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A SIMULATION MODEL FOR EVALUATING AIRCRAFT SYSTEM OPERATIONAL AVAILABILITY

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ABSTRACT

The cost effective utilization and acquisition of equipment is vitally important to the air force of any national defence force. This paper describes a simulation model which was developed to aid the decision makers of such an air force in determining aircraft system requirements for carrying out specific missions within different conflict scenarios. Comprehensive validation of the model has not been completed.

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Die kostedoeltreffende gebruik en aanskaffing van toerusting is belangrik vir die lugmag van enige nasionale weermag. Hierdie artikel beskryf 'n simulasiemodel wat ontwikkel is as 'n hulpmiddel vir die besluitnemers van so 'n lugmag en wat gebruik kan word om vliegtuigstelselbehoeftes te bepaal vir die uitvoering van 'n spesifieke missie binne verskillende konflikscenarios. Volledige validasie van die model is tans nog nie uitgevoer nie.

1. INTRODUCTION

Any national defence force should be aware of the vital importance of the effective utilization of its existing equipment and the necessity to acquire new equipment in a cost effective manner. These factors are even more important in the case of aircraft systems because of the extremely high cost and limited operational lifespan. The cost of a modern military aircraft system, including the logistic support, may be in excess of R100 million. A relative accurate idea of the equipment requirements, both aircraft and operational logistic support equipment, for specific conflict scenarios is essential for effective planning and operation and to ensure that the stated goals in terms of national security are met in a cost effective way.

This paper describes the development of a simulation model which could be used as an aid to determine what the aircraft requirements are within a given threat scenario by specifically including the temporary loss of mission ready aircraft due to maintenance actions and permanent loss due to attrition. It was also required of the model to aid the user in determining the effect of logistic delays on the operational utilization and therefore availability of specific aircraft systems

The level of detail to which the system was modelled was determined primarily by the data availability, the size of the model which could be handled by a micro-computer and the time and manpower available. The model was developed on a micro-computer in an effort to enhance the accessibility of the model to the potential user. This decision was considered to be practical since the lack of detailed logistical data for new aircraft systems makes a detailed database driven simulation model, which would also need considerable computing ability, practically impossible.

Given these constraints and uncertainties, it was recognized that it would be impossible to develop a model which would provide the optimum number of aircraft required, or the optimum spare part and other maintenance requirements per individual item to ensure a specified availability for a particular aircraft system. The model should therefore be seen as an experimental aid for evaluating the general performance of a given system under a set of given circumstances.

2. THE SIMULATION MODEL

One of the important objectives of the project was perceived to be the learning process resulting from the structured approach required for effective modelling which is forced on all those directly involved during the modelling process. Close participation by the user team in the development of the structure of the model was therefore very important.

Two separate background studies, one covering the operational and the other the logistic aspects of the system, were carried out. This approach resulted in the model also being developed in two distinct sections. The operational section schedules deployments and missions, assuming one hundred percent availability of all equipment, and stores the results on disk files. These files are then accessed by the logistics section where the logistic delays resulting from maintenance actions, ferrying to and from deployments, and spares out-of-stock occurrences, are taken into account.

The background studies into the operational and logistic aspects of the system showed that whereas the logistic system was one where specific data regarding reliability, maintenance, logistics and administrative factors are mostly unknown, the operational requirements, although based on estimates, are easier to define in specific numeric terms such as the frequency, type and duration of missions over a period of time. To accommodate this difference it was decided that the two sections would be developed separately and that the interface between the two models would consist of commonly accessible data files.

The uncertainties surrounding many of the aspects of the systems to be modelled were the deciding factors in the choice of simulation as the means of modelling. For the logistics section of the model it was decided that the simulation language SLAM (a Simulation Language for Alternative Modeling) would provide an efficient modelling tool [1]. The network approach of SLAM could be used to described the different processes and interactions in the system. Complex logical detail may at the same time be addressed by means of user-defined FORTRAN subroutines and functions which are called from the network. The SLAM facilities such as those available for data collection, random sampling from predefined statistical distributions and built in event scheduling, could be used to good advantage. The operational aspects, on the other hand, required very specific exception-handling logic and this section's main output, the files to be accessed by the logistic section, needed very specific input/output routines. A general purpose programming language such as FORTRAN was considered to be more suitable for this process than SLAM.

The logistics section was initially developed on an eight MHz 16 bit micro-computer and later on a ten MHz 16 bit micro-computer equipped with an arithmetic co-processor. The operational section was developed on a 32 bit minicomputer and transported to the micro-computer by means of a Local Area Network.

To allow the model to be used for a variety of applications, parameters which are specific to a given system must be provided to the model before execution. Screen control with FORTRAN being very cumbersome, it was decided to develop a separate program using the data base development system Dbase III to enter this data into a sequentially formatted

ASCII file which is easily accessible from within the model. The sequential execution of the Dbase III program, the FORTRAN based operational section and the SLAM network discrete event program, is facilitated by means of an MS-DOS batch file.

2.1 The operational section

The operational section consists of a three level scheduling program. The first level of scheduling is that of conflicts and associated theatres of deployment. This is done by randomly generating conflict/deployment start dates, until the specified number of occurrences of each conflict type has been reached. If a clash occurs between different conflict/deployments, the start date of one of the conflict/deployments is either regenerated or the end date of the conflict/deployment with the lowest priority is moved further into the future by the appropriate number of days. Conflict/deployments of higher priority can thus occur within a conflict/deployment of lower priority, with all the conflict/deployments still conforming to the specified duration.

The second level of scheduling encompasses the random scheduling of the different operations specified for each conflict/deployment. Appropriate checking is performed to ensure that operations do not overlap.

The third level consists of the random scheduling of the appropriate missions for every operation. The user may specify which missions may overlap according to what would best reflect the real world military situation.

2.2 The Logistics Section

The logistics process may be summarized as consisting of the accumulation of data regarding missions which are flown or should be flown by an aircraft, the occurrence of system failures, the resultant maintenance actions required and the effect of spare part inventory levels and the resupply of spares parts.

2.2.1 Missions

Details of conflict levels, deployments, missions and attrition rates per mission are read from the files drawn up in the operational section of the model. Deployments and missions are scheduled by placing them as events on the SLAM event calendar. This is done from within the FORTRAN event subroutines using an internal SLAM function.

At the scheduled occurrence time of either a mission or a deployment, an order is entered into the SLAM network as an entity. The location, mission start and end times, number of aircraft that must fly a mission or be deployed, and attrition rates accompany the entity as its attributes. If the order is a deployment order, the attributes remain intact until the deployment is scheduled to end and the aircraft returns to its base. A deployment is interrupted if another deployment, which has a higher priority as determined by its conflict level, has to be scheduled in the same theatre. The attributes of the interrupted deployment are stored in a temporary array so that once the higher priority deployment has been completed, the lower priority deployment may be continued. This manipulation is necessary to ensure that the specified ratio of the different conflict levels, which is a user input, is maintained.

If sufficient aircraft are not available for a deployment which is scheduled for a different theatre than any previously scheduled deployments still under way, and the new deployment and theatre has a higher priority than the old deployment, the existing deployment is terminated and these aircraft routed to the new deployment theatre.

Besides the operational missions which may be flown from locations far removed from the squadron's home base, peace-time mission orders, which represent training missions, ferry operations etc., are created within the network. These missions may occur at regular intervals if aircraft are available at the home base. When a deployment is under way, the probability that there are aircraft available for these missions is small. Furthermore the regular creation of these mission orders and subsequent termination thereof if aircraft are not available, is time consuming and prolongs the model execution time markedly. To bypass this problem program logic was developed which allows or disallows the creation of new peace-time mission orders depending on whether a deployment is under way or not. A user specified variable controls the number of scheduled peace-time mission orders which may be processed during a deployment.

In the network the entered mission order entities are replicated to represent the number of aircraft required for flying the mission or for deployment. Each mission entity is attached to an aircraft if available at its location. If an aircraft is not available, the mission entity is routed into a section of the network where, at constant time intervals specified by the user as part of the initializing process, a check is made whether the scheduled mission can take place or not. This process is continued until a user-specified time period has elapsed. If this time is reached, the mission is recorded as an aborted mission.

2.2.3 System Failures

After each period of flying either an operational mission, a training exercise or a transport flight to or from its point of deployment, each aircraft entity passes into a section of the network where the probability of a system failure having occurred, is determined. This calculation is done in a FORTRAN function program unit to which the relevant mean time between system failure data has been passed. If no failure has occurred the aircraft entity is rerouted to the queue representing the relevant flight line of operationally ready aircraft. If a failure is deemed to have occurred the entity is broken down into the relevant subsystems each with their own mean time between failure characteristics. If a subsystem has failed, it is routed to the corrective maintenance section of the network. If not, it awaits the other subsystems of the specific aircraft to be repaired and re-assembled.

2.2.4 System maintenance

The maintenance of aircraft systems is extremely complex. For the purposes of this project it was decided that only the delay caused by component replacement at the first level of maintenance, would be modelled. This simplification was considered reasonable because in operational circumstances air force policy dictates that everything possible should be done to ensure that a failed component is replaced almost immediately even if this may result in the pirating of spare parts from undeployed aircraft.

The maintenance delay at this level is therefore simulated by an activity with a duration representing the component replacement time. The resources which each subsystem entity must compete for before the maintenance activity can commence are personnel, facilities and subsystem availability. During the initializing phase, the user specifies the number of these resources available and the number required per subsystem repair action, for each location. Personnel and facilities become available immediately after the maintenance activity has been completed.

2.2.5 Spare part inventory level

The modelling of the changing spare part inventory levels presented one of the biggest challenges during this project. The two extreme methods which could have been used are:

* The design and incorporation into the model of a detailed database of the location and availability of every spare part item which is updated on every maintenance occurrence requiring a replacement, or

* at the occurrence of a system failure, the probability of an out of stock position may be determined by sampling from a statistical distribution which represents the change in probability of this occurrence over time.

For the second alternative, although attractive in its simplicity, the determination of the type and parameters of these distributions proved to be extremely difficult. Furthermore, if a distribution is estimated, the assumptions required to perform the estimation may have had a detrimental effect on the practical validity of the model.

With almost no data available on spare part requirements for new aircraft systems, and the expected computing capacity and programming effort required for the data-base approach, it was decided to break the system down into a limited number of subsystems. At each location spare part inventory level variations and out-of-stock situations are represented by the demand for the resources which represent the different subsystems. It is assumed that each subsystem failure requires one unit of the relevant spare part. Resupply levels are calculated by calculating the consumption rate and assuming a twenty four hour resupply lead time. The actual replenishment takes place by scheduling a replenishment event when the reorder point is reached. These calculations are done in a FORTRAN subroutine with the subsystem being entered into the network as an entity.

3. COMMENTS AND CONCLUSIONS

At he time of writing this paper, the comprehensive validation of the model had not been completed. The initial results, however, were roughly checked by physically following the progress of entities through the network using the trace facilities of SLAM. Furthermore, the printouts of a number of runs of the operational section of the program have produced deployment and mission calendars which the user team have considered to be very realistic.

Although the simulation model was developed at a conceptual level the process of developing the model raised certain important questions which had not previously been addressed. For example preliminary results have shown that some often quoted system mean time between failure figures and operational availability requirements for certain aircraft systems are not compatible unless maintenance downtime can be reduced considerably.

If the objective that the user must be provided with a model which may be used as an interactive and cost effective evaluation tool is paramount, then the exercise of developing the model for execution on a micro-computer may prove to be a success. On the other hand, despite the dramatic improvements in the processing power and memory capacity of micro-computers, using a micro-computer may place limitations on the complexity and therefore practical usefulness of the model.

REFERENCES

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