41 HAS 34.50 TOT.FHRS
CREW NUMBER 42 HAS 43.50 TOT.FHRS
CREW NUMBER 43 HAS 40.50 TOT.FHRS
CREW NUMBER 44 HAS 34.50 TOT.FHRS
CREW NUMBER 45 HAS 23.25 TOT.FHRS
CREW NUMBER 46 HAS 48.75 TOT.FHRS
CREW NUMBER 47 HAS 54.00 TOT.FHRS
CREW NUMBER 48 HAS 45.00 TOT.FHRS
CREW NUMBER 49 HAS 33.00 TOT.FHRS
CREW NUMBER 50 HAS 34.50 TOT.FHRS
CREW NUMBER 51 HAS 25.50 TOT.FHRS
CREW NUMBER 52 HAS  3.75 TOT.FHRS
CREW NUMBER 53 HAS  3.75 TOT.FHRS
CREW NUMBER 54 HAS  0.   TOT.FHRS
```

FIGURE 14 CREWMAN EXAMPLE OUTPUT (III)

Mnemonic or Abbreviation	Interpretation
AIRCREW SEAT RATIO	Ratio of the effective number of aircrews used in the 30-day scenario to the number of squadron U/E aircraft
CREW SORTIES FLOWN (MEAN)	Mean number of air missions flown by each aircrew used in the scenario
CREW SORTIES FLOWN (STD.DEV)	Standard deviation in the number of air missions flown by each aircrew used in the scenario
CREW SORTIES FLOWN (MAX)	Maximum number of air missions flown by any one aircrew used in the scenario
CREW SORTIES FLOWN (MIN)	Minimum number of air missions flown by any one aircrew used in the scenario
CREW TTL FLIGHT HRS (MEAN)	Mean number of flight hours accumulated by each aircrew used in the scenario
CREW TTL FLIGHT HRS (STD.DEV)	Standard deviation in the number of flight hours accumulated by each aircrew used in the scenario
CREW TTL FLIGHT HRS (MAX)	Maximum number of flight hours accumulated by any one aircrew used in the scenario
CREW TTL FLIGHT HRS (MIN)	Minimum number of flight hours accumulated by any one aircrew used in the scenario
CREW LOSS (ADMIN)	Aircrews lost to administrative policy during the 30-day scenario
CREW LOSS (KIA)	Aircrews lost in combat during the 30-day scenario
CREW COUNT	Effective number of aircrews used during the 30-day scenario*

*Effective number of aircrews refers only to those aircrews whose accumulated flight hours exceed the minimum aircrew use cutoff described in Subsection III.D.

Mnemonics or Abbreviation	Interpretation
CREW TTL MISC.DUTY (MEAN)	Mean number of non-flying duty hours accumulated by each aircrew used in the scenario*
CREW TTL MISC.DUTY (STD.DEV)	Standard deviation in the number of non-flying duty hours accumulated by each aircrew used in the scenario
CREW TTL MISC.DUTY (MAX)	Maximum number of non-flying duty hours accumulated by any one of the aircrews used in the scenario
CREW TTL MISC.DUTY (MIN)	Minimum number of non-flying duty hours accumulated by any one of the aircrews used in the scenario
A/C USED	Total number of aircraft used during the 30-day scenario, including replacements
A/C SORTIE RATE	Average number of sorties per aircraft per day as realized in the scenario
MISSION STATS (MET)	Total number of air and ground alert missions met during the 30-day scenario
MISSION STATS (MISSED)	Total number of air and ground alert missions missed during the 30-day scenario

A final element of the SCENARIO TOTALS presents a breakdown of the total flight hours (TOT.FHRS) accumulated by each aircrew that participated in the scenario. As shown, the aircrews are assigned a number upon entering the scenario, so that the analyst can be aware of which aircrew entered on which day. (CREW NUMBER 1 was the first aircrew to enter the scenario, CREW NUMBER 2 was the second aircrew to enter the scenario, and so on.)

---

*This does not include briefing times for air missions, but it does include briefing times and station times for ground alert missions.

3. MULTIPLE CASE STATISTICS

Results contained in the MULTIPLE CASE STATISTICS section of the SIMULATION RESULTS are shown for an example CREWMAN simulation in Figure 15. These results show the mean, standard deviation, maximum value, and minimum value for both aircrew seat ratio and realized sortie rate based on the aggregate analysis of the results of the replicated runs of the same case.

MULTIPLE CASE STATISTICS:

(STATISTICS FOR 10 REPLICATIONS OF THIS CASE)

AIRCREW SEAT RATIO				SORTIE RATE			
MEAN	STD.DEV	MAX	MIN	MEAN	STD.DEV	MAX	MIN
1.61	.11	1.78	1.39	1.33	.01	1.34	1.32

FIGURE 15 CREWMAN EXAMPLE OUTPUT (IV)

Appendix A

ANALYSIS USING THE CREWMAN MODEL

Appendix A

ANALYSIS USING THE CREWMAN MODEL

The CREWMAN model offers the analyst a flexible and multi-faceted tool with which to analyze the effect of numerous factors on the determination of an aircrew seat ratio requirement for each of the Marine Corps squadrons. However, its effective application and interpretation depend on a thorough understanding of the relationship of the model to the real world (which it strives to represent), and of the numerous interrelationships that exist among the parameters that drive the model.

The purpose of this appendix is to discuss several aspects of the model that bear significantly on its use as an analytic tool. The basis for the discussion is a series of computer exercises that SRI conducted to check out the logic and credibility of CREWMAN during its development. While this was not an exhaustive demonstration of the model's nature, it was sufficient to identify several casual relations that will affect all applications of the model.

There appear to be three major areas in which a discussion of CREWMAN treatment promotes understanding of the model's results and ultimate effectiveness. These areas are:

- The influence of stochastic processes embedded in the CREWMAN formulation on the variability of simulation results.
- The significance of "edge effects" inherent in the CREWMAN abstraction of real world activities and processes.
- The effect of scale in interpreting the simulation results.

Each of these factors is the subject of a subsection below. Additionally, one other subsection is presented to provide a potpourri of assorted findings, observations, and conclusions that will prove helpful to any prospective analyst using CREWMAN.

1. Stochastic Process Influences in CREWMAN

Replications of a given CREWMAN scenario invariably result in the calculation of different aircrew seat ratio requirements. In some cases, these differences will be quite substantial. Differences also appear in other statistics contained in the CREWMAN results, although usually their significance is less apparent (since their contribution to the determination of the aircrew seat ratio may not be readily transparent).

The basis for such differences are the stochastic processes that CREWMAN uses to represent real world events. These processes directly affect mission scheduling, aircraft and aircrew attrition, and the determination of non-flying days in CREWMAN, but the influence that they exert is significantly more widespread and, in some cases, quite subtle.

An indication of the magnitude of the variation in aircrew seat ratio that CREWMAN can be expected to produce is shown for several replicated scenarios in Table A-1. As indicated there, differences approaching one aircrew per aircraft (as in the observed spread for Scenario B) can occur because of the interaction of random events.

It should also be noted that the general "scatter" of results from all the different scenarios in Table A-1 is substantial. If one were to assume that the results of individual simulations formed a normal distribution around the calculated mean, the standard deviations shown in Table A-1 could be interpreted in a practical sense. That is, the interval defined by the expression, (mean) ± 0.67 (standard deviation), could be expected to contain only 50% of all results; hence, 50% of the results

Table A-1

AIRCREW SEAT RATIO VARIABILITY

Results and Calculations	Computer Simulation Designation				
	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Aircrew seat ratios observed	1.43	1.80	1.55	1.60	1.28
	1.40	1.75	1.60	1.22	1.40
	1.31	1.35	1.75	1.53	1.29
	1.32	1.95	1.45	1.31	1.14
	1.22	1.50	1.55	1.40	1.21
	1.37	1.95	1.55	1.53	1.18
	1.28	2.25	1.50	1.33	1.18
	1.31	1.55	1.55	1.60	1.26
	1.60	1.65	1.60	1.24	1.12
	1.53	1.85	1.40	1.47	1.14
Mean	1.32	1.76	1.55	1.42	1.22
Spread (max-min)	0.22	0.90	0.35	0.36	0.28
Standard deviation	0.13	0.26	0.09	0.17	0.09

for Scenario A, for example, would be expected to lie outside the interval 1.23-1.41.

The results clearly indicate that conclusions regarding aircrew seat ratio requirements should be based on the average results of a series of simulation runs rather than on the results of a single isolated run. The rationale for this action is that the fluctuations in the aircrew seat ratio caused by the stochastic occurrences should "cancel out" over a series of runs. A practical question arises, however, about the number of computer runs necessary to establish a representative mean aircrew seat ratio.

This question was addressed by SRI by examining several replication series. It was determined that, although the individual results were quite disparate as indicated above, there was a quick convergence of the mean of these results to a stable value as the number of results considered was increased.

The method of examination was to plot the mean of successive simulation runs as the number of simulations increased. Figure A-1 provides the results found by applying this technique to one of the several simulation replication series that SRI analyzed. As shown in Figure A-1, the mean of 13 simulation replications was closely approached after about 8 runs.

This result was characteristic of the other series that SRI evaluated. Based on this similarity, it appears that 8-12 replications of a scenario are sufficient to establish its representative aircrew seat ratio requirement. Therefore, SRI recommends that aircrew seat ratio requirements be established on the basis of the mean obtained from at least 8-12 simulation runs.

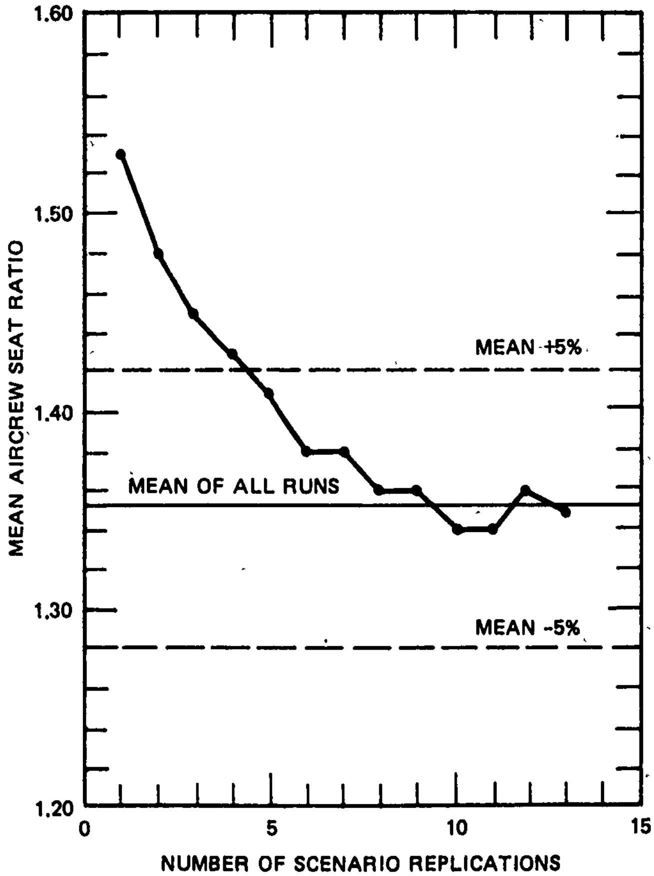

FIGURE A-1 AIRCREW SEAT RATIO CONVERGENCE FOR REPEATED RUNS

2. CREWMAN Abstraction Edge Effects

One consequence of the random occurrence of missions in CREWMAN is that situations arise in which an aircrew will be introduced into the scenario to fill a particular mission, but for one reason or another that aircrew will not fill any other missions during the scenario (or perhaps only a very small number). For example, an uncommonly high number of missions may appear in a short time span on one of the final days of the scenario and cause a new aircrew to be introduced. If no other crowding of missions occurs for the remainder of the scenario, that particular aircrew may never be used again.

Another situation may arise for scenarios in which flights only take place during the daylight (or conversely only during the darkness). In this case, a mission may occur extremely late in the day. Because aircrews already in the scenario do not have enough duty time left in their duty day to accept it, another aircrew may be introduced. An aircrew introduced at such a time, however, begins its duty day at the time according to the simulation algorithm. The effect is that every day that aircrew comes on duty just before all flights are terminated for the day. The probability is low that an aircrew with such a duty day can accumulate significant flight duty.

If these types of situations arise several times during the simulation, the aircrew seat ratio is rather artificially inflated for little apparent benefit (for example, a meaningful gain in total number of missions met). Figure A-2 provides a good representation of this situation in a graphical form. It is seen for the case represented in Figure A-2 (having an aircrew ratio of 2.42) that 8 aircrews accumulated less than 6 flight hours during the 30-day scenario. This is less than 10% of the maximum number of hours they would be allowed to accumulate based on the administrative policy contained in CREWMAN.

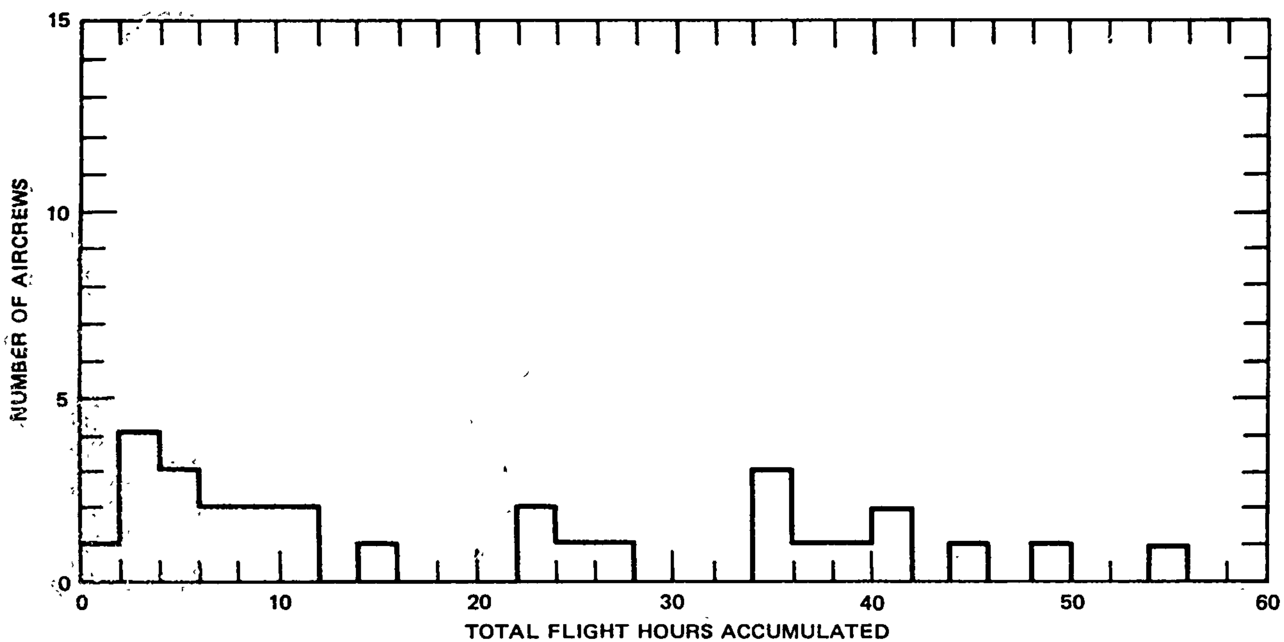

FIGURE A-2 EXAMPLE DISTRIBUTION OF AIRCREW USAGE

It was for such situations that the minimum aircrew use cutoff was included in the CREWMAN formulation (see Paragraph III.D.1.c for a description of the minimum aircrew use cutoff). Were it employed in the case shown in Figure A-2, and were it set for 6.0 flight hours, then 8 aircrews would be eliminated from consideration in the aircrew seat ratio. The result would be that the aircrew seat ratio would be calculated to be 1.75 rather than 2.42. From all aspects, it appears that this is a more realistic determination.

As an aside, one might hypothesize that those aircrews that have very low flight hours could represent the effect of having overhead aircrews associated with a squadron. The concept of overhead aircrews is discussed in Part II.A.4.

During our investigation of the effect of using the minimum aircrew use cutoff, we found that a good "rule of thumb" for its specification appears to be about 10% of the flight hour ceiling that the aircrews are restricted to during the 30-day scenario. An additional benefit of the minimum aircrew use cutoff, when it is employed, is that it reduces the scatter of the results of individual simulations--making the mean of an increasing set of results converge even faster. This is explained by the fact that it is reducing the effect of unusual random events.

3. Effect of Scale in CREWMAN

The effects of scale have been noticed in the analysis SRI conducted with the CREWMAN model. That is, discernible trends have been identified that show that the aircrew seat ratio calculated by CREWMAN decreases for increasing numbers of aircraft included in the scenario (given that attrition, turnaround times, and ratio of missions to aircraft remain constant). Another related feature of this phenomenon is that the standard deviation (measure of the scatter) of the results of replicated scenarios decreases as more aircraft are applied to a scenario.

Neither of these results are unexpected or inexplicable, but the knowledge of the degree to which they appear is germane to analysis using the CREWMAN model. To provide that insight, Figure A-3 was constructed from some of the results of SRI's test of the CREWMAN simulation. Three cases are presented there in which the number of aircraft was increased from 20 to 45 to 72 under the same scenario conditions. As shown, a definite trend exists with respect to the effect of the number of aircraft considered on the aircrew seat ratio.

Of particular importance to the Marine Corps analyst is the "steepness" of the curve at aircraft levels associated with typical Marine Corps squadrons. The "flattening out" of the curve at higher aircraft U/Es suggests that a lower bound is being approached below which the aircrew seat ratio is unlikely to fall with any realistic number of aircraft considered. (Such information may be important for specifying an absolute minimum aircrew seat ratio that could ever be expected to meet Marine Corps requirements.)

The rationale for the effect observed in Figure A-3 has to do with the effect of small and large numbers. With the larger number of aircraft, it is more likely that a match can be made between a requested mission and an aircrew already in the scenario than it is for small numbers of aircraft. Analagously, the loss of an aircrew in combat has a much less dramatic effect on the large aircrew pool in the one case than it does on the small aircrew pool of the other case.

4. <u>Miscellaneous Findings and Observations</u>

When examining the results of any CREWMAN simulation exercise, an analyst is likely to notice one or more pieces of information that require a detailed knowledge of the internal workings of the simulation model for a satisfactory interpretation. The following paragraphs describe situations that SRI analysts have come across during the exercises of the model that fall into this category.

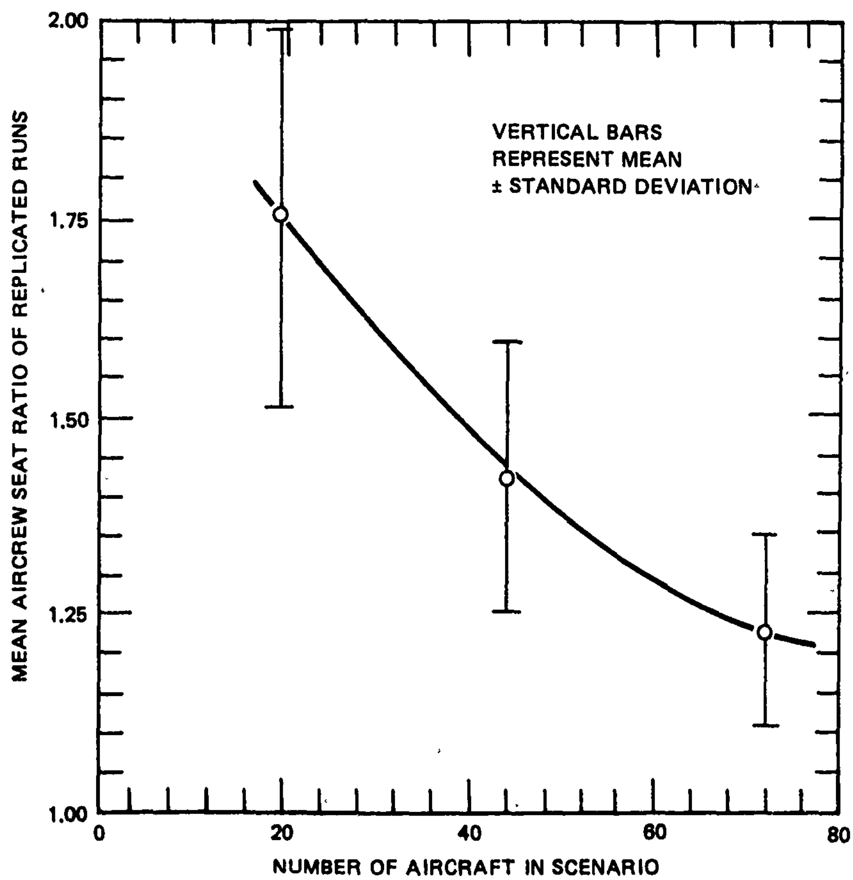

FIGURE A-3 EFFECT OF SCALE IN CREWMAN

a. Aircrew Flight Hour Ceilings

Situations may occur in which a particular aircrew's total flight hours for the scenario may exceed the supposed bound established as administrative policy. This effect is the result of the CREWMAN formulation whereby the test to see if the ceiling has been violated occurs at the end of the aircrew's duty day rather than after each mission. Therefore, an aircrew may enter a day needing only one more flight to exceed its ceiling, but because of the assignments that day the aircrew makes two flights and surpasses the flight hour ceiling.

b. Aircraft Attrition

The output category A/C USED includes the number of aircraft that have been supplied to the scenario to replace aircraft lost in action. It does not necessarily include the total aircraft lost in the scenario due to the time lag of the resupply delay which may extend past the termination of the scenario.

c. Aircrew Attrition

Aircrew attrition appears to be a major source of the differences in aircrew seat ratio observed among individual members of a simulation replication series. Its effect is stronger in scenarios having a small number of aircraft than it is in scenarios having a large number of aircraft. Contrasts between scenarios in which aircrew attrition was considered and those in which it was not considered indicates that the standard deviation of simulation replications from the mean of an entire set may increase by as much as 100% when aircrew attrition is considered. Of course, aircrew seat ratios are also higher when aircrew attrition is considered.

d. General Results

The following general results were noted, although they were not studied in detail to derive quantitative estimating relations:

- Lengthening of the daily duty day reduces the aircrew seat ratio requirement.
- Increasing the mission requests increases the aircrew seat ratio requirement--especially around a breakpoint established by multiplying the number of U/E aircraft by their normal sortie rate.
- Decreasing the turnaround (maintenance and rearm/refuel) times of aircraft included in the simulation increases the aircrew seat ratio requirement when the number of missions requested is approximately equal to or exceeds the number of sorties the squadron can produce.

Appendix B

CREWMAN MODEL STRUCTURE, SUBROUTINES, VARIABLES, AND LISTING

Appendix B

CREWMAN MODEL STRUCTURE, SUBROUTINES, VARIABLES, AND LISTING

This appendix is intended to supplement the user-oriented description and operating instructions for the CREWMAN model contained in the main body of this report. It provides a precise exposition of the CREWMAN structure, a list of the model subroutines, a list of the model variables, and a complete listing of the CREWMAN program. It also gives a Job Control Language (JCL) listing that compiled, cataloged, and executed the CREWMAN model.

Table B-1

CREWMAN EVENT NAMES

Event Name	Description
END.DUTY	Accounts for rest period due an aircrew following its duty period
END.MISSION	Accounts for an aircrew ending a mission
END.SORTIE	Accounts for an aircraft completing a sortie
MISSION	Processes all missions, finding eligible aircraft and aircrews
NEW.DAY	Initiates a new day
READY	Accounts for aircraft leaving maintenance
START.DUTY	Accounts for aircrews initiating a duty day

Table B-2

CREWMAN ENTITY NAMES

Entity	Attribute	Type*	Description
CREW	NUMBER	I	Entry position of aircrew in scenario
	TOT.FLIGHTS	I	Total flights by aircrew
	TOT.FHRS	R	Total flight hours by aircrew
	TOT.MISC.DUTY	R	Total miscellaneous duty hour accumulated by aircrew
	CUR.SORT	I	Sorties by aircrew in current day
	CUR.FHRS	R	Flight hours by aircrew in current day
	LAST.OFF	I	Last non-duty day for aircrew (that is, last extended rest day)
	CUM.FHRS	R	Accumulated flight hours since last non-duty day
AIRCRAFT	BACKLOG	R	Maintenance backlog acquired by aircraft during surge operation
	FLT.TIME	R	Flight time of current mission
AC.STATE	†		
CREW.STATE	†		

*A - Alpha, R - Real, I - Integer
†Has no explicit attribute defintion.

Table B-3

CREWMAN SET STRUCTURE

Entity	Owns	Belongs To
CREW		CREW.SET ALL.CREWS
AIRCRAFT		AC.SET
CREW.STATE	CREW.SET	
AC.STATE	AC.SET	
SYSTEM*	ALL.CREWS	

Table B-4

CREWMAN SUBPROGRAM NAMES

Subprogram Names	Description
REP.AC	Reconstitutes aircraft lost to attrition
SR.CALC	Calculates the sortie rate realized in the scenario
TRACE	Used to produce a time trace of every event executed (debug routine)

*SYSTEM is not actually an entity, but rather a SIMSCRIPT II.5 modeling concept.

Table B-5

CREWMAN GLOBAL ARRAYS

Mnemonic	Type*	Description
AC.RELIEF(30)	I	Number of replacement aircraft due on day i
DAY.CREW.LOSS(2)	I	Daily aircrew losses i = 1 (administrative policy loss) i = 2 (KIA loss)
DAY.MISS.STATS(2)	I	Daily mission statistics i = 1 (missions met) i = 2 (missions missed)
LITE.REQS(2)	I	Daylight mission density i = 1 (air missions) i = 2 (ground alert missions)
MISS.TIME(2)	R	Mission time i = 1 (air missions) i = 2 (ground alert missions)
NITE.REQS(2)	I	Night mission density i = 1 (air missions) i = 2 (ground alert missions)
RATIOS(50)	R	Aircrew seat ratios for replicated runs
SRATES(50)	R	Sortie rates for replicated runs
SUM.CREW.LOSS(2)	I	Total aircrew losses i = 1 (administrative policy loss) i = 2 (KIA loss)
SUM.MISS.STATS(2)	I	Total mission statistics i = 1 (missions met) i = 2 (missions missed)
TEMPO(30)	I	Aircraft availability tempo for day i 1 signifies normal 2 signifies surge 4 signifies no fly

*I - Integer, R - Real

Table B-6

CREWMAN GLOBAL VARIABLES

Mnemonic	Type*	Description
AC.LR	R	Aircraft attrition per sortie
ARM.FUEL	R	Rearm and refuel time
BRIEF	R	Number of hours for pre-mission brief (also used for length of post-mission debrief)
CONSECUTIVE.DAYS	I	Consecutive duty days allowed by policy
CUT.OFF	R	Value of total flight hours above which aircrew is included in summary statistics
CREW.LR	R	Aircrew attrition per sortie
CREW.SIZE	I	Number of Marine Corps Aviators/Naval Flight Officers comprising the aircrew
DAILY.LOSS	I	Number of aircraft lost in current day
DAY	I	Current day in the scenario
DAYS.IN.SCENARIO	I	Number of days in the scenario (=30)
DUTY.HRS	R	Number of hours aircrews will be on-duty each day
EJECT.SEAT	A	Indication whether or not aircraft has an ejection seat
HI.CREW	I	Number of aircrews used in the scenario
LAST.RELIEF	I	Last day replacement aircraft arrived
MULTI.PILOT	A	Indication whether or not aircraft is multi-piloted
NAME	A	Aircraft type
NOFLY.DAYS	I	Number of non-flying days in scenario
NORM.MAINT	R	Normal maintenance hours per flight hour
NUM.RUN	I	Current computer run number in a replication series
PRESSURE	A	Indication whether or not aircraft is pressurized
QUANTITY	I	Quantity of aircraft on hand at start of the day
SOR.RATE	R	Current sortie rate realized in the scenario
SURGE.DAYS	I	Number of surge days at start of the scenario
SURGE.MAINT	R	Surge maintenance hours per flight hour
TOT.USED	I	Total number of aircraft used
TYPE	A	Squadron type
UE	I	Number of aircraft in squadron
UE.DELAY	I	Number of days delay before aircraft replacement
UE.RECONST	I	Number of aircraft allowed every delay period
30DFT	I	Maximum allowed flight hours per aircrew in 30 days
7DFT	I	Maximum allowed flight hours per aircrew in 7 days
24HFT	I	Maximum allowed flight hours per aircrew in 24 hours
24HF	I	Maximum allowed aircrew sorties in 24 hours

*A - Alpha, I - Integer, R - Real

CREWMAN PROGRAM LISTING

```
''      CREWMAN
''  ROBERT S. GARNERO
''  SRI INTERNATIONAL
''  DECEMBER    1977

   PREAMBLE

NORMALLY MODE IS INTEGER AND DIMENSION IS 0

PERMANENT ENTITIES

      EVERY AC.STATE OWNS AN AC.SET
''    1-IDLE  2-ASSIGNMENT  3-NOT AVAILABLE

      EVERY CREW.STATE OWNS A CREW.SET
''    1-REST  2-MISC. DUTY  3-FLIGHT DUTY

TEMPORARY ENTITIES

      EVERY AIRCRAFT HAS A BACKLOG AND A FLT.TIME AND BELONGS TO AN AC.SET

      DEFINE BACKLOG,FLT.TIME AS REAL VARIABLES

GENERATE LIST ROUTINES

      EVERY CREW HAS A NUMBER, A TOT.FLIGHTS, A TOT.FHRS, A TOT.MISC.DUTY,
      A CUR.SORT, A CUR.FHRS, A LAST.OFF, A CUM.FHRS, AND A TIME.REST AND
      BELONGS TO THE ALL.CREWS AND A CREW.SET

      DEFINE TOT.FHRS,TOT.MISC.DUTY,CUR.FHRS,CUM.FHRS,TIME.REST
      AS REAL VARIABLES

INHIBIT LIST ROUTINES

EVENT NOTICES

      EVERY END.MISSION HAS A PILOT IN WORD 6
      EVERY END.DUTY HAS A PILOT IN WORD 6
      EVERY END.SORTIE HAS A PLANE IN WORD 6
      EVERY READY HAS A PLANE IN WORD 6
      EVERY START.DUTY HAS A PILOT IN WORD 6
      EVERY MISSION HAS A KIND IN WORD 6
      EVENT NOTICES INCLUDE NEW.DAY

THE SYSTEM OWNS THE ALL.CREWS

DEFINE UE,CREW.SIZE, NOFLY.DAYS,SURGE.DAYS,UE.DELAY,UE.RECONST,
         DAY,HI.CREW,TOT.USED,QUANITY,DAILY.LOSS,LAST.RELIEF,CONSECUTIVE.DAYS,
          DAYS.IN.SCENARIO,30DFT,7DFT,24HFT,24HF,NUM.RUN AS VARIABLES

DEFINE MULTI.PILOT,EJECT.SEAT,PRESSURE,TYPE,NAME AS ALPHA VARIABLES

DEFINE LITE.REQS,NITE.REQS,DAY.MISS.STATS,DAY.CREW.LOSS,SUM.MISS.STATS,
```

```
        SUM.CREW.LOSS,AC.RELIEF.TEMPO AS 1-DIM ARRAYS

DEFINE NORM.MAINT,SURGE.MAINT,CREW.LR,AC.LR,DUTY.HRS,BRIEF,SOR.RATE
        ,CUT.OFF ,ARM.FUEL AS REAL VARIABLES

DEFINE MISS.TIME,SRATES,RATIOS AS REAL 1-DIM ARRAYS

END
```

```
MAIN

DEFINE DUM AS AN ALPHA VARIABLE
DEFINE REC.RATE,INIT.CREWS,GO.ON AS REAL VARIABLES
DEFINE STATS AS REAL 1-DIM ARRAY

   LET DAYS.IN.SCENARIO=30
   LET CONSECUTIVE.DAYS=6
   LET 30DFT.S= 65
   LET 30DFT.M=100
   LET 30DFT.P=120
   LET 30DFT.E=80
   LET  7DFT.S= 30
   LET  7DFT.M= 50
   LET 24HFT.S=  7
   LET 24HFT.M= 12
   LET 24HF.S =  2
   LET 24HF.M =  3
RESERVE LITE.REQS AS 2, NITE.REQS AS 2, DAY.MISS.STATS AS 2,
        DAY.CREW.LOSS AS 2, SUM.MISS.STATS AS 2, SUM.CREW.LOSS AS 2,
        AC.RELIEF AS 30, TEMPO AS 30, MISS.TIME AS 2
RESERVE RATIOS AS 50, STATS AS 8, SRATES AS 50
CREATE EVERY AC.STATE(3)
CREATE EVERY CRUW.STATE(3)

''READ A NEW CARD
'READ'
START NEW CARD
READ DUM
   IF DUM="END "

''STOP SIMULATIONS
     STOP
   ALWAYS
   IF DUM="SQDN"

''SQUADRON CARD
   READ DUM,TYPE
   READ DUM,NAME
   READ DUM,UE
   READ DUM,NORM.MAINT
   READ DUM,SURGE.MAINT
   READ DUM,ARM.FUEL
   READ DUM,MULTI.PILOT
   READ DUM,PRESSURE
   READ DUM,EJECT.SEAT
   GO TO READ
   ALWAYS
   IF DUM="SCEN"

''SCENARIO CARD
   READ DUM,AC.LR
   READ DUM,CREW.LR
```

```
    READ DUM,NOFLY.DAYS
    READ DUM,SURGE.DAYS
    READ DUM,UE.DELAY
    READ DUM,UE.RECONST
    GO TO READ
    ALWAYS
    IF DUM="OPNS"

''OPERATIONS CARD
    READ DUM,DUTY.HRS
    READ DUM,LITE.REQS(1),DUM,NITE.REQS(1)
    READ DUM,LITE.REQS(2),DUM,NITE.REQS(2)
    READ DUM,MISS.TIME(1),DUM,MISS.TIME(2)
    READ DUM,BRIEF
    GO TO READ
    ALWAYS

''RUN CARD
    READ NUM.REPS,WARM.UP,CUT.OFF
    LET NUM.RUN=0

''RANDOMIZE START POINT IN RANDOM SEQUENCE
    FOR I=1 TO WARM.UP LET GO.ON=RANDOM.F(1)

''REPLICATION LOOP

    FOR IL=1 TO NUM.REPS
    DO
    ADD 1 TO NUM.RUN
    LET BETWEEN.V=0

''CALCULATE DAILY TEMPO
    FOR I=1 TO 30  LET TEMPO(I)=1 ''ASSUME NORMAL''
    IF SURGE.DAYS=0
       GO TO WX
    ALWAYS
       FOR I=1 TO SURGE.DAYS LET TEMPO(I)=2  ''SURGE

''INSERT NON FLYING DAYS
'WX'
    FOR I=1 TO NOFLY.DAYS  DO
       LET IDAY=RANDI.F(1,DAYS.IN.SCENARIO,1)
       LET TEMPO(IDAY)=4
                        LOOP

''INITIAL THIS RUN
    FOR I=1 TO UE    DO
       CREATE AN AIRCRAFT
       FILE AIRCRAFT IN AC.SET(1)
                   LOOP



    LET HI.CREW=0
```

```
    LET DAY=0
    LET SOR.RATE=0
    LET LAST.RELIEF=0
    FOR I=1 TO 30 LET AC.RELIEF(I)=0
    FOR I=1 TO 2 DO
       LET SUM.CREW.LOSS(I)=0
       LET SUM.MISS.STATS(I)=0
                LOOP

''OUTPUT INPUT PARAMETERS
    IF NUM.RUN GT 1 GO TO RUN ELSE
    START NEW PAGE
    PRINT 11 LINES WITH TYPE.NAME.UE.NORM.MAINT.SURGE.MAINT.
     ARM.FUEL,MULTI.PILOT,PRESSURE,EJECT.SEAT AS FOLLOWS
                              INPUT SUMMARY

    SQUADRON ATTRIBUTES:

      SQDN     A/C     SQDN    MAINT HR/FLIGHT HR    REARM   MULTI PRESS  EJECT
      TYPE     TYPE    U/E      NORMAL    SURGE      REFUEL  PILOT URIZED SEAT

      ******** ******* ***       **.**     **.**      **.**    ***   ***    ***


    PRINT  8 LINES WITH AC.LR,CREW.LR,NOFLY.DAYS,SURGE.DAYS,UE.DELAY,
    UE.RECONST AS FOLLOWS
    SCENARIO PROPERTIES:

    ATTRTN PER SORTIE       NONFLY    SURGE      A/C RESUPPLY
   A/C             CREW      DAYS      DAYS     DELAY  ALLOTMNT

   *.****        *.****       **        **        **      **


    PRINT  8 LINES WITH DUTY.HRS,LITE.REQS(1),NITE.RECS(1),LITE.REQS(2),
    NITE.REQS(2),MISS.TIME(1),MISS.TIME(2),BRIEF AS FOLLOWS
   OPERATIONS DOCTRINE:

      DAILY     MISSION REQUESTS     ALERT REQUESTS     MISSION TIME    BRIEF
     DUTY HRS  DAY           NITE   DAY          NITE  NORMAL   ALERT   TIMES

       **.*     ***           ***    ***          ***   **.*     **.*    **.*


 PRINT 6 LINES WITH NUM.REPS,WARM.UP.CUT.OFF AS FOLLOWS
    RUN INFORMATION:

     NUMBER       RANDOM NO.    FLIGHT HOUR
   REPLICATIONS     SEED          CUT OFF
```

```
      ***          *******          **.**

''DETERMINE STANDARDS THAT APPLY: ASSUME SINGLE SEAT,NO PRESSURE
''AND NO EJECTION SEAT
   LET CREW.SIZE=1
   LET 30DFT=30DFT.S  ''UNITS ARE HOURS
   LET  7DFT= 7DFT.S
   LET 24HFT=24HFT.S
   LET 24HF =24HF.S
   IF MULTI.PILOT="YES "
      LET CREW.SIZE=2
      LET 30DFT=30DFT.M
      LET  7DFT= 7DFT.M
      LET 24HFT=24HFT.M
      LET 24HF =24HF.M
      IF PRESSURE="YES "
         LET 30DFT=30DFT.P
         IF EJECT.SEAT="YES "
            LET 30DFT=30DFT.E
         ALWAYS
      ALWAYS
   ALWAYS

'RUN'
   SCHEDULE A NEW.DAY NOW
   START SIMULATION
''END REPLICATION
   LOOP
     FOR IL=1 TO NUM.REPS
     COMPUTE STATS(1) AS MEAN,
             STATS(2) AS STD,
             STATS(3) AS MAX,
             STATS(4) AS MIN OF RATIOS(IL)
     FOR IL=1 TO NUM.REPS
     COMPUTE STATS(5) AS MEAN,
             STATS(6) AS STD,
             STATS(7) AS MAX,
             STATS(8) AS MIN OF SRATES(IL)
     START NEW PAGE
     PRINT  8 LINES WITH NUM.REPS,STATS(1),STATS(2),
        STATS(3),STATS(4),STATS(5),STATS(6),STATS(7),STATS(8) AS FOLLOWS
MULTIPLE CASE STATISTICS:

        (STATISTICS FOR ** REPLICATIONS OF THIS CASE)

        AIRCREW SEAT RATIO                        SORTIE RATE
   MEAN    STD.DEV    MAX    MIN         MEAN    STD.DEV    MAX    MIN

  **.**    **.**    **.**  **.**        **.**    **.**    **.**  **.**

   GO TO READ
   END
```

LOCAL VARIABLES OF THIS ROUTINE

CUM	ALPHA	WORD	1	GO.ON	REAL	WORD	4
I	INTEGER	WORD	30	I.1	INTEGER	WORD	19
I.2	INTEGER	WORD	20	I.3	INTEGER	WORD	21
IDAY	INTEGER	WORD	32	IL	INTEGER	WORD	31
INIT.CREWS	REAL	WORD	3	J.1	INTEGER	WORD	22
K.1	INTEGER	WORD	24	K.2	INTEGER	WORD	25
K.3	INTEGER	WORD	26	K.4	INTEGER	WORD	27
L.28	DOUBLE	WORD	33	L.29	DOUBLE	WORD	35
L.30	DOUBLE	WORD	37	L.31	DOUBLE	WORD	39
L.32	DOUBLE	WORD	41	L.33	DOUBLE	WORD	43
L.37	DOUBLE	WORD	45	L.38	DOUBLE	WORD	47
L.39	DOUBLE	WORD	49	L.40	DOUBLE	WORD	51
L.41	DOUBLE	WORD	53	L.42	DOUBLE	WORD	55
N.1	INTEGER	WORD	23	NUM.REPS	INTEGER	WORD	28
R.1	DOUBLE	WORD	17	REC.RATE	REAL	WORD	2
STATS	REAL	WORD	5	WARM.UP	INTEGER	WORD	29
24HFT.M	INTEGER	WORD	13	24HFT.S	INTEGER	WORD	12
24HF.M	INTEGER	WORD	15	24HF.S	INTEGER	WORD	14
30DFT.E	INTEGER	WORD	9	30DFT.M	INTEGER	WORD	7
30DFT.P	INTEGER	WORD	8	30DFT.S	INTEGER	WORD	6
7DFT.M	INTEGER	WORD	11	7DFT.S	INTEGER	WORD	10

```
EVENT NEW.DAY

DEFINE SEAT.RATIO AS A REAL VARIABLE
DEFINE STATS, CREW.STATS AS REAL 1-DIM ARRAYS
RESERVE STATS AS 8, AND CREW.STATS AS 3

LET TIME.V=TIME.S
LET YTD=DAY
ADD 1 TO DAY

''TRIGGER DEBUG TRACE ON DAY INDICATED
IF DAY=99 LET BETWEEN.V='TRACE'
ALWAYS

IF DAY=1
IF NUM.RUN GT 1 JUMP AHEAD ELSE
   START NEW PAGE
   PRINT 8 LINES AS FOLLOWS
                              SIMULATION RESULTS


DAILY SUMMARIES (RUN NO. 1 IF CASE REPLICATED):

 DAY   CREW LOSS    HI  AVAIL  CREW FLT.HR    CREW AVE    MISSION STATS
      ADMIN   KIA  CREW  A/C  AVE       MAX  MISC.DUTY  MET       MISSED

HERE
   LET QUANITY=UE
   LET TOT.USED=UE
   GO TO GEN
ALWAYS
   CALL SR.CALC
   IF TEMPO(YTD)=4
   IF NUM.RUN GT 1 JUMP AHEAD ELSE
     PRINT 1 LINE WITH YTD AS FOLLOWS
 **  NONFLYING DAY

HERE
   ADD NITE.REQS(1)+NITE.REQS(2)+LITE.REQS(1)+LITE.REQS(2) TO
   SUM.MISS.STATS(2)
   GO TO END.CHECK
   ALWAYS

''OUTPUT DAILY STATISTICS  SKIPPING LOST CREWS
  IF NUM.RUN GT 1 JUMP AHEAD ELSE
   FOR EACH CREW OF ALL.CREWS, WITH TIME.REST(CREW) GE 0
   COMPUTE CREW.STATS(1) AS MEAN, CREW.STATS(2) AS MAXIMUM OF CUR.FHRS(CREW)
   FOR EACH CREW OF ALL.CREWS , WITH TIME.REST(CREW) GE 0
   COMPUTE CREW.STATS(3) AS MEAN OF
    DUTY.HRS-CUR.FHRS(CREW)-CUR.SORT(CREW)*2*BRIEF
   PRINT 1 LINE WITH YTD,DAY.CREW.LOSS(1),DAY.CREW.LOSS(2),HI.CREW,QUANITY,
   CREW.STATS(1),CREW.STATS(2),CREW.STATS(3),DAY.MISS.STATS(1),
   DAY.MISS.STATS(2) AS FOLLOWS
```

```
     **    ***    ***  ***   ***  **.*     **.*    **.*     ***       ***

HERE
'END.CHECK'
   IF DAY=DAYS.IN.SCENARIO+1

''OUTPUT SUMMARY STATISTICS

   LET COUNT=0
   FOR EACH CREW OF ALL.CREWS WITH TOT.FHRS(CREW)
      GT CUT.OFF ADD 1 TO COUNT
   LET SEAT.RATIO=COUNT/UE
   LET RATIOS(NUM.RUN)=SEAT.RATIO
   LET SRATES(NUM.RUN)=SOR.RATE
   IF NUM.RUN GT 1 GO TO NEW ELSE
   START NEW PAGE
   FOR EACH CREW OF ALL.CREWS WITH TOT.FHRS(CREW) GT CUT.OFF
   COMPUTE STATS(1) AS MEAN, STATS(2) AS STD, STATS(3) AS MAX, STATS(4) AS MIN
   OF TOT.FLIGHTS(CREW)
   FOR EACH CREW OF ALL.CREWS WITH TOT.FHRS(CREW) GT CUT.OFF
   COMPUTE STATS(5) AS MEAN, STATS(6) AS STD, STATS(7) AS MAX, STATS(8) AS MIN
   OF TOT.FHRS(CREW)

  PRINT 10 LINES WITH CUT.OFF, SEAT.RATIO AS FOLLOWS
SCENARIO TOTALS (RUN NO. 1 IF CASE REPLICATED):

(STATISTICS REFLECT THOSE CREWS WITH TOTAL FLIGHT HRS GREATER THAN **.**)

                               AIRCREW SEAT
                                  RATIO

                                  *.**


   PRINT 6 LINES WITH STATS(1),STATS(2),STATS(3),STATS(4),STATS(5),STATS(6),
   STATS(7),STATS(8),SUM.CREW.LOSS(1),SUM.CREW.LOSS(2),COUNT AS FOLLOWS
    CREW SORTIES FLOWN    CREW TTL FLIGHT HRS    CREW LOSS    CREW
   MEAN STD.DEV  MAX MIN  MEAN STD.DEV MAX  MIN   ADMIN  KIA   COUNT

   **.*  **.*    **  **   **.*  **.*   **.* **.*  ***    ***    ***


   FOR EACH CREW OF ALL.CREWS WITH TOT.FHRS(CREW) GT CUT.OFF
   COMPUTE STATS(1) AS MEAN, STATS(2) AS STD, STATS(3) AS MAX, STATS(4) AS MIN
   OF TOT.MISC.DUTY(CREW)

   PRINT 4 LINES WITH STATS(1),STATS(2),STATS(3),STATS(4),TOT.USED,SOR.RATE,
   SUM.MISS.STATS(1),SUM.MISS.STATS(2) AS FOLLOWS
       CREW TTL MISC.DUTY      A/C     A/C SORTIE     MISSION STATS
    MEAN  STD.DEV  MAX   MIN   USED       RATE       MET      MISSED
```

```
         ***.*  ***.*  ***.* ***.*   ***          *.**       ****       ****

   PRINT 4 LINES AS FOLLOWS

      TOTAL FLIGHT HRS FOR EACH CREW (RUN NO. 1 IF CASE REPLICATED)


   FOR EACH CREW OF ALL.CREWS
     PRINT 1 LINE WITH NUMBER(CREW), TOT.FHRS(CREW) AS FOLLOWS
                  CREW NUMBER *** HAS  ***.**  TOT.FHRS

''PREPARE TO RUN A NEW CASE

'NEW'
   FOR I=1 TO 3      DO
'KC' FOR EACH CREW OF CREW.SET(I),FIND THE FIRST CASE
       IF NONE
          JUMP AHEAD
       ALWAYS
          REMOVE THE CREW FROM ALL.CREWS
          REMOVE THE CREW FROM CREW.SET(I)
          DESTROY THE CREW
          GO TO KC
HERE
'KA' FOR EACH AIRCRAFT OF AC.SET(I),FIND THE FIRST CASE
       IF NONE
          CYCLE
       ALWAYS
          REMOVE THE AIRCRAFT FROM AC.SET(I)
          DESTROY THE AIRCRAFT
          GO TO KA
                        LOOP

'K1' FOR EACH END.DUTY OF EV.S(I.END.DUTY), FIND THE FIRST CASE
       IF NONE
          JUMP AHEAD
       ALWAYS
          CANCEL THE END.DUTY
          DESTROY THE END.DUTY
          GO TO K1
HERE
'K2' FOR EACH END.MISSION OF EV.S(I.END.MISSION), FIND THE FIRST CASE
       IF NONE
          JUMP AHEAD
       ALWAYS
          CANCEL THE END.MISSION
          DESTROY THE END.MISSION
          GO TO K2
HERE
'K3' FOR EACH END.SORTIE OF EV.S(I.END.SORTIE), FIND THE FIRST CASE
       IF NONE
          JUMP AHEAD
```

```
         ALWAYS
            CANCEL THE END.SORTIE
            DESTROY THE END.SORTIE
            GO TO K3
   HERE
   'K4' FOR EACH READY OF EV.S(I.READY), FIND THE FIRST CASE
         IF NONE
            JUMP AHEAD
         ALWAYS
            CANCEL THE READY
            DESTROY THE READY
            GO TO K4
   HERE
   'K5' FOR EACH START.DUTY OF EV.S(I.START.DUTY), FIND THE FIRST CASE
         IF NONE
            JUMP AHEAD
         ALWAYS
            CANCEL THE START.DUTY
            DESTROY THE START.DUTY
            GO TO K5
   HERE
   'K6' FOR EACH MISSION OF EV.S(I.MISSION), FIND THE FIRST CASE
         IF NONE
            JUMP AHEAD
         ALWAYS
            CANCEL THE MISSION
            DESTROY THE MISSION
            GO TO K6
   HERE
   'K7' FOR EACH NEW.DAY OF EV.S(I.NEW.DAY), FIND THE FIRST CASE
         IF NONE
            LET TIME.V=0  LET TIME.S=0  GO TO CONT
         ALWAYS
            CANCEL THE NEW.DAY
            DESTROY THE NEW.DAY
            GO TO K7
      ALWAYS

   ''REPLACE AIRCRAFT
      CALL REP.AC
      IF TEMPO(DAY)=4  GO TO SKIP ''NO MISSION GENERATION ON NO FLY DAY
      ALWAYS

   ''SCHEDULE MISSIONS
   'GEN'
      FOR I=1 TO 2  DO
         FOR J=1 TO LITE.REQS(I) DO
            SCHEDULE  A MISSION(I) AT TIME.V+UNIFORM.F(0.,.5,1)
                                      LOOP
         FOR J=1 TO NITE.REQS(I) DO
            SCHEDULE  A MISSION(I) AT TIME.V+UNIFORM.F(.5,1.,2)
                                      LOOP
                         LOOP
```

```

''INITIAL DAILY COUNTERS AND SCHEDULE A NEW DAY
'SKIP'
    FOR I=1 TO 2 DO
       LET DAY.CREW.LOSS(I)=0
       LET DAY.MISS.STATS(I)=0
                    LOOP
    LET DAILY.LOSS=0
    SCHEDULE A NEW.DAY IN 1 DAYS
'CONT'
    RETURN
    END
```

LOCAL VARIABLES OF THIS ROUTINE

COUNT	INTEGER	WORD 33	CREW.STATS	REAL	WORD 3
I	INTEGER	WORD 78	I.1	INTEGER	WORD 7
I.2	INTEGER	WORD 8	I.3	INTEGER	WORD 9
J	INTEGER	WORD 88	J.1	INTEGER	WORD 10
K.1	INTEGER	WORD 12	K.2	INTEGER	WORD 13
K.3	INTEGER	WORD 14	K.4	INTEGER	WORD 15
L.100	INTEGER	WORD 87	L.12	INTEGER	WORD 25
L.13	DOUBLE	WORD 27	L.14	DOUBLE	WORD 29
L.15	DOUBLE	WORD 31	L.19	INTEGER	WORD 34
L.23	INTEGER	WORD 35	L.24	DOUBLE	WORD 37
L.25	DOUBLE	WORD 39	L.26	DOUBLE	WORD 41
L.27	DOUBLE	WORD 43	L.28	DOUBLE	WORD 45
L.29	DOUBLE	WORD 47	L.33	INTEGER	WORD 49
L.34	DOUBLE	WORD 51	L.35	DOUBLE	WORD 53
L.36	DOUBLE	WORD 55	L.37	DOUBLE	WORD 57
L.38	DOUBLE	WORD 59	L.39	DOUBLE	WORD 61
L.4	INTEGER	WORD 16	L.43	INTEGER	WORD 63
L.44	DOUBLE	WORD 65	L.45	DOUBLE	WORD 67
L.46	DOUBLE	WORD 69	L.47	DOUBLE	WORD 71
L.48	DOUBLE	WORD 73	L.49	DOUBLE	WORD 75
L.5	DOUBLE	WORD 17	L.53	INTEGER	WORD 77
L.6	DOUBLE	WORD 19	L.60	INTEGER	WORD 79
L.65	INTEGER	WORD 80	L.7	DOUBLE	WORD 21
L.70	INTEGER	WORD 81	L.75	INTEGER	WORD 82
L.8	DOUBLE	WORD 23	L.80	INTEGER	WORD 83
L.85	INTEGER	WORD 84	L.90	INTEGER	WORD 85
L.95	INTEGER	WORD 86	N.1	INTEGER	WORD 11
R.1	DOUBLE	WORD 5	SEAT.RATIO	REAL	WORD 1
STATS	REAL	WORD 2	YTD	INTEGER	WORD 4

```
EVENT MISSION(KIND)

DEFINE SDAY AS A REAL VARIABLE

LET TIME.V=TIME.S
IF N.AC.SET(1) EQ 0   ''NO AC AVAILABLE
   ADD 1 TO DAY.MISS.STATS(2)
   ADD 1 TO SUM.MISS.STATS(2)
   RETURN

ALWAYS  ''MISSION WILL BE FILLED
   ADD 1 TO DAY.MISS.STATS(1)
   ADD 1 TO SUM.MISS.STATS(1)

''FIND CREW MOST NEAR END DUTY WITH TIME TO FILL MISSION
   FOR EACH CREW OF CREW.SET(2), WITH TIME.V+MISS.TIME(KIND)/24+2*BRIEF/24 LE
   TIME.REST(CREW) AND 24HFT-CUR.FHRS(CREW) GE MISS.TIME(KIND)/24 AND
   24HF-CUR.SORT(CREW) GT 0
      FIND THE FIRST CASE
      IF NONE GO TO BIRTH
      ALWAYS
      FOR EACH CREW OF CREW.SET(2), WITH TIME.V+MISS.TIME(KIND)/24
      +2*BRIEF/24 LE TIME.REST(CREW) AND 24HFT-CUR.FHRS(CREW) GE
      MISS.TIME(KIND)/24 AND 24HF-CUR.SORT(CREW) GT 0
      COMPUTE IMIN AS MIN(CREW) OF TIME.REST(CREW)
      LET CREW=IMIN
      REMOVE THE CREW FROM CREW.SET(2)
      GO TO GETAC

''NEED A CREW
'BIRTH'
   CREATE A CREW    FILE CREW IN ALL.CREWS
   ADD 1 TO HI.CREW LET NUMBER(CREW)=HI.CREW
   LET TIME.REST(CREW)=TIME.V+DUTY.HRS/24
   SCHEDULE AN END.DUTY(CREW) AT TIME.REST(CREW)
   LET IDAY=RANDI.F(1,CONSECUTIVE.DAYS,1)
   LET LAST.OFF(CREW)=DAY-IDAY

'GETAC'
   FOR EACH AIRCRAFT OF AC.SET(1) FIND THE FIRST CASE
   REMOVE THE AIRCRAFT FROM AC.SET(1)
   LET FLT.TIME(AIRCRAFT)=MISS.TIME(KIND)
   IF BETWEEN.V NE 0 PRINT 1 LINE WITH CREW, AIRCRAFT AS FOLLOWS
-----CREW          * AND AIRCRAFT          * ARE FILLING THE MISSION

   ALWAYS
''TREAT ALERT MISSION
   IF KIND=2
         FILE AIRCRAFT IN AC.SET(2)   ''ASSIGNMENT
         FILE CREW     IN CREW.SET(3) ''FLIGHT DUTY
         SCHEDULE AN END.MISSION(CREW) AT TIME.V+MISS.TIME(2)/24+2*BRIEF/24
         SCHEDULE AN END.SORTIE(AIRCRAFT)  AT TIME.V+MISS.TIME(2)/24+ BRIEF/24
         RETURN
```

```
    ALWAYS

''DETERMINE CREW SURVIVABILITY
    LET NEXT.STATE=3
    IF RANDOM.F(1) LE CREW.LR ''CREW LOST

''REMOVE THE END.DUTY EVENT FOR THIS CREW
            FOR EACH END.DUTY OF EV.S(I.END.DUTY) WITH
            PILOT(END.DUTY)=CREW FIND THE FIRST CASE
            CANCEL THE END.DUTY
            DESTROY END.DUTY
            ADD MISS.TIME(1)/2  TO TOT.FHRS(CREW)  ''GIVE CREDIT FOR 1/2 SORTIE
            ADD MISS.TIME(1)/2  TO CUR.FHRS(CREW)
            LET SDAY=TIME.REST(CREW)-DUTY.HRS/24
            ADD (TIME.V-SDAY)*24-CUR.SORT(CREW)*(MISS.TIME(1)+2*BRIEF) TO
            TOT.MISC.DUTY(CREW)      ADD 1 TO DAY.CREW.LOSS(2)
            LET NEXT.STATE=1  ADD 1 TO SUM.CREW.LOSS(2)
            LET TIME.REST(CREW)=-1 ''FLAG KIA LOST CREW

            IF BETWEEN.V NE 0  PRINT 1 LINE WITH CREW AS FOLLOWS
-----CREW     * LOST

            ALWAYS  JUMP AHEAD
    ALWAYS
            ADD MISS.TIME(1) TO TOT.FHRS(CREW)
            ADD MISS.TIME(1) TO CUR.FHRS(CREW)
            ADD MISS.TIME(1) TO CUM.FHRS(CREW)
            SCHEDULE AN END.MISSION(CREW) AT TIME.V+MISS.TIME(1)/24+2*BRIEF/24
            ADD 1 TO CUR.SORT(CREW)
            ADD 1 TO TOT.FLIGHTS(CREW)
HERE
    FILE CREW IN CREW.SET(NEXT.STATE)

''DETERMINE A/C SURVIVABILITY
    IF RANDOM.F(1) LE AC.LR  ''A/C LOST
            ADD 1 TO DAILY.LOSS
            DESTROY THE AIRCRAFT
            IF BETWEEN.V NE 0 PRINT 1 LINE WITH AIRCRAFT AS FOLLOWS
-----AIRCRAFT     * LOST

            ALWAYS RETURN
    ALWAYS SCHEDULE AN END.SORTIE(AIRCRAFT) AT TIME.V+MISS.TIME(1)/24+BRIEF/24
    FILE AIRCRAFT IN AC.SET(2) ''ASSIGNMENT
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

I.1	INTEGER	WORD 21	I.2	INTEGER	WORD 22
I.3	INTEGER	WORD 23	IDAY	INTEGER	WORD 16
IMIN	INTEGER	WORD 15	J.1	INTEGER	WORD 24
K.1	INTEGER	WORD 26	K.2	INTEGER	WORD 27
K.3	INTEGER	WORD 28	K.4	INTEGER	WORD 29
KIND	INTEGER	WORD 1	L.10	DOUBLE	WORD 7
L.11	DOUBLE	WORD 9	L.12	DOUBLE	WORD 11
L.13	DOUBLE	WORD 13	L.17	INTEGER	WORD 17
L.21	INTEGER	WORD 31	L.4	INTEGER	WORD 4
L.9	INTEGER	WORD 5	N.1	INTEGER	WORD 25
NEXT.STATE	INTEGER	WORD 30	R.1	DOUBLE	WORD 19
SDAY	REAL	WORD 3			

```
EVENT END.DUTY(PILOT)

DEFINE RESTYM AS A REAL VARIABLE

LET TIME.V=TIME.S
LET CREW=PILOT
REMOVE THE CREW FROM CREW.SET(2)
FILE THE CREW IN CREW.SET(1)
ADD DUTY.HRS-CUR.SORT(CREW)*(MISS.TIME(1)+2*BRIEF) TO TOT.MISC.DUTY(CREW)

IF TOT.FHRS(CREW) GE 30DFT ''30 DAY EXHAUSTION; LEAVE CREW IN REST FOR EVER
    ADD 1 TO DAY.CREW.LOSS(1)
    ADD 1 TO SUM.CREW.LOSS(1)
    LET TIME.REST(CREW)=-1 ''FLAG ADMIN LOST CREW
    RETURN
ALWAYS

IF CUM.FHRS(CREW) GE 7DFT ''7 DAY EXHAUSTION'' OR DAY-LAST.OFF(CREW) GE
CONSECUTIVE.DAYS ''TO MANY CONSECUTIVE DUTY DAYS
    LET CUM.FHRS(CREW)=0
    LET LAST.OFF(CREW)=DAY+1
    LET RESTYM=1+1-DUTY.HRS/24            ''EXTENDED REST
    GO TO RESET
ALWAYS
    LET RESTYM=1-DUTY.HRS/24  ''NORMAL REST

'RESET'
SCHEDULE A START.DUTY(CREW) AT TIME.V+RESTYM
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

PILOT	INTEGER	WORD	1	RESTYM	REAL	WORD	3

```
EVENT END.MISSION(PILOT)

LET TIME.V=TIME.S
LET CREW=PILOT
REMOVE THE CREW FROM CREW.SET(3)
FILE THE CREW IN CREW.SET(2)
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

```
PILOT       INTEGER  WORD  1
```

```
EVENT START.DUTY(PILOT)

LET TIME.V=TIME.S
LET CREW=PILOT
REMOVE THE CREW FROM CREW.SET(1)
FILE THE CREW IN CREW.SET(2)
LET TIME.REST(CREW)=TIME.V+DUTY.HRS/24
SCHEDULE AN END.DUTY(CREW) AT TIME.REST(CREW)
LET CUR.SORT(CREW)=0
LET CUR.FHRS(CREW)=0
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

```
PILOT       INTEGER  WORD  1
```

```
EVENT END.SORTIE(PLANE)

DEFINE DOWN AS A REAL VARIABLE
LET TIME.V=TIME.S
LET AIRCRAFT=PLANE
REMOVE THE AIRCRAFT FROM AC.SET(2)
FILE AIRCRAFT IN AC.SET(3)
LET INDEX=TEMPO(DAY)
IF INDEX=2 GO TO SURGE ELSE
''NORMAL MAINT
LET DOWN=(BACKLOG(AIRCRAFT)+FLT.TIME(AIRCRAFT)*NORM.MAINT+ARM.FUEL)/24
LET BACKLOG(AIRCRAFT)=0
GO TO SCHED
'SURGE'
LET DOWN=(FLT.TIME(AIRCRAFT)*SURGE.MAINT+ARM.FUEL)/24
LET BACKLOG(AIRCRAFT)=BACKLOG(AIRCRAFT)+MAX.F(0.(NORM.MAINT-SURGE.MAINT)
                                                        *FLT.TIME(AIRCRAFT))
'SCHED'
LET FLT.TIME(AIRCRAFT)=0
SCHEDULE A READY(AIRCRAFT) AT TIME.V+DOWN
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

DOWN	REAL	WORD 3		INDEX	INTEGER	WORD 4	
PLANE	INTEGER	WORD 1					

```
EVENT READY(PLANE)

LET TIME.V=TIME.S
LET AIRCRAFT=PLANE
REMOVE THE AIRCRAFT FROM AC.SET(3)
FILE THE AIRCRAFT IN AC.SET(1)
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

```
PLANE      INTEGER  WORD  1
```

```
RCUTINE REP.AC
''THIS ROUTINE RECONSTITUTES AIRCRAFT

''SCHEDULE FUTURE REPLACEMENTS
LET GCNE=DAILY.LOSS
LET ORDAY=MAX.F(DAY-1+UE.DELAY,LAST.RELIEF)
'MORE'
      IF ORDAY GT DAYS.IN.SCENARIO JUMP AHEAD
      ALWAYS
      LET LAST.RELIEF=CRDAY
      LET AVAIL=UE.RECCNST-AC.RELIEF(ORDAY)
      ADD MIN.F(GCNE,AVAIL) TO AC.RELIEF(ORDAY)
      LET GONE=GONE-AVAIL
      IF GONE GT 0
            LET ORDAY=ORDAY+UE.DELAY
            GO TC MCRE
      ALWAYS
      IF AC.RELIEF(ORCAY)=UE.RECONST
      LET LAST.RELIEF=CRDAY+UE.DELAY
      ALWAYS
HERE
      ADD AC.RELIEF(DAY) TO TOT.USED
      LET QUANITY=QUANITY-DAILY.LOSS+AC.RELIEF(DAY)

''REPLACE A/C
      FOR I=1 TO AC.RELIEF(DAY)
      DC
            CREATE AN AIRCRAFT
            FILE AIRCRAFT IN AC.SET(1)
      LOOP
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

AVAIL	INTEGER	WORD	3	GONE	INTEGER	WCRC	1
I	INTEGER	WORD	4	ORDAY	INTEGER	WORC	2

```
ROUTINE SR.CALC
''THIS ROUTINE CALCULATES CURRENT SORTIE RATE

DEFINE NO.AC AS A REAL VARIABLE

''A/C REDUCED BY 1/2 LOST
LET NO.AC=QUANITY-DAILY.LOSS/2
LET SOR.RATE=(DAY.MISS.STATS(1)/NO.AC+(DAY-1)*SOR.RATE)/DAY
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

```
NO.AC        REAL        WORD  1
```

```
ROUTINE TO TRACE
''THIS ROUTINE USED FOR DEBUGGING IF DESIRED
''IT TRACKS THE TIME OF EACH EVENT WITH ASSOC. INFO

GO TO 1,2,3,4,5,6,7 PER EVENT.V

'1'
PRINT 1 LINE WITH TIME.V,PILOT(END.DUTY) AS FOLLOWS
$$$$$AT TIME **.**  CREW           * IS ENDING DUTY
RETURN
'2'

PRINT 1 LINE WITH TIME.V,PILOT(END.MISSION) AS FOLLOWS
$$$$$AT TIME **.**  CREW           * IS ENDING MISSION
RETURN

'3'
PRINT 1 LINE WITH TIME.V,PLANE(END.SORTIE) AS FOLLOWS
+++++AT TIME **.**  A/C            * IS ENDING SORTIE
RETURN

'4'
PRINT 1 LINE WITH TIME.V,PLANE(READY) AS FOLLOWS
+++++AT TIME **.**  A/C            * IS READY
RETURN

'5'
PRINT 1 LINE WITH TIME.V,PILOT(START.DUTY) AS FOLLOWS
$$$$$AT TIME **.**  CREW           * IS STARTING DUTY
LIST ATTRIBUTES OF CREW CALLED PILOT(START.DUTY)
RETURN

'6'
PRINT 1 LINE WITH TIME.V,KIND(MISSION) AS FOLLOWS
>>>>>AT TIME **.**  MISSION        * OCCURS
RETURN

'7'
PRINT 1 LINE WITH DAY+1,TIME.V AS FOLLOWS
>>>>>DAY           *  STARTING AT        **.**
RETURN
END
```

LOCAL VARIABLES OF THIS ROUTINE

I.1	INTEGER	WORD	3	I.2	INTEGER	WORD	4
I.3	INTEGER	WORD	5	J.1	INTEGER	WORD	6
K.1	INTEGER	WORD	8	K.2	INTEGER	WORD	9
K.3	INTEGER	WORD	10	K.4	INTEGER	WORD	11
N.1	INTEGER	WORD	7	R.1	DOUBLE	WORD	1

```
//RSGZZ519 JOB (2490,#SS,4)                                                    JOB 519
***ROUTE PRINT REMOTE34                                                        *OSIWYL*
***ROUTE PUNCH REMOTE34                                                        *OSIWYL*
***RES C=190K
***MESSAGE  DELIVER TO BOB GARNERO  S.R.I. BLDG 30
//SIM EXEC SIM25C
*** CTL CN=A340,JDATE=77189                                                    00000010
***  SIMSCRIPT II.5 COMPILE ONLY                                               00000020
XXSIM    EXEC  PGM=COMP,REGION=190K                                            00000030
XXSTEPLIB  DD  DISP=SHR,DSN=SYS2.SIM25R8                                       00000040
XXSYSPRINT DD  SYSOUT=A                                                        00000050
XXSYSUT1   DD  UNIT=3330,SPACE=(3200,(200,200))                                00000060
XXSYSUT2   DD  UNIT=3330,SPACE=(3200,(50,50))                                  00000070
XXSYSLIN   DD  UNIT=3330,DSN=&&LOADSET,DISP=(MOD,PASS),                        00000080
XX             SPACE=(3200,(120,90))                                           00000090
//SYSIN     DD *                 GENERATED STATEMENT
IEF236I ALLOC. FOR RSGZZ519 SIM       SIM
IEF237I 573    ALLOCATED TO STEPLIB
IEF237I 753    ALLOCATED TO SYSPRINT
IEF237I 585    ALLOCATED TO SYSUT1
IEF237I 584    ALLOCATED TO SYSUT2
IEF237I 585    ALLOCATED TO SYSLIN
IEF237I 720    ALLOCATED TO SYSIN
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I    SYS2.SIM25R8                                 KEPT
IEF285I    VOL SER NOS= STR315.
IEF285I    SYS78006.T135018.RV000.RSGZZ519.R0022922     DELETED
IEF285I    VOL SER NOS= STR317.
IEF285I    SYS78006.T135018.RV000.RSGZZ519.R0022923     DELETED
IEF285I    VOL SER NOS= STR303.
IEF285I    SYS78006.T135018.RV000.RSGZZ519.LOADSET      PASSED
IEF285I    VOL SER NOS= STR317.
IEF373I STEP /SIM      / START 78006.1350
IEF374I STEP /SIM      / STOP  78006.1351 CPU    0MIN 13.94SEC MAIN 174K LCS    0K
****************************************************************************************************
* MACHINE UNITS      1.86          TIME OF DAY        13.51.4  I/O TIME       0.12 STEP TIME       0.23  *
* REGION SIZE    190K USED  174K  NO. OF TAPES-DISKS 00-03 CMP CODE        CC 0000 JOB TIME        0.23  *
* EXCP COUNT       DISK=     669  TAPE=       0  RDR =      750  WTR =      925  PCH =        0          *
****************************************************************************************************
// EXEC SIM25LG
*** CTL CN=A340,JDATE=77189                                                    00000010
***  SIMSCRIPT II.5 LINK-EDIT AND EXECUTE                                      00000020
XXLKED   EXEC  PGM=IEWL,REGION=160K,PARM='LIST,MAP'                            00000030
XXSYSLIB   DD  DISP=SHR,DSN=SYS2.SIMLIB8                                       00000040
XXSYSLIN   DD  DSN=&&LOADSET,DISP=(OLD,DELETE)                                 00000050
XXSYSPRINT DD  SYSOUT=A                                                        00000060
XXSYSUT1   DD  UNIT=3330,SPACE=(1024,(50,20),,,ROUND)                          00000070
//LKED.SYSLMOD DD DSN=CN2490.RSG.LOADLIB(CREWMAN),DISP=(,CATLG,DELETE)
X/SYSLMOD  DD  DSN=&&GOSET(GO),UNIT=(3330,SEP=(SYSUT1)),                       00000080
XX             SPACE=(1024,(50,20,1)),DISP=(,PASS)                             00000090
IEF236I ALLOC. FOR RSGZZ519 LKED
IEF237I 573    ALLOCATED TO SYSLIB
IEF237I 585    ALLOCATED TO SYSLIN
IEF237I 753    ALLOCATED TO SYSPRINT
IEF237I 585    ALLOCATED TO SYSUT1
IEF237I 584    ALLOCATED TO SYSLMOD
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I    SYS2.SIMLIB8                                 KEPT
IEF285I    VOL SER NOS= STR315.
IEF285I    SYS78006.T135018.RV000.RSGZZ519.LOADSET      DELETED
IEF285I    VOL SER NOS= STR317.
IEF285I    SYS78006.T135018.RV000.RSGZZ519.R0022926     DELETED
```

```
IEF285I   VOL SER NOS= STR317.
IEF285I   CN2490.RSG.LOADLIB                                      CATALOGED
IEF285I   VOL SER NOS= STR303.
IEF373I STEP /LKED    / START 78006.1351
IEF374I STEP /LKED    / STOP  78006.1352 CPU    0MIN 01.44SEC MAIN  96K LCS   0K
*****************************************************************************************************
* MACHINE UNITS      0.52          TIME OF DAY          13.52.27 I/O TIME      0.36 STEP TIME        0.02  *
* REGION SIZE    160K USED    96K  NO. OF TAPES-DISKS 00-03 CMP CODE      CC 0000 JOB TIME        0.25  *
* EXCP COUNT        DISK=      503  TAPE=         0  RDR =         0  WTR =     138  PCH =         0       *
*****************************************************************************************************
XXGO      EXEC  PGM=*.LKED.SYSLMOD,REGION=100K                                        00000100
XXSIMU05   DD  DDNAME=SYSIN                                                            00000110
XXSIMU06   DD  SYSOUT=A                                                                00000120
XXSIMU17 DD  DISP=SHR,DSN=SYS2.SIMERR8                                                00000130
//GO.SYSIN DD DSN=CN2490.RSG.TDATA,DISP=SHR
//
IEF236I ALLOC. FOR RSGZZ519 GO
IEF237I 584    ALLOCATED TO PGM=*.DD
IEF237I 345    ALLOCATED TO SIMU05
IEF237I 753    ALLOCATED TO SIMU06
IEF237I 573    ALLOCATED TO SIMU17
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   CN2490.RSG.LOADLIB                                 KEPT
IEF285I   VOL SER NOS= STR303.
IEF285I   CN2490.RSG.TDATA                                   KEPT
IEF285I   VOL SER NOS= WYL301.
IEF285I   SYS2.SIMERR8                                       KEPT
IEF285I   VOL SER NOS= STR315.
IEF373I STEP /GO      / START 78006.1352
IEF374I STEP /GO      / STOP  78006.1352 CPU    0MIN 02.06SEC MAIN  84K LCS   0K
*****************************************************************************************************
* MACHINE UNITS      0.24          TIME OF DAY          13.52.38 I/O TIME      0.01 STEP TIME        0.03  *
* REGION SIZE    100K USED    84K  NO. OF TAPES-DISKS 00-03 CMP CODE      CC 0000 JOB TIME        0.29  *
* EXCP COUNT        DISK=        3  TAPE=         0  RDR =         0  WTR =     128  PCH =         0       *
*****************************************************************************************************
IEF375I  JOB /RSGZZ519/ START 78006.1350
IEF376I  JOB /RSGZZ519/ STOP  78006.1352 CPU    0MIN 17.44SEC
*****************************************************************************************************
*****************************************************************************************************
*                                                           (RLSE 21.8)                                *
*   O P T I M U M   S Y S T E M S   I N C.   2801 NORTHWESTERN  PARKWAY.   SANTA CLARA,   CALIFORNIA.   *
*                                                                                                       *
*                                                                                                       *
* PROJECT                        MACHINE UNITS              2.62   PRIOR 8    DATE      78006      01/06/78   *
*                                                                                                       *
* ACCT-BIN     2490-#SS          TIME EST.,MINUTES             4   CLASS=B    INITIAL TIME         13.50.38   *
*                                                                                                       *
* PROGRAM NO. RSGZZ              LINE ESTIMATE              0100              FINAL TIME           13.52.38   *
*                                                                                                       *
* LOG NO.      519               CARD ESTIMATE              0000              JOB TIME,MINUTES         0.29   *
*                                                                                                       *
*                                                                             COMPUTER           370165 3   *
*                                                                                                       *
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