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COMPUTER SIMULATION OF KC-135 AIRCREW MANNING REQUIREMENTS.(U)
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USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
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NOTICES

This interim report was submitted by personnel of the Data Processing Branch, Biometrics Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 7930-10-02.

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

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This report describes a crew-oriented computer simulation program. It demonstrates the feasibility of using computer simulations to study the aircrew manning requirements for the KC-135 jet tanker. The program simulates the major operational attributes of a squadron of jet tankers, and produces data on system-wide operations in formats which facilitate management decisions on manning.

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COMPUTER SIMULATION OF KC-135 AIRCREW MANNING REQUIREMENTS

INTRODUCTION

A general simulation program capable of representing major operational attributes of a typical squadron of SAC KC-135 jet tanker aircraft and aircrewmen has been developed by the Biometrics Division of the USAF School of Aerospace Medicine. The purpose of this report is to demonstrate the feasibility of using this technique to study the aircrew manning requirements for various peacetime, surge, and wartime tanker requirements. Given the resources (how many planes, crews), the workload (number and type of mission), the rules under which to operate (various regulations regarding rest, leave, briefings, maxima for crew and planes, etc.), 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--departures, cancellations, flying times and delays--which can be later assembled into such statistics as sortie rates and flying time distributions.

The following sections describe the general mechanics of the simulation program and indicate the assumptions and inputs (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 results of an initial set of runs are illustrated and some possible studies using a more complex model are discussed. While the program has not yet been thoroughly validated, its predecessor (a similar simulation of C-141 transport operations) has been validated several times in several ways and used to support successful operational and resource planning.

DESCRIPTION OF THE SIMULATION PROGRAM

Assumptions and Inputs

Actual inputs for the first exercise of this model were based on the operating policies used by several tanker squadrons. Because of significant differences in local squadron policies, the squadron modeled is not necessarily typical of any one wing. It represents and contains the most salient aspects of the operating rules used by each of the squadrons. Each input, as it is defined below, is illustrated by the value used for the first exercise of the model.

The information to be supplied to the simulation prior to a run can be grouped into five general categories: policy, mission characteristics, resources, workload, and predestined events. The first three are placed in the computer at the beginning of the run; the last two are prepared prior to the run and placed on a file to be read 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 most important policy input parameters are:

1. Maximum Time Allowed for Delay at Home Base. This parameter is used in determining when to cancel a mission. The strategy used thus far is as follows: If the plane departed within 30 minutes of scheduled departure, a successful refueling sortie was recorded. If the departure was delayed less than 3 hours, a successful training sortie was credited. Larger delays caused the mission to be cancelled.

2. Maximum Flying Time Limits. The simulation provides for two kinds of limitations on maximum flying time per individual per period. Definition of such a period is quite flexible. Typical values used are 125 hours for a 30-day period and 330 hours for a 90-day period.

3. Length of Crew Rest. This is the number of hours which policy states a crew shall rest prior to the mission departure or to beginning of alert status. The current value used is 12 hours.

4. 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. This input parameter specifies the number of hours of air time that shall not be exceeded before minor maintenance (phase) will take place. Similar provisions are made to remove the aircraft periodically for Corrosion Control Inspection (CCI) and Periodic Depot Maintenance (PDM). Thus, the interactive effects of periodic maintenance limitation upon the 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 accumulated air time since last maintenance. Typical times used for the various out-of-service statuses are: 2 days for CCI, 4 1/2 days for phase, and 40 to 60 days for PDM.

5. Sortie Types. Sorties are classified into types; each type is represented by the scheduled or average air times per sortie. The scheduled air time essentially identifies the type of refueling mission (fighter, bomber) over the same geographic route. For each different type of refueling mission or geographic route, a new sortie type is defined. Currently we have provided for sortie lengths of 2, 3, 4, 5, 6, and 7 hours.

6. Mission Type. For each kind of mission to be flown, a code is entered to identify the type of mission, the sortie type, and the maximum duty day for that mission. 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 file will indicate several times a month that a specific mission type should be launched and the specific time and day. That information gives the identifying code and time of departure; the simulation will then refer to the initialized mission and sortie type information to find out all the details involved in setting up each sortie.

7. Preflight Length and Delays. In actual practice and, hence, in the simulation, the length of time for 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 sortie is about to be launched, the simulation gets a random sample from this specified distribution and sets the actual departure time accordingly. For the results presented in this report, the simulations were initialized to choose randomly from a distribution which guarantees in the long run that roughly 95% will be within 10 minutes of schedule, 3% will be between 10 minutes and 3 hours, and 2% will be between 3 hours and 12 hours.

8. Weather and Other Variabilities in the Air. To provide the random fluctuations in length of air times brought about operationally by fluctuations in such things as wind, power settings, and a miscellany of other factors, we provide for an initial specification of a distribution of factors to be applied to the average or scheduled length of a sortie.

9. Postflight Length. As with preflight, the planned or average value for completing a postflight inspection and the repair of all uncovered discrepancies is given here. Similarly, a random sample from a specified distribution is used at run time to yield the actual time a plane will remain out of service.

10. Number of Flight-Qualified Personnel. The number of pilots, copilots, navigators, and boom operators in the squadron is specified separately and need not be equal. Within each of these groups all personnel are presumed to be qualified, and no provision has thus far been made for trainees and examiners.

11. Number of Planes. The total number of planes assigned to the squadron. (This number and the number of crews are used to compute a crew ratio (CR)). Thus far 14 planes have been used as a squadron's assigned complement.

Exogenous Events--The second type of information which is prepared in advance of a run is an exogenous event file. This file is a calendar of events due to occur at a time independent of what goes on in the simulation.

1. Mission Workload. The mission workload is placed in the exogenous file in the form of a series of time-ordered notices to the squadron, each mission notice 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 produce these notices we sample a random distribution which on the average will give us the experience incurred operationally as to frequency of emergency calls and periods of illness and the length of each. The results of this sampling are then placed in the exogenous file in order of occurrence so that during the run the system will find out about each occurrence only when it happens.

3. Scheduled Leave. Two periods of annual leave per year are provided for each crew. No more than two crews may be on this type of leave at any one time. These events occur regularly and must be fulfilled as scheduled so that during run time our program 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 the leave specified here.

Thus, the exogenous file provides the simulation program with a timing sequence for setting up missions and putting crew members on scheduled or unscheduled leave. The first results, displayed in Tables 1, 2, 3, and in Figure 1, are based on the current 5-day workweek and a training scenario used during peacetime conditions.

Simulation Logic

A simulation run is begun by loading the program, opening the exogenous file, and reading the initialization values. All planes and crewmen are placed in pools of available planes and crewmen. The simulation clock is started by reading the first notice from the exogenous file. As mentioned earlier, the exogenous file 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 illustrate the most important events involved by tracing a single mission from start to finish. First, we discuss those events which occur prior to mission departure and then those events which occur at the completion of the mission. The computer program actually performs the actions for all missions by the simulator clock so that it may successively select a crew for tomorrow's mission, select a plane crew for alert duty, land an early mission, place men on leave or sick call, and compute all mission statistics such as flying times, delays and cancellations, 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 in the exogenous file so that the notice appears on the calendar (the computer program finds out about it) the day before the scheduled departure time for the mission. At this time, plane and crew selection begins. Sortie type, maximum duty day, and other mission parameters are 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 will not be assigned to a mission which will conflict with his leave, alert duty, or time off after alert duty.

2. Is he qualified? At the beginning of each sortie, maximum flying time per crewman is imposed without waiver except to complete a sortie whose average length would not put him over the limit for both short (normally 30-day) and long (normally 90-day) periods. His start of duty day is also checked to see that the maximum duty-day limit is not violated.

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 or generation?

2. Will the plane return in time for a scheduled corrosion control inspection or in time to depart for a periodic depot maintenance?

3. Will completion of the current mission cause the plane's accumulated air time to exceed the maximum and thus require a phase? Or alternatively, will the proposed mission departure time plus average mission elapsed time interfere with a scheduled 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 delay at home base. The selected crew is placed on mission planning status. This time is used by the crew to plan the exact navigation coordinates, the refueling procedures, and other training requirements for the mission. This planning activity usually takes from 4 to 6 hours and must be completed by 1600 hours so that a commander's briefing can be presented. For early departures, the crew selected is placed on home crew rest. For late departures the crew is placed on layover at home status until time to start 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. Next, the crew begins their predeparture briefing for weather updates and other last-minute instructions about the mission. At the conclusion of this hour-long activity, preflight of the plane normally begins. It is possible, however, for the plane assigned to this mission to be unavailable. This will occur if the plane assigned is still in phase or in postflight inspection, but will be available in time to prevent a major delay. If the crew has to wait, it is 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 (corresponding to ramp pounding due to unscheduled maintenance or weather delays or perhaps even operational delays). The crew is allowed to depart if the ramp time does not exceed 3 hours (a figure set at initialization). Otherwise, the mission is cancelled. Prior to preflight inspection for the plane, the plane may be required to be generated (a 5-hour period used to get the plane ready) if it has not been generated during the previous 48 hours.

Postmission Events--As soon as the plane arrives, the plane is placed on service status (a 2-hour period used to refuel or defuel the plane as required for the next mission) while the crew performs postflight inspection (currently set at 1 hour). At the completion of postflight, the program checks to see if the crew is scheduled for another sortie that day. If so, the crew is placed on predeparture briefing status or in layover status at home depending on the departure time of that sortie. If this is the last mission for the day, the crew is returned to the available pool (provided no unscheduled leave is pending), thus completing the mission cycle. The plane goes from service into preflight if it is to fly a second sortie that day. Otherwise, basic postflight inspection and maintenance are performed. As previously stated, the actual time in this status is determined by sampling from the specified distribution. The plane is then returned to the available plane pool.

An additional series of statuses which the plane and crew can pass through is that involved with alert duty. Each week four crews and one aircraft are selected for alert duty. Crews are selected on the basis of least alert points (one point is granted for each day of alert duty and one-third point for each day on TDY or leave) while the plane is selected on a rotating basis (plane with the oldest alert duty date is selected). Crews are required to take the usual 12-hour crew rest prior to starting their 7-day alert duty. A 3 1/2-day period of time off is granted after alert duty during which the crew is unavailable for any missions. The plane remains on alert duty for 28 days so that four planes are on alert at any given time. This completes all the major statuses which the plane and crew perform during the life of the simulation.

Output Measures

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. This analysis phase is not truly an integral part of the simulation itself. Some of the variables which have been computed are self explanatory. They are separated roughly into three categories: those pertaining to individuals in crews, those pertaining to planes, and those pertaining to the system as a whole.

Crew Measures--

1. Total time spent in unscheduled leave by month or man.

2. Total time spent in scheduled leave by month or man.

3. Total time spent as free time by month or man.

4. Average time away from home by month.

5. Average time between missions by month.

6. Average flying hours per man by month.

7. Distribution of flying hours per man by month.

8. Average length of preflight time. (Note that this measure merely confirms that the program is actually sampling the distribution which was initially submitted to it.)

9. Time spent in postflight duties.

10. Time spent on alert duty.

Plane Measures (by plane or by month or total as pertinent)--

1. Number and length of home layovers.

2. Time spent in generation.

3. Time spent in preflight.

4. Time spent in flying.

5. Average time spent in basic postflight.

6. Number and time spent in CCI, Phase, and PDM.

7. Time spent in alert duty.

System Measures--

1. Missions scheduled by type.

2. Missions rescheduled by type.

3. Missions cancelled by type.

4. Mission departures by type.

5. Mission arrivals by type.

6. Sortie rates achieved.

RESULTS

Since the major factors affecting the performance of the system are the workload stresses and the resources available to it, we made several exploratory runs to compare the responses of the system to variations in these factors. For a fixed complement of planes, the resources made available can be summarized by the number of crews made available, expressed succinctly as the CR or number of crews per aircraft. To maintain simplicity and assure that any effects observed can be reasonably attributed to the factor being investigated, we ran an equal number of pilots, copilots, navigators, and boom operators. If, in actuality, these are unequal numbers, the results will apply using the smallest number available. Four levels of CR encompassing the range of operational interest were chosen: 1.0, 1.2, 1.5, and 2.0. The workload may be expressed in various ways. For a fixed number of planes such as we are using, it may be expressed as the number of departures per month or sortie rate. We chose to explore the range from 40 to 110 sorties per month. Since mission length has a significant impact on the number of missions a crew may fly per day, we chose to explore mission lengths of 4, 5, and 6 hours per sortie.

By making one run at each logical combination of CR and sortie rate, while holding all other factors as constant as possible, we created the data that would enable a comparison of the combined effects of these two factors. We repeated this matrix of CR versus sortie rate for each of the three mission lengths of interest. Tables 1, 2, and 3 display the results of this set of runs and Tables 4, 5, and 6 display the percent achieved sortie rate.

When the mission length is 4 hours (Table 1), up to 40 sorties per month can be accomplished with a CR of 1.0. The current CR of 1.2 (17 crews per squadron of 14 aircraft) can support up to 60 sorties per month, while increasing the CR to 1.5 yields sortie rates just over 100 per month. Beyond a CR of 1.5 the system is totally limited by factors other than crew. For mission lengths of 5 hours (Table 2) a CR of 1.0 is inadequate even for relatively small sortie rates of 40. The current CR of 1.2 is adequate for sortie rates up to 50; by considering achievement of 96% of planned sorties to be acceptable (Table 5), the CR of 1.2 is adequate for sortie rates up to 70 per month. Table 3 shows this degradation of system efficiency more dramatically for the longer mission length of 6 hours. Even with a CR of 2.0, the system begins to break down badly if more than 80 sorties per month are scheduled. This failure is attributable more to insufficient aircraft than to crews, since no appreciable improvement was observed when increasing the CR from 1.5 to 2.0.

The achieved sortie rates are shown graphically in Figure 1, plotted against the planned sortie rates. As one example: for 5-hour sortie lengths and a CR of 1.2, by increasing the scheduled sorties a corresponding increase in achievement results up to about 60 sorties; after that, there is a lesser increase which gradually flattens out to a maximum where attempting 110 sorties achieves only 78 sorties. Only the points close to the ideal slanting line are useful in practice. As the CR is changed from 1.0 to 1.2 to 1.5, system capability is increased (for 5-hour sorties) from 45 to 65 to 75 sorties per month, indicated by the neighborhoods where the 1.0, 1.2, and 1.5 curves break away from the ideal line. Similar numbers for 6-hour missions might well be 40, 60, and 70 sorties per month. For 4-hour missions the corresponding numbers might be 50, 70, and 100.

It is important here to note that we have only shown what can be studied with a simulation of this type. To estimate the figures more precisely would require a more definitive study, thoroughly debugged and validated against field data.

Figure 1 also displays the effect of changing sortie length while holding CR fixed. A CR of 1.2 can have its capability increased from 60 to 65 to 70 sorties per month by decreasing the sortie length from 6 to 5 to 4 hours per sortie. If the CR is 1.5, the effect is more dramatic, increasing the capability from 70 to 75 to 100 sorties per month by decreasing the sortie length from 6 to 5 to 4 hours per sortie. Again these figures merely illustrate the kinds of information a more definitive study could develop. In addition to the runs at a single sortie length, trial runs have been made to demonstrate the effect of scheduling the same squadron with a variety of sortie lengths. The runs were successful and gave no new information in that results conformed closely to those expected by use of (weighted) average sortie lengths.

TABLE 1. ACHIEVED SORTIE RATE FOR MISSION LENGTH OF 4 HOURS

Crew ratio	Scheduled sorties per month: 40	50	60	70	80	90	100	110
1.0	40	49	55	58	60			
1.2	40	50	60	68	77	81	84	86
1.5	40	50	60	70	80	90	100	106
2.0	40	50	60	70	80	90	100	106

TABLE 2. ACHIEVED SORTIE RATE FOR MISSION LENGTH OF 5 HOURS

Crew ratio	Scheduled sorties per month: 40	50	60	70	80	90	100	110
1.0	39	46	52	54	52			
1.2	40	50	59	67	72	74	78	78
1.5	40	50	60	70	79	85	89	86
2.0	40	50	60	70	79	88	89	86

TABLE 3. ACHIEVED SORTIE RATE FOR MISSION LENGTH OF 6 HOURS

Crew ratio	Scheduled sorties per month: 40	50	60	70	80	90	100	110
1.0	39	45	49					
1.2	40	50	59	66	70	71	72	
1.5	40	50	60	70	77	74	72	
2.0	40	50	60	70	77	74	72	

TABLE 4. PERCENT ACHIEVED SORTIE RATE FOR MISSION LENGTH OF 4 HOURS

Crew ratio	Scheduled sorties per month							
	40	50	60	70	80	90	100	110
1.0	100	98	92	83	75			
1.2	100	100	100	97	96	90	84	78
1.5	100	100	100	100	100	100	100	96
2.0	100	100	100	100	100	100	100	96

TABLE 5. PERCENT ACHIEVED SORTIE RATE FOR MISSION LENGTH OF 5 HOURS

Crew ratio	Scheduled sorties per month							
	40	50	60	70	80	90	100	110
1.0	98	92	87	77	65			
1.2	100	100	98	96	90	82	78	71
1.5	100	100	100	100	99	94	89	78
2.0	100	100	100	100	99	98	89	78

TABLE 6. PERCENT ACHIEVED SORTIE RATE FOR MISSION LENGTH OF 6 HOURS

Crew ratio	Scheduled sorties per month							
	40	50	60	70	80	90	100	110
1.0	98	90	82					
1.2	100	100	98	94	88	79	72	
1.5	100	100	100	100	96	82	72	
2.0	100	100	100	100	96	82	72	

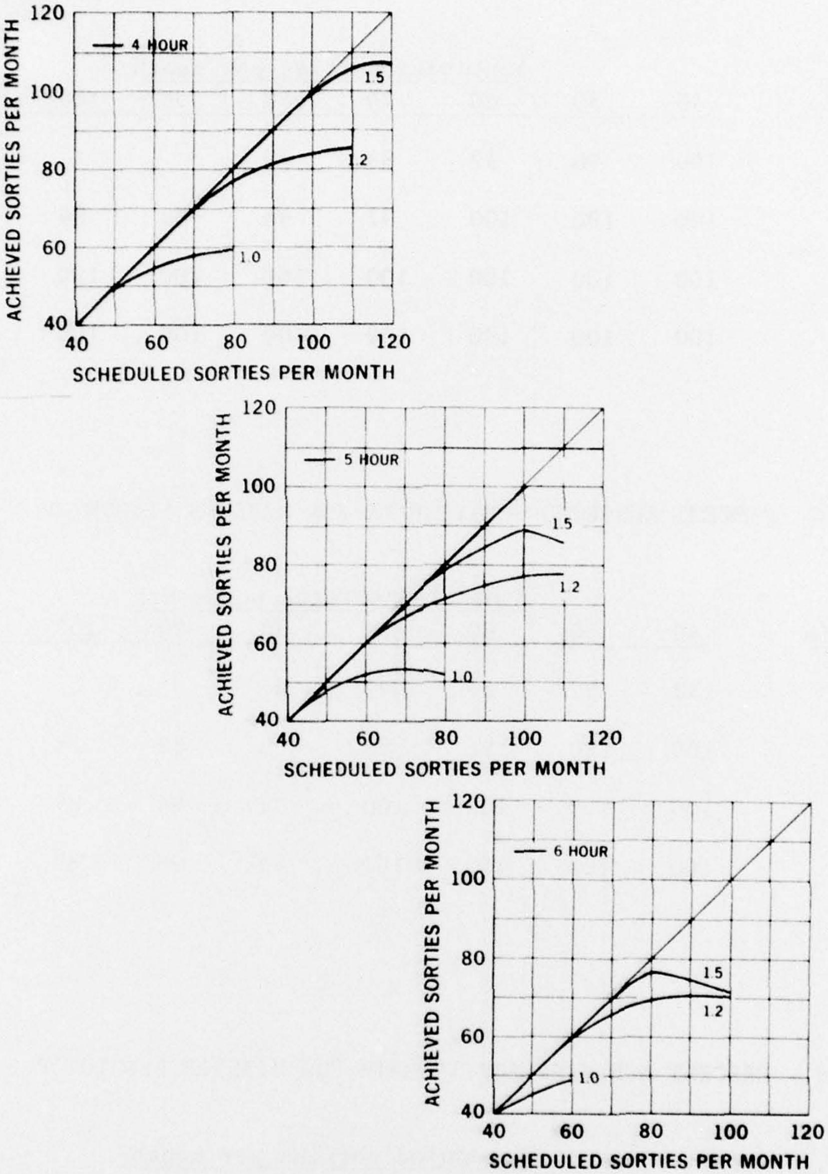

Figure 1. Achieved sortie rates vs. planned sortie rates.

FUTURE POSSIBILITIES

We can use the model to explore surge or wartime scenarios. The model can yield optimum crew ratios to satisfy given refueling sortie requirements in support of SAC bombers, MAC transport aircraft, or TAC fighters. If we use recent empirical data to generate the different distributions used by our model, we can produce more conclusive results. We can investigate the effect on sortie rate due to changes in various operating policies including not only the mission lengths already displayed, but also flying hour limits, deployments, and the use of isochronal maintenance policy. If and when maintenance manning studies show that some of the current rules for making planes available from maintenance can be relaxed or must be tightened, simulations can show the resulting effect on crews. The potential benefits are an enhanced model which can be used to study simple and radical departures from existing aircrew management policies. Such studies can be made at exceptionally low cost compared to actual operational implementation.