MAINTENANCE ACTIVITIES AND RESOURCES SIMULATION (MARS) MODEL

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Abstract

MARS is a Vertol Developed Aircraft Operations and Maintenance Simulation Model written in GPSS for application on the IBM-360-65 computer. The MARS model was developed to provide visibility of an aircraft's ability to comply with an imposed flight schedule and maintenance philosophy. Scheduled flight operations and available maintenance resources are interfaced to determine their effect upon aircraft availability and maintenance resource usage rates.

Various relationships, such as the Availability/Utilization Function, may be investigated and optimized in compliance with the constraints imposed by the resources available, and mission profile designated.

Primary applications of MARS are in the fields of Engineering and Logistics Support Planning Analyses.

Objective

The primary objective of MARS (Maintenance Activities & Resource Simulation Model) is to provide a means of evaluating operational relationships that are impractical or impossible to investigate analytically. In the operation and maintenance of any dynamic system, Cost & System Effectiveness must be assessed. MARS provides a means by which resources can be allocated in such a manner, as to permit determination of the maximum System Availability and Utilization while, at the same time, defining an acceptable minimum level of resource requirements. That is, MARS is a tool for conducting trade-offs of cost versus system effectiveness.

Level Of Detail

MARS has been structured in a manner that provides its user a high degree of flexibility. It can be run on any level of detail required. That is, in simulating system operations and maintenance, MARS can consider servicing and repairs on the system, subsystem or component level.

The scope of MARS in its present form is as follows: The program, consisting of more than 1500 logic steps, requires 256K Bytes to operate. More than 1700 unscheduled maintenance tasks and 18 scheduled maintenance actions can be identified. The program has the capability of individually monitoring and directing 42 different personnel type, 113 special tools, and 346 types of spares components.

MARS has been operated to simulate time frames ranging from 15 to 450 days, with central processing unit times ranging from 30 seconds to 40 minutes.

Real World Representation

Maintenance of dynamic systems is often a multi-base process. That is, in many instances parts are removed from a system and replaced by a like part. The failed component is then sent to a shop for repair, and upon repair, it is returned to the supply line. Thus, MARS has been set up to simulate an entire repair cycle without any loss of continuity. All repair bases are in operation simultaneously, and the real world Logistics Support Cycle is represented without distortion.

Analytical Problems

Numerous mathematical models have been written to evaluate the effects of resource availability upon System Availability. However, to evaluate the effect of fluctuations in one parameter, upon all other parameters of Logistics Support, and at the same time, have the capability to direct and monitor repairables throughout their repair cycle is impossible without the assistance of a computerized simulation model such as MARS.

Model Description

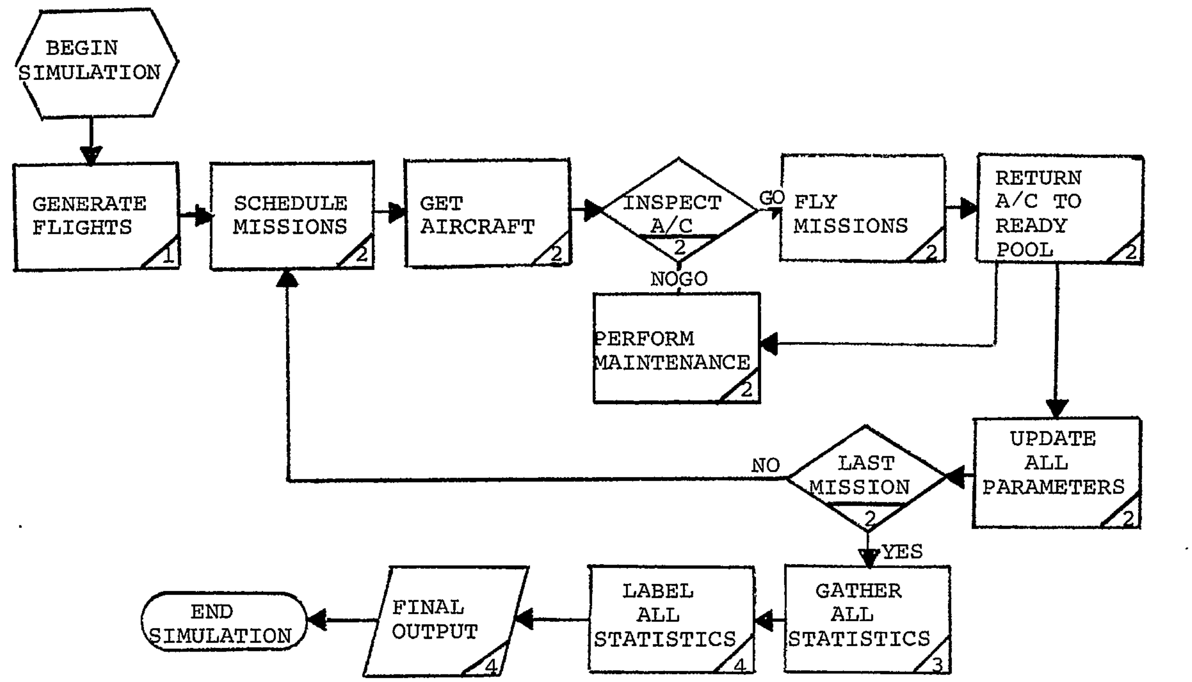
The Maintenance Activity and Resource Simulation model has been constructed in four distinct steps. The function of each of these steps is explained in the following paragraphs and related charts (See Chart A).

Step 1

This step develops an operational flight schedule to be flown during the simulated period, and generates an output tape that contains both flight schedule and aircraft transactions to be used in Step 2.

Step 2

This step assigns the aircraft to a ready status pool to await assignment to a scheduled flight, or delays them for scheduled or unscheduled maintenance. The flight schedule releases, from the ready status pool, the required quantity of aircraft to fly a mission. These aircraft are subjected to inspection routines, abort rates, flight routines, probability of scheduled or unscheduled maintenance, and servicing, before returning to the ready status pool for reassignment. Maintenance generated during inspections, is performed by drawing necessary personnel, parts, and equipment from the resources available, and performing the tasks necessary to repair randomly chosen failed components. As the simulation continues through out the desired time frame, all maintenance and queuing statistics are accumulated and placed on an output tape.



OUTPUT PARAMETERS

OPERATIONAL	MAINTENANCE	LOGISTIC
SYSTEM	COMPONENT	RESOURCE UTILIZATION
UTILIZATION	FAILURES	PERSONNEL/EQUIPMENT
AVAILABILITY	MANHOURS	SPARES
DOWNTIME	ELAPSED MAINT. TIME	RESOURCE DEMANDS
READY TIME	INSPECTIONS	PERSONNEL/EQUIPMENT/SPARES
MISSIONS	MANHOURS	QUEUING FOR RESOURCES
DELAYED/ABORTED	ELAPSED MAINT. TIME	
CANCELLED		

CHART A

Step 3

This is the General Purpose System Simulation (GPSS) Output Generator. It takes the tape from Step 2 and prints out, in tables and graphs, the data accumulated therein. Step 3 also generates a tape containing these statistics in tabularized form.

Step 4

This final step takes the Step 3 output tape and applies nomenclature to all the data it contains. This step is a Fortran Program that generates a printout which is more suited for analysis than the GPSS output.

Problem Translation

To provide an accurate representation of the problem, it was necessary that the MARS model be aligned as closely as possible to the real world environment to be simulated. Therefore, it was concluded that the ability to contain and monitor all resources required to operate and maintain the system under simulation must be provided. On the other hand, MARS is flexible enough to handle systems which are in the design stage and for which all resource requirements have not yet been defined. That is, MARS serves as a design support tool capable of analyzing the quantity of resources required to support a proposed system.

The following is a brief description of the manner in which the simulation operates. Chart B provides an over-view of the manner in which the simulation flows.

1. Upon entry of the program into the computer, and generation of the flight matrices, missions are scheduled at the designated times. Each mission attempts to seize, from the ready pool, the maximum number of aircraft required. Based upon the number of aircraft available, the mission is either sent to take-off, delayed for more aircraft, or cancelled. Those aircraft sent to take-off are checked for Operational Readiness. Aircraft found un-

safe are sent to maintenance. Flyable aircraft take-off, and while in flight are subjected to a probability of abort. Aborted aircraft are sent back for maintenance and all other aircraft continue to completion of the mission. Upon landing, all aircraft are serviced, and those requiring maintenance are sent to the repair facility. Aircraft not requiring maintenance are sent to the ready pool to await rescheduling.

2. The probability of passing each check is computed prior to running the program and entered as input. Determination of the outcome (Yes or No) of all checks cited above, is accomplished by utilization of a Monte Carlo Random Selection Routine. Each check is made by generating a random number which is compared to the probability of passing that check. If the number generated is greater than or equal to the value of the probability, the aircraft passes the check. Otherwise, the aircraft fails the check.

3. Inherent in the statement "Perform Maintenance" is the restriction that maintenance can be performed only if all resources (men, spare parts, maintenance shift duration, special tools) required to perform the maintenance are available. If this is the case, the required resources are seized and the maintenance is performed.

4. Prior to running the program, a frequency distribution of quantity of maintenance actions per maintenance downtime is computed. and entered as input to the program. Determination of the quantity of maintenance is accomplished by utilizing the Random number generator. The generated number is compared with the probability that X maintenance tasks are required, thus determining the number to be performed at this time.

5. Once the quantity of maintenance actions to be performed on an aircraft has been chosen, a random selection routine is used to determine which components require these repairs. Previous to the operation of the program the probability of each component failing, relative to the probabilities of failure of all other components is computed. Thus, if we have m components $X_1, X_2, X_3, \ldots, X_m$, we have respective probabilities of $P_1, P_2, P_3, \ldots, P_m$ of each component failing relative to all other components. These probabilities are expressed as a cumulative distribution with $0 < P_1 < P_2 < P_3 < \cdots < P_m = 1$. Thus, if the random generated is Y_i where $P_i < Y_i \doteq P_{i+1}$ the task to be performed is the repair of component X_{i+1}

OVER-VIEW OF REAL WORLD REPRESENTATION

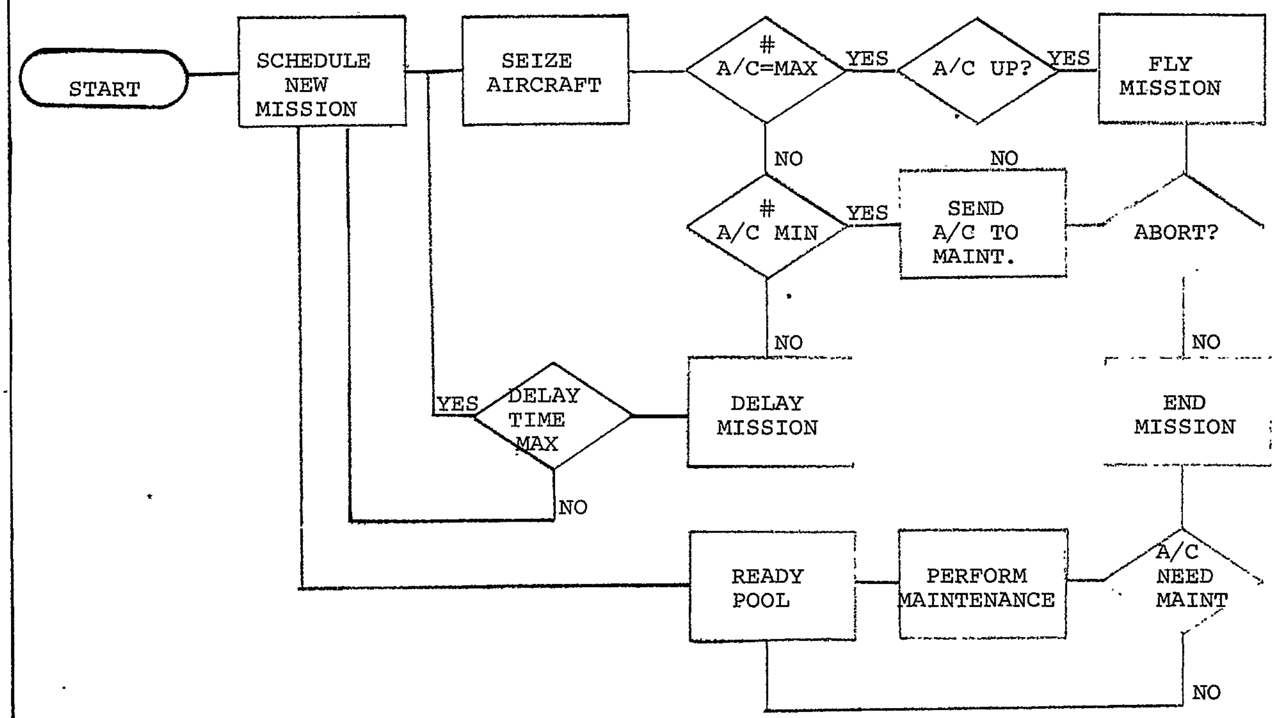


CHART B

Language

To accomplish the simulation discussed above, the language selected for MARS is General Purpose System Simulation (GPSS). Many techniques required by MARS such as gaming, queuing, randomness, and statistical capabilities are included as an integral part of the GPSS/360 software. Thus use of GPSS eliminated any requirement for development of separate sub-routines to perform these functions.

Data Collection Problems

To achieve optimum utilization of MARS a great number of parameters must be calculated and inputed. These parameters include the following:

1. Number and type personnel performing maintenance.

2. Maintenance manhours and elapsed maintenance time for each task.

3. Special tools, if any, required for each task.

4. Spare parts, if any, required for each task.

5. Identification of task type.

6. For all removable parts, identification of whether to repair, if removed.

These data are not always explicitly identified in Field Experience Data Reports. Thus, analysis of Field Data is necessary to generate the parameters required by MARS.

After collection and reduction of data into the desired parameters, construction of function tables containing these data must begin. Data are seperated into functionally independent tables interrelated by address numbers. Each table contains a set of items such as; component identification numbers, task probabilities, personnel requirements, etc.

Related Experience

Development of MARS was begun in January 1967, as an Independent Research and Development program. To date, approximately seven (7) man-years of Engineering Analyst time, and six (6) man-years of Programmer/Analyst effort have been expended in the development and refinement of this program.

MARS has been used to simulate the following aircraft, at varying levels of detail:

1. Marine CH-46 - Using Maintenance Engineering Analysis Records (MEAR) as a source of Reliability and Maintainability data, this program was debugged, verified and declared operational in 1969. In this model, data was used to simulate repairs at the component level. Both On- and Off- aircraft repair data were included.

2. Army CH-47 - Using United States Army Aviation Test Board Fort Rucker data as a source of Reliability and Maintainability data, a company of CH-47 aircraft was simulated. Due to the size of the data base (2278 flight hours), repairs were identified at the subsystem level to guarantee significance of the data sample. Analysis and verification of the results of this program have been documented in Boeing Document D300-1003-2, January 1970.

3. Army HLH - A MARS model has been developed to identify the operational impact of Reliability and Maintainability projections for the Boeing Vertol proposed Advanced Heavy Helicopter. Efforts in this area have identified certain potential problems which have been rectified.

4. Airforce A-X - A MARS model has been developed to support Boeing Vertol Product Assurance in the A-X proposal. The primary application of this model is in the area of Table of Organization and Equipment (TO&E) optimization.

Model Verification

The operation of MARS has been verified on each of the aircraft cited above (CH-46 CH-47, HLH, A-X). Primary parameters used as a measure of model effectiveness are the following:

1. Malfunctions Per Operating Hour

2. Maintenance Manhours Per Operating Hour

3. System Operational Availability

4. System Utilization

The following is a sample of the validation exercise performed on the CH-47 MARS model.

Using MARS to simulate the activities of a company of CH-47 aircraft for a time frame of 360 days the following results were generated:

PARAMETER	MARS VALUE	EXPECTED VALUE
Malfunctions/Flt Hr	1.05	1.07
Unscheduled Maint. Manhours/Flt Hr	2.33	2.63
Total Maintenance Manhours/Flt Hr	8.59	7.90
Utilization	42.6 hrs/mo	43 hrs/mo
Availability	85.0%	84.9%

Many other measures of validity were also considered, and compared favorably with the expected values.

In order to evaluate model validity for drawingboard aircraft, such as HLH and A-X, the parameter values generated by MARS are compared to expected values which are calculated analytically. Statistical equality of generated and expected values is indicative of valid model logic and operation.

Applications

1. Spares Allocation - By manipulating spare parts levels of various components and observing the effects of these changes on availability, one can determine the quantity of spares necessary to stock for a given component to support a desired availability.

2. Personnel Allocations - By examining maintenance delay times due to lack of personnel, one can determine the quantities and types of personnel needed to support a given quantity of aircraft, to achieve a certain desired availability.

3. Reliability and Maintainability Changes - Inherent in the make-up of the model is the ability to immediately reflect the impact of reliability and maintainability changes on availability, maintenance times, spares and special support equipment usage. Thus, the model will prove extremely valuable in the evaluation of planned design modifications.

4. Maintenance Philosophies - For aircraft in development, such as HLH and A-X, where there exists a question of "What kind of maintenance philosophy should be employed," the model will give its user the ability to test many philosophies and evaluate the results generated by each. One example of a comparison of this kind would be to. "consider the impact of having phased inspections rather than those that are restricted to a stringent time schedule".

5. Utilization Surge - The MARS model gives its user the ability to simulate a surge in utilization above the normal, and evaluate its effect on availability and maintenance. Thus, the model's user can see how sustained a surge can be absorbed without causing unacceptable availability due to lack of parts or queuing for personnel.

6. Sortie Length - By keeping flight hours constant, and varying mission lengths and number of flights per mission, the model's user can measure the effect of sortie length on maintenance and availability.