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COMPUTER SIMULATION OF AIRCREW MANAGEMENT POLICIES

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NOTICES

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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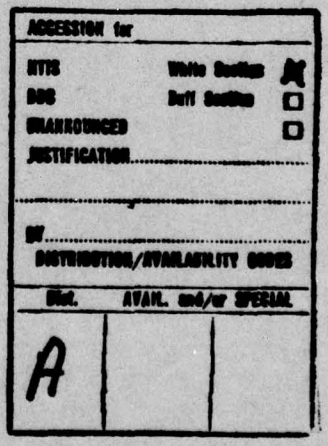

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This report describes a computer program which enables studies on aircrew management policies to be performed. It describes the various inputs, the run time procedures, and the various outputs that were employed in a transport airlift study utilizing the program. The comprehensive but flexible complex of subroutines is easily adapted to inventive, even novel, employment of aircrews. The outputs can then be analyzed for the performance measures of the system.

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COMPUTER SIMULATION OF AIRCREW MANAGEMENT POLICIES

INTRODUCTION

A general simulation computer program capable of representing the major operational attributes of a typical squadron of MAC jet transport aircraft and aircrewmen has been developed by the USAF School of Aerospace Medicine. Given the resources (how many planes, crews), the workload (number and route of missions), and the rules under which to operate (various regulations), the program schedules the missions, selects the crews and planes, and flies the missions, inserting random fluctuations to represent delays and weather variations. During the course of the simulation, the program tracks how the system is performing by acquiring operational data such as cancellations, flying time on each leg, and delays, which can be later assembled into such statistics as time away from home and work-month-hours. Thus, the program permits observing the impact of various management policies on total system performance.

The following sections describe in some detail the general mechanics of the simulation program indicating the input requirements (what we decide beforehand), the simulation logic (what happens while it is running), and the output measures generated by each simulation run (what can be analyzed afterward). The simulation program focuses on "people measures" as well as system measures. Its outputs have been validated twice against operational data of the total MAC C-141 force and have been found to be consistent with total operations.

DESCRIPTION OF THE SIMULATION PROGRAM

Input Requirements (What We Decide Beforehand)

The information to be supplied to the simulation prior to a run can be grouped into five general categories: policy, route system characteristics, resources, workload, and predestined events. The first three of these are placed in the computer at the beginning of the run; the last two are prepared prior to the run and placed on a tape to be fed in as their dates and times come up during the run. These two groups of information are described under the headings "Initialization" and Exogenous Events" respectively.

Initialization--The first group of input parameters provides the means by which policy rules are established. Some of the more important policy input parameters are:

1. Crew Type--The crew types which we have thus far provided are either basic (five members flying according to regulations), augmented

(a complement of up to ten men on duty at the same time), or double (five men on duty at any given time while a second shift of five men is aboard in a resting status). This latter type, which alternates crews from duty to rest during the entire mission, is one of the suggested policies that this simulation was developed to investigate. The initialization defines the number of pilots, navigators, flight engineers, and loadmasters in the squadron. These crew types can be simulated without further computer programming; other crew types could be introduced with rather simple additional programming.

2. Factor for Awarding Free Time--At the completion of a mission, free time is awarded by multiplying the time away from home by a factor set during initialization. A maximum limit for the amount of free time awarded at any one time is also established at initialization. Free time based on differing credits for differing kinds of duty time would require additional programming.

3. Maximum Time Allowed for Delay at Home Base--This parameter is used in determining when to reschedule or cancel a mission. At bases other than home base, missions are not rescheduled or cancelled, but they may be further delayed if the maximum duty day initially prescribed for that mission is exceeded.

4. Maximum Flying Time Limits--The simulation program provides for two kinds of limitations on maximum flying time per individual per period. Definition of such periods is quite flexible.

5. Length of Crew Rest--This is the number of hours which policy states that a crew shall rest prior to the mission departure. The same or another figure is specified for crew rest enroute upon arrival at a stage base or upon expiration of a duty day.

6. Air Time Between Aircraft Maintenance--While the principal emphasis of this simulation lies on crew data and crew effects, provision has been made to take aircraft out of service at home base for two different lengths of periods called minor maintenance and major maintenance. This input parameter specifies the number of hours of air time that shall not be exceeded before minor maintenance, the number of hours the plane will be out of service for minor maintenance, the number of air hours that shall not be exceeded between periods of major maintenance, and the number of days required for major maintenance. The simulation program during the run will utilize the expected air time of any proposed mission to estimate whether a particular aircraft would exceed its maintenance limitations and will accept or reject the aircraft for that mission on that basis. Thus the interactive effects of periodic maintenance limitations upon crews are taken into account. A simple modification also provides the ability to simulate isochronal maintenance, taking planes out of service at fixed periods of calendar time irrespective of their air time.

7. Number of Stage Crews at Each Base--Part of the initialization is to place the number of stage crews needed at each of the stage points according to policy to be used in that run. This policy is usually expressed as a ratio such as 1/30, meaning one stage crew for each 30 missions per month planned to move through that stage pool.

Having looked at some of the major initialization parameters which specify policy, we will now describe some which specify the system characteristics.

8. Route Types--This set of parameters specifies for each route type the number of legs, the direction of each leg (inbound or outbound), scheduled or average air times of each leg, and identification of the bases. The leg direction is pertinent to the setting up of directional stage crew pools. Note that the inclusion of scheduled air times essentially identifies one type of aircraft with a route type. For a different type of aircraft over the same geographic route, an additional route type is defined to the simulation.

9. Mission Type--For each kind of mission to be flown a code is entered identifying that type of mission, the crew type to be used on that mission, the route type of the mission, the bases where staging will occur, the total estimated air time, and the maximum duty day for each leg. Note that this does not specify any dates of departure or arrival but merely describes the characteristics of a particular type of mission. Later during the course of the run, the exogenous tape will indicate several times during the course of a month when a specific type of mission should be launched and will specify the time and date of launch. That information gives the identifying code and time of launch; the simulation will then refer to the initialized mission type information to find out all the details involved in the setup.

10. Preflight Length and Delays--In actual practice and, hence, in the simulation, the length of time in preflight has a normal planned value which is initially furnished here, but for various causes occurring in fairly random fashion actual takeoffs are delayed. Excluding the nonavailability of plane or crew, we have made provision for all other delays to be included in a random distribution which is initially submitted at this point. Later during run time as each leg is about to be launched, the simulation gets a random sample from this specified distribution and sets the actual departure time accordingly.

11. Weather and Other Variabilities in the Air--To provide for random fluctuations in length of air time along a particular leg in a particular direction brought about operationally by fluctuation in such things as wind, power settings, weights, and a miscellany of other factors, we provide for an initial specification of a distribution of factors to be applied to the average no-wind-time for any leg.

Finally, in the initialization phase we specify the resources that a particular run will have available. They include the following parameters:

12. Number of Flight-Qualified Personnel--The number of pilots, copilots, navigators, engineers, and loadmasters in the squadron is specified separately and need not be equal. Within each of these groups all personnel are presumed to be flight qualified, and no provision has thus far been made for trainees and examiners. It is quite feasible with a small amount of additional programming to include other types of personnel. The crew type parameter described above would then have to be supplemented so that at least one crew type calls for one of the new type of personnel.

13. Number of Planes--The total number of planes assigned to the squadron is initially entered.

Exogenous Events--The second type of information which is prepared in advance of a run is an exogenous event tape. This tape is a calendar of events due to occur at a time independent of what goes on in the simulation. It includes preplanned calls upon the squadron for missions, and it provides a mechanism for handling sick leave, planned leave, emergency leave, general military duties, and special time-clocked squadron duties.

1. Mission Workload--The mission workload is placed on the exogenous tape in the form of a notice to the squadron; each mission notice is received just in time to designate a crew and aircraft for that mission.

2. Unscheduled Leave--This is provided by notices at random times that a particular person becomes sick or has an emergency call for leave. To generate these notices we sample a random distribution which on the average will give us the experience incurred operationally as to frequency of emergency calls, illness, and the length of the illness. Sampling results are then placed on the exogenous tape in order of occurrence so that during the run the system will find out about each occurrence only when it happens.

3. Adjustable Duties--Those military duties included in manpower analysis under the heading "AFNAT," which stands for Air Force Non-available Time and includes ordinary leave, are spread out over the month and assigned to each individual at specified times on the exogenous tape. The difference from the foregoing categories is that during the run a crewman, called upon for this type of activity while away from home base, will have these duties saved for him until he returns and completes his free time; then he will be assigned to these duties.

4. Fixed Duties--The third type of predetermined assignment for an individual is intended to cover such items as squadron alpha alert, ground training, and scheduling officer duties. These events occur not randomly but regularly and must be fulfilled as scheduled, so that during run time our computer looks ahead and will not select a crewman for a particular mission if the forecast length of that mission would conflict with his being back in time for a duty specified here.

Thus the exogenous tape provides the simulation program with a timing sequence for setting up missions and for putting crew members on leave or special duties.

Simulation Logic (What Happens While It Is Running)

A simulation run is begun by loading the program, mounting the exogenous tape, and reading in the initialization values. This includes assembling the required initial stage crews and prestaging them out in the system. All planes and remaining crewmen are placed in pools of available planes and crewmen. The simulation clock is started by reading in the first notice from the exogenous tape. As mentioned earlier, the exogenous tape contains notices which schedule a mission or notices to place an individual man on some "blocked out" status (making him unavailable for a mission for a specified period). We will illustrate the detailed events involved, by tracking a single mission from start to finish. We will discuss first those events which occur at home base prior to mission departure, then the events which take place at an enroute base, and finally those events which occur at the completion of the mission. The computer actually performs the actions for all missions by the simulator clock so that it may successively select a crew for tomorrow's mission launch, alert a stage crew at base F for an imminent departure, take a crew off free-time status, launch an inbound mission from an intermediate base, launch today's noon mission from home base, land yesterday's mission at an enroute base, and compute its subsequent time of launch from the delay distribution--all in order of the clock time at which each event is supposed to occur.

Predeparture Events--Notices to schedule a mission have been placed on the exogenous tape so that the notice appears on the calendar (the computer finds out about it) 24 hours before the scheduled departure time for the mission. At this time, selection of the plane and crew begins. Information about crew type, route, number of staging bases, and length of time the crew will be away from home is obtained from the input. This information is used to insure that policy rules are not violated in selecting the crew and plane. A crewman's eligibility is determined by:

1. Is he available? A crewman is not assigned to a mission which will conflict with his fixed duties. If a conflict inadvertently occurs because the mission actually lasts longer than the normal time, the duties will be performed at the completion of the mission. He is

not available if he is on unscheduled leave (sick, emergency). He may be assigned to a mission even if it conflicts with adjustable duties, which are then carried out after completion of the mission.

2. At the beginning of each leg, maximum flying time per crewman is imposed, for both short (normally 30-day) and long (normally 90-day) periods, without waiver except to complete a leg whose normal length would not have put him over the limit. In making up crews at home base, an attempt is made to see that each crewman selected can complete the entire mission without exceeding his short or long flying time maximums. If no one of a particular position--such as flight engineer--meets this criterion, then only the flying time to the first staging point is used to determine availability.

3. Who goes first? If more than one crewman of a given position is available, the one with the least accumulated flying time for the quarter (long period) is selected. In case of ties, the one with the least accumulated flying time for the month (short period) is selected.

A plane's eligibility is determined by:

1. Will the plane be at home base in time to begin preflight?

2. Will the sum of the plane's accumulated air time and the air time required for this mission exceed the time for the next minor or major maintenance for that aircraft? Or alternatively, will the proposed mission departure time plus normal mission elapsed time interfere with a scheduled ischronal maintenance for that plane?

If there is either no plane or no crew for a particular mission, the mission is cancelled. However, the mission is merely rescheduled to depart at the earliest possible time if a plane and crew can be found so that such rescheduling will not exceed the maximum time (supplied in the initialization) allowed for a delay at home base. As soon as selection of the crew is completed, they are placed on home crew rest. Upon completing crew rest (usually 12 hours), they are allowed travel time to report to the base. The length of this status is currently fixed at 1 hour. Normally, preflight of the plane begins at this time. It is possible, however, for the plane assigned to this mission to be unavailable. This can occur if the assigned plane is still in maintenance, but will be available in time to prevent a major delay. If the crew has to wait, they are placed in a status called ramp time. As soon as both plane and crew are available, preflight status begins for all. As stated earlier, the actual ground time is a random value. If the actual ground time does not exceed the scheduled ground time, the plane departs; and the crew status changes to flying time which is charged against their monthly and quarterly limits. If the scheduled ground time is exceeded, then the crew is placed in ramp status (corresponds to ramp pounding due to unscheduled maintenance or weather delays). The crew is allowed to depart if the ramp time does not exceed 6 hours (a figure set at initialization).

Otherwise, the crew must be replaced. A new crew is selected and restarts the cycle with home crew rest. The program will continue to select crews until it succeeds in getting the plane off.

Enroute Events--At the time of launch from any base, the simulator ascertains the normal leg time and a random factor, computes actual arrival time, and sets a reminder to act again on the mission at that time, or in some cases an hour earlier as we shall see. If the next base is not a staging point, on arrival time the program must check to see if the crew is qualified to fly the following leg. The program must verify that each member would not exceed his flying time limits on this leg and assures that the maximum duty day will not be violated. If the flying time limits or the maximum duty day would be exceeded or if 3 consecutive days of maximum duty have transpired, the crew is placed on enroute crew rest and the plane is placed on enroute layover until the crew is qualified to fly again. Upon completion of crew rest, they are allowed time to report to the flight line and preflight begins for the following leg.

If the next base is a staging point, a notice will be given 1 hour before arrival to alert a stage crew to report for preflight at arrival time. The arriving crew goes directly to crew rest after completing their postflight inspection. They will be placed in the staging pool as soon as they finish crew rest. Crews in this staging pool rotate on a first-in, first-out basis.

Upon arrival the program samples its ground time distribution and sets a departure time. If, as the clock runs, the actual ground time exceeds the scheduled time, the outgoing crew is placed on ramp status. If the ramp time is less than 6 hours (or as initially specified), the mission continues. Otherwise, the crew is replaced. In general, this does not cause a large enroute layover of the plane at a stage point since the replacement crew normally has already taken the enroute crew rest. That crew must, however, perform its own preflight inspection of the aircraft. The program's strategy calls for alerting this replacement crew 1 hour before the unscheduled maintenance is completed. If less than 1 hour of unscheduled maintenance remains, the plane is placed on enroute layover status until the crew arrives. The crew is allowed the usual hour to report to base operations.

Postmission Events--As soon as the plane arrives at home base, the program checks to see if minor or major maintenance is required. If maintenance is not needed, postflight inspection is performed. The plane is then returned to the available pool. Those planes requiring maintenance are returned to the available pool as soon as maintenance is completed. The crew members are granted free time based on the amount of time they have been away from home this mission. As each crewman completes his free time, the program will check to see if a period of adjustable duties is pending. Before placing the crewman on such duties, the program insures that these duties will not cause

cancellation of a mission. Eventually, the men are returned to the available pool, completing the cycle of all possible statuses.

Output Measurements (What Can Be Analyzed Afterwards)

During the course of the simulation run, a log is maintained of every change in status of every man and every aircraft. This log is recorded on a history tape in which each transaction consists of one change in status of one individual or plane. This history tape can then be used as source data for various summaries to describe what happened and for analyses that compare this run to other runs. Just as in operational activities themselves, there are many different variables that might be summarized and many different ways of summarizing each one. Since this analysis phase is not truly an integral part of the simulation itself, we will merely mention at this a point a listing (by names which are self-explanatory) of some variables which have been computed. These variables are separated roughly into four categories: those pertinent to individuals, those pertinent to crews, those pertinent to planes, and those pertinent to the system as a whole.

Individual Measures--

1. Total time spent in adjustable duties by month or by crew position or both.

2. Total time spent in unscheduled leave by month or by crew position or both.

3. Total time spent in fixed duties by month or by crew position or both.

4. Total time spent as free time by month or by crew position or both.

5. Average length of free time period by month or by crew position or both.

6. Distribution of length of free time period.

7. Average time away from home by month.

8. Distribution of time away from home by month.

9. Average time between missions by month.

10. Distribution of time between missions by month.

11. Average flying hours per person by month.

12. Distribution of flying hours per person by month.

Crew Measures--

1. Average length and distribution of preflight time. This measure merely confirms that the program is actually sampling the distribution which was initially submitted to it.

2. Average and distribution of inflight times per leg. This is really more of a system measure which is pertinent to the formula approach to crew management. Out of the simulation we get merely what we initially put in, within random variation.

3. Time spent in postflight duties.

4. Time spent in enroute crew rest.

5. Time spent in enroute waiting. This is an important indicator of the staging effect and will appear in many of the analyses.

Plane Measures--

1. Number and length of home layovers.

2. Time spent in preflight.

3. Time in flight by leg and by mission and by month.

4. Number and length of enroute plane layovers. This measure reflects those periods when crews were an impediment to the system.

5. Time in minor and major maintenance.

6. Utilization rate. This figure, the number of air hours per day per plane, is the most often-used management measure of plane availability and workload. It is used in planning, but appears here as utilization rate actually achieved per period.

System Measures--

1. Missions scheduled.

2. Missions rescheduled.

3. Missions cancelled.

4. Mission departures.

5. Mission arrivals.

6. Mission legs delayed, and distribution of delay time.

7. Rescheduling delay, total, and average time.

8. Work-month-hours. This is a measure of personnel availability or utilization most often used in a manpower management and planning context to the extent that it reflects an individual's contribution to the Air Force out of his 30 days. It is also an individual measure, of interest both as a squadron average and as a distribution from minimum to maximum.

DISCUSSION

We have described a crew-oriented computer simulation program which is very versatile. It was validated using operational data for C-5's and C-141's during both the Vietnam conflict and the Israeli crisis. The simulation program yields data on system-wide operations in formats which facilitate management decisions on manning, crew welfare, tolerable workload, and mission effectiveness. Using this simulation package, management can study the interrelationship among ground times, route structures, and maximum achievable surge rates. This crew-oriented technique allows management to study simple and radical departures from existing aircrew management policies at a very low cost.