THE BRITISH AEROSPACE SHIP AVAILABILITY MODEL

BY

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The article 'A New Availability Model' by Dr C. French in the Journal[1] *described the Ship Availability Model developed by British Aerospace, its application, and the procedures for using it as they were in 1977. Since then the modelling program suite has been developed as a result of experience in its application and changes in computing practice. The present article is a reprint of a paper presented at the National Reliability Conference in 1985, bringing the story forward to that time.*

The suite of programs which makes up the Ship Availability Model is in the ICL computer at Bu West where it is now operated by Section ME512 in the Sea Systems Controllerate at Bath. It can be used there for evaluating availability in design projects.

Introduction

The Ship Availability model has been developed by British Aerospace for the Ministry of Defence to provide a general procedure for modelling ship systems, individually and in groups, and predicting a number of Availability, Reliability and Maintainability parameters during single activity or multi-activity missions. Though developed with ships and submarines in mind, it is a generalized procedure which could be used in other fields.

This article describes the main features of the model and presents two examples of its use.

Model Outline

The successful performance of a ship activity depends upon a number of systems successfully performing their functions. The systems in turn depend on the successful performance of functions by specific subsystems and equipments. Thus for availability modelling a ship can be conceived as a hierarchy of functions with a given ship activity being ultimately dependent on a set of primary functions which are essentially those of equipments.

When the functional hierarchy, usually called dependency logic, has been defined it is possible to calculate the availability of all the functions in the hierarchy if the failure and repair characteristics of the basic equipment are known.

The Ship Availability Model is a functional dependency model of this kind. It can accept detailed data about failure and repair characteristics, spares data etc. It can provide calculated information about the functions at each level in the logic. It can explore criticality and sensitivity at each of these levels and hence provide the means of identifying the causes of unavailability at any functional level.

The heart of the model is a large computer program. This can be operated in two different modes—analytical and simulation.

Analytical Mode

In the analytical mode the functional dependency logic is analyzed to establish which combinations of functions are sufficient for the ship or system function to work. From the failure and repair data for the primary function equipment the availability of each combination is calculated and the results combined to yield the availability for the ship or system function. A variety of availability parameters can be produced in this way at all functional levels. Since mission operating data are also input the outputs represent average values for the mission period, taking into account the different modes of system operation.

The analytical mode has the advantage of yielding precise values for the output parameters. However, the analysis of the logic normally yields large numbers of equipment combinations which have to be evaluated from the failure and repair data. As a model gets bigger and more complex so this task grows rapidly. Thus there is a practical limit to the size and complexity of the model which can be evaluated in the analytical mode. In practice this mode is used for single systems such as feed and condensate or chilled water.

Simulation Mode

The simulation mode on the other hand uses Monte Carlo procedures. Sampling failure and repair distributions for the equipments allows an artificial history of system operation to be built in terms of what equipment states obtain at any given moment. Measurements of time available taken from this history yield the availability measure for the system. A variety of availability parameters can be produced in a similar way at all functional levels.

The simulation mode depends on sampling. Hence the values for the output parameters are not precise but are best estimates of mean values. Each estimate has a confidence interval around it, the size of which depends on the extent of the simulation running. However it is not constrained, like the analytical mode, by the need to evaluate large numbers of equipment combinations and hence can handle much larger and more complex models. It can for example, take into account limits on numbers of spares and repair men. In addition, because of the sampling procedure, it is able to simulate a ship or system operating through a succession of diverse activities such as it might encounter during a real mission. In practice this model is mainly used for groups of systems, rather than single systems, and for multi-activity missions.

Modelling Procedure

A block diagram in Fig. 1 summarizes model operating procedure.

For each mode there are four phases:

(*a*) Preparing a paper model.

(*b*) Building a computer model.

(*c*) Calculating the availability parameters.

(*d*) Providing output.

Analytical Mode

(*a*) *Paper Model.* The paper model forms the computer input. It includes a Dependency Chart on which is drawn the dependency logic for a

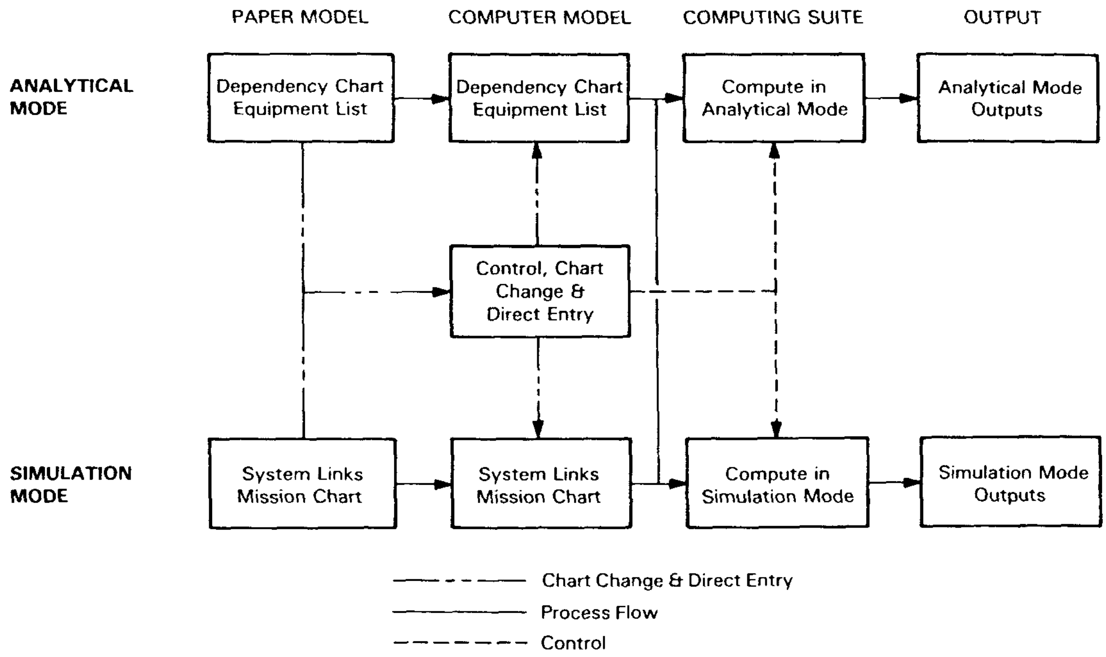


FIG. 1—MODEL OPERATING PROCEDURE

system and on which are shown the failure and repair data for the equipment within the system. It also includes an Equipment List, a chart on which is assembled the data about equipments and components to yield the failure and repair data for the Dependency Chart. Together they provide all the information which is necessary for running the model program in the analytical mode. Laid out to facilitate keying the data to disc for computer input, they also provide full disclosure of the design for a particular model application.

(*b*) *Computer Model.* The computer model is normally built by keying the paper model data direct to the computer disc. Apart from a minor change in symbols, due to computer character limitations, the Dependency Chart and Equipment List are stored and retrievable in the same format as the paper model.

(*c*) *Calculating Availability Parameters.* When called upon to do so the calculation program draws on the dependency, failure and repair data held in the computer model, performs the necessary calculations and retains the results.

(*d*) *Outputs.* As instructed when calculation is initiated, outputs selected from a wide range are printed out.

Simulation Mode

(*a*) *Paper model.* For a single system the simulation mode uses the same Dependency Charts and Equipment Lists, though one or two additional pieces of data have to be added to both charts. If a multi-activity mission is concerned, additional information about which functions are used for each ship activity are needed. This is provided by a Mission Chart.

When several systems are involved additional logic has to be added to the dependency charts to state the dependency of each system upon the functions of other systems.

(*b*) *Computer Model.* This is built in the same way as that for the analytical mode; by keying the paper model data to the computer disc. Alternatively it can be assembled from single system models, if they are already held in the computer and contain all the necessary data. The Mission Chart is also stored and retrievable in its paper model format except for similar minor symbol changes.

(*c*) *Calculating Availability Parameters.* When called upon to do so the calculation program draws on the dependency, failure and repair data held in the computer model, carries out the simulation and retains the results.

(*d*) *Outputs.* As instructed when calculation is initiated, outputs selected from a wide range are printed out. While the range includes some parameters covered by the analytical model there are many more which are peculiar to the simulation process, e.g. listing the events and occurrence times generated by the simulation process.

Model Operation

The program operation is controlled from a terminal which is used to initiate a run, set run parameters, and select outputs. The terminal can also be used for keying a particular paper model direct to the computer or for retrieving and modifying a stored model. This method is an effective means of exploring the availability effects of design options, and more economical than keying in each system option separately.

Outputs

Analytical Mode

The outputs from the analytical mode consist of seventeen tables. Of these two form a record of the charts put in and seven provide model build and management aids like, for example, Unassigned Function References and a system interconnection Correlation Table. The remaining eight carry the computed values for various parameters together with a record of certain associated assumptions. Four of them refer to single system dependency charts without any links to charts for other systems. They are provided as an intermediate step in the construction of a multi-system model. This subset is also used for single system models. The final four are for the same system charts but include any functional links to other systems. These sets of four outputs consist of:

(*a*) *Dependency Statements.* These contain a Boolean algebraic description of the dependence on related equipment functions for each major function and the four system availability levels of full, acceptable, degraded and minimum.

(*b*) *Dependency Coefficient Tables.* These show for each equipment the ratio of the number of alternative dependency configurations which require the equipment to the total number of possible configurations which produce the functions listed.

(*c*) *Availability Predictions.* This table displays the calculated availability and reliability parameters for Equipment, Major Functions and the four Availability Levels.

(*d*) *Equipment Sensitivity Coefficients.* These show the percentage change in the instantaneous availability at the end of the mission for a 10% change in the MTBF or MART (mean active repair time) of each constituent equipment.

The complete set of outputs is shown in TABLE I.

TABLE I—*Analytical mode outputs*

Equipments	Major Functions
Active Repair Code	Steady State Availability
Repair at Sea Probability	Instantaneous Availability at Mission End
Time at Risk Code	Reliability
Time at Risk Factor	Mean Downtime (in hours)
Deployment Factor	Repairable at Sea
Required Hours	Not Repairable at Sea
Steady State Availability	Total
Instantaneous Availability at Mission End	
Reliability	*Availability Levels*
Number of Repairs	Steady State Availability
Equipment Sensitivity to MTBF or MART change	Instanteous Availability at Mission End
	Reliability

TABLE II—*Simulation mode—availability analysis*

	Group Function	*Major Function*	*Equipment Function*
Availability			
Mean	*	*	*
90% Confidence Limits	*	*	
Usage	*	*	*
Reliability			
Reliability	*	*	
90% Confidence Limits	*	*	
Mean Repair Hours			
Defects			*
Failures			*
Mean Downtime Hours			
Repair	*	*	
Down—no spare or not repairable	*	*	*
Total			*
Mean Number of Repairs			
Defects			*
Failures			*
Mean Number of Failures	*	*	
Mission End States			
Up	*	*	*
Down & repairable	*	*	*
Down no spare	*	*	*
Down not repairable	*	*	*
Emergency repair	*	*	*

TABLE III—*Simulation mode—mission results*

Mission Analysis Number & percentage of missions successful. Mean, max and min duration of successful missions. Number of missions which completed the last activity. Analysis of failed missions: Which activity failed Which equipment caused the failure Equipment failure state Last successful activity
System Availability Levels For each system, and the four availability levels Full, Acceptable, Degraded, Minimum: The Instantaneous Availability at Mission End. The change in Instantaneous Availability during the mission.

Simulation Mode

Because of the different nature of the calculation the simulation mode outputs differ considerably from the analytical mode ones but they have a similar pattern of records, build and management aids, and results. Essentially the results are concerned with three areas of interest:

(*a*) *Availability Analyses* yield information on availability and reliability, also more detailed information on repairs and downtime and the material state at the end of the mission. This is done for the equipment, major functions, and selected groups of major functions (TABLE II). In addition the availability achieved at the end of the mission and the change during the mission is presented for system availability levels (TABLE III).

(*b*) *Mission Results* (TABLE III) reveal the number and proportion of missions which failed and the way in which they failed.

(*c*) *Logistics* in this context are concerned with the numbers of shipborne and support unit spares required and used and the number of support unit interventions required (TABLE IV)

TABLE IV—*Simulation mode—ship and support unit loading during mission*

Number of missions in which each activity starts.
Number of missions in which each activity fails.
Shipborne spares used, per specific mission activity.
Mean number
Max number
Min number
Support Unit spares ordered per specific mission activity.
Mean number
Max number
Min number
Number of repairs completed, per specific mission activity.
Mean number
Max number
Min number
Emergency Repair, per specific mission activity.
Mean number
Max number
Min number
Number of support unit visits.
Number of spares shipped per visit.

Inputs

Input Data

The variety of the input data reveals the large range of factors that are taken into account by the model in calculating the outputs. Thus they indicate the level of detail which the model is designed to accommodate. A complete list of input data is shown in TABLE V.

Input Preparation

The paper model is prepared on 160 column × 100 row sheets, individually designed for the Dependency Chart, the Equipment List and the Mission Chart, as shown in outline in TABLE VI. In the original concept some years ago, these each matched 2 × 80 column cards, and card punching and reading was the computer entry method. Now keying to disc is the method used but the original forms have been retained for their utility as records.

TABLE V—*Input data*

Dependency Chart	*Mission Chart*
Dependency Logic	Dependency Logic
MTBD/MCBD	Major Function Title
Failure/Defect Per cent.	Group Function Title
Repair at Sea Probability	Activity Title
Time at Risk Code	Activity Required Time
Time at Risk Factor	Next Activity (Success)
Deployment Factor—Equipment Function	Next Activity (Failure)
Standby Operating Code	Failure Code
Standby Repair Code	Repair Code
Failure Detection Code	
MART	
MART Factor	

Equipment List	
Equipment	*Component*
Time at Risk Code	Time at Risk Code
Ship Repair Constraint	MTBD/MCBD
Support Unit Repair Probability	MTBF/MCBF
Repair Priority Code	Time at Risk—Component ÷ Time at Risk—Equipment
	Repair at Sea Probability
	Mean Active Repair Time (MART)
	MART Factor
	Failure Data Confidence Code
	Failure Data Source
	Repair Data Confidence Code
	Repair Data Source
	Data Sheet Reference

TABLE VI—*Paper model*

(80 Columns)		(80 Columns)	
Row No.	(66 Data Columns)	Row No.	(66 Data Columns)
100 Rows	(*Dependency and Mission Charts*) Dependency Logic Notation *OR* (*Equipment Lists*) Titles and Operating, Logistic and Failure Data	100 Rows	Titles and Operating Data Operating, Failure and Repair Data and Notes

On the Equipment List, equipments and their constituent components are listed vertically and the component reliability and maintainability data laid out along the associated rows. On computer entry, equipment data are calculated from it for internal transfer to the Dependency Chart.

The Dependency Chart lists the equipment and functions for the appropriate equipment with equipment data which is usually derived from the equipment list, though it can be put in independently. Dependency logic is also shown on the chart.

FIGS. 2 and 3 illustrate the logic notation used on the Dependency Chart. FIG. 2 shows a simple hypothetical feed system having $2\times100\%$ extraction pumps which can take suction from both condensers, $3\times50\%$ feed pumps which can be fed by either extraction pump, and $2\times50\%$ boilers which can be fed by the feed pump combination. FIG. 3 shows the associated dependency logic for three major functions, viz. one-third power, half power, and full power. The Boolean interpretation of the logic is also shown for guidance.

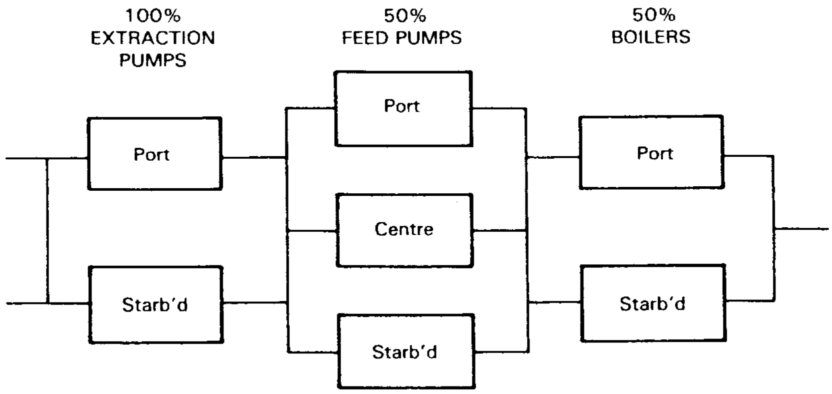
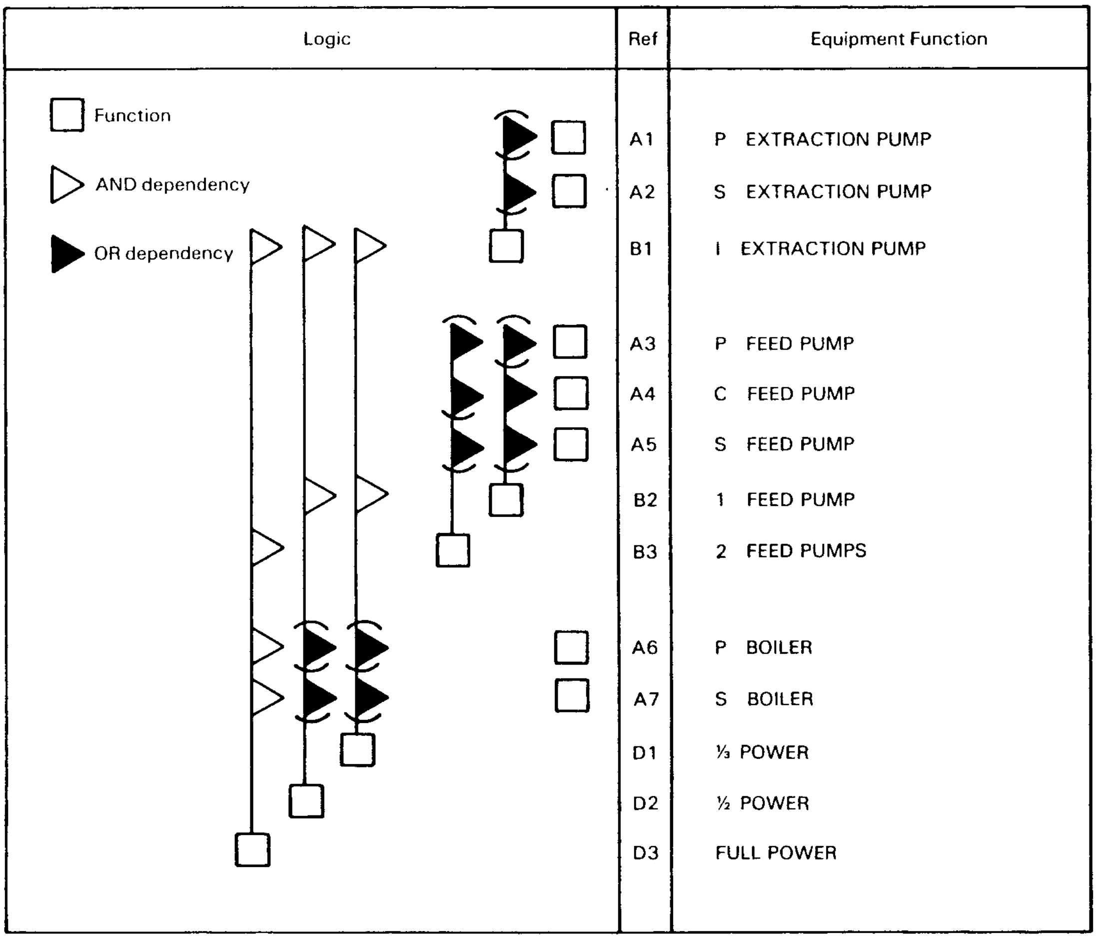


FIG. 2—HYPOTHETICAL FEED SYSTEM



In Boolean Terms

D1 = (A1 + A2). (A3 + A4 + A5). (A6 + A7)

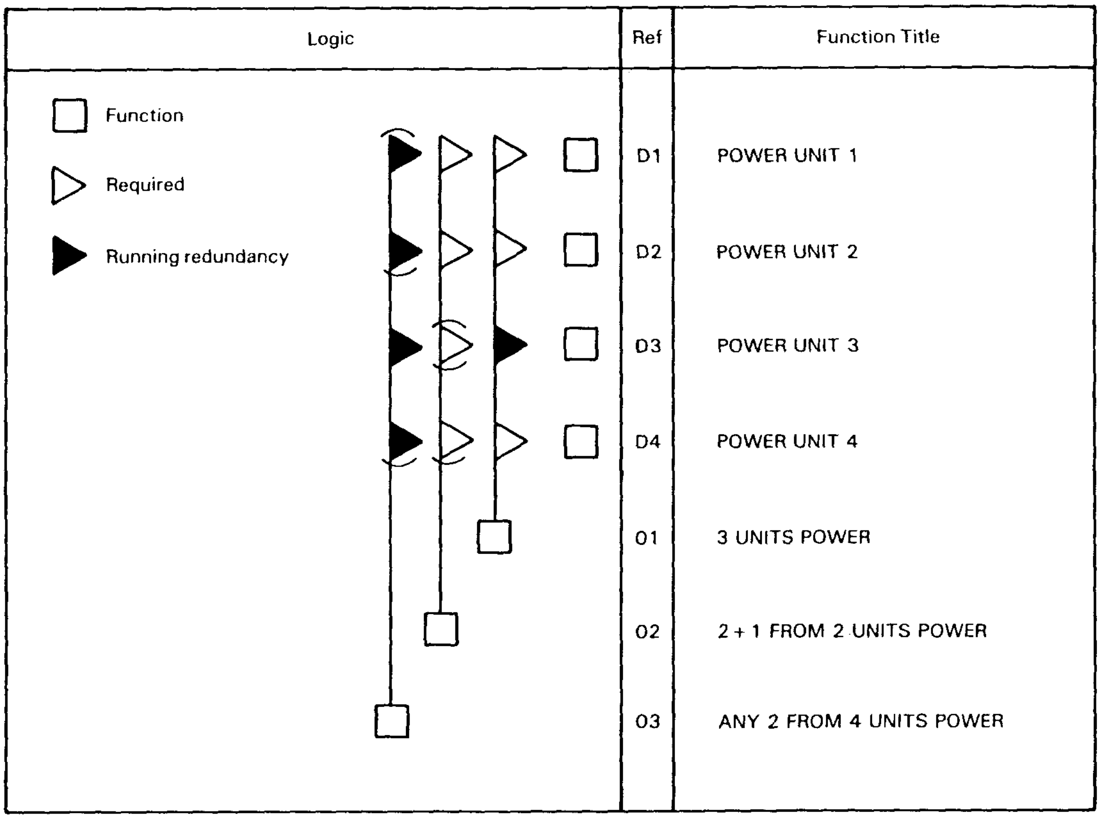
D2 = (A1 + A2). (A3 + A4 + A5). (A6 + A7)

D3 = (A1 + A2). (A3. A4 + A3.A5 + A4.A5). A6. A7

FIG. 3—DEPENDENCY CHART FOR HYPOTHETICAL FEED SYSTEM

This interpretation is part of the computer process which leads to the dependency statement output and forms the basis for calculation.

The Mission Chart lists sequentially the ship's activities and mission operating and decision data together with the associated Major Functions. Dependency logic is also shown on the chart.



In Symbolic Terms

01 = D1. D2. 3. D4

02 = D1. D2. (D3) D4)

03 = (1.2) 3.4)

NOTE THAT THE D IS SUPPRESSED TO SIGNIFY RUNNING REDUNDANCY

FIG. 4—MISSION CHART FOR HYPOTHETICAL POWER SEQUENCE

FIG. 4 illustrates the logic notation used on the Mission Chart. Three mission activities which call upon different combinations of 4 power units are shown. The first shows all 4 units running with one specific unit not loaded; the second shows all 4 units running with the first 2 units and either one of the second two being on load and the remaining one stationary; the third shows all 4 units running, with any two units being loaded. The symbolic interpretation of the logic is also shown for guidance. This interpretation is part of the computer process which determines the equipment operating pattern throughout the mission.

Data Processing Aspects

From the range and variety of inputs and outputs it will be clear that a large amount of data is put into the computer from the paper model. As the input outline reveals, this results in both a paper and computer record of the specific application before processing. Thus it is easy to discover later exactly what characteristics and operating pattern were allocated to any equipment or component for a particular computer run.

Calculation Procedure

Analytical Mode

Steady State Availability, Instantaneous Availability at Mission End and Reliability are the key quantities calculated by this mode. These are calculated initially for each equipment function. The path sets defined by the dependency logic put into the computer are interpreted in Boolean algebraic form and factorized to reduce the extent of subsequent calculation. The sets associated with each major function are then evaluated using the equipment function probabilities as input data. Series equipments are assumed to be independent for this purpose.

The familiar steady state availability expression:

$$A_{ss} = \frac{\mu}{\mu + \lambda}$$

where μ = repair rate
λ = failure rate

is used when all equipment failures are repairable at sea.

The existence of some failures which are not repairable at sea introduces a complication. For an equipment susceptible to both types of failure the following expression for instantaneous availability A_{inst} at mission end is used:

$$A_{inst} = \text{EXP} - \lambda(n)t \left[\frac{\mu - \lambda(n)}{\mu + \lambda(r) - \lambda(n)} + \frac{\lambda(r)}{\mu + \lambda(r) - \lambda(n)} \text{EXP}\{ - [\mu + \lambda(r) - \lambda(n)]t\} \right]$$

where $\lambda(n)$ = not repairable at sea failure rate
$\lambda(r)$ = repairable at sea failure rate
t = mission length

A component of this expression represents a pseudo steady state condition and is used for computing steady state availability (A_{ss}):

$$A_{ss} = \frac{\mu - \lambda(n)}{\mu + \lambda(r) - \lambda(n)}$$

The last two expressions account for both types of failure and their interactions.

Simulation Mode

The key elements of the simulation process are shown in the form of a very much simplified flow chart in FIG. 5.

At the start of a mission activity the activity duration is set and the major functions required for it are compared with the major function state list to establish whether the activity can start. If it cannot, the activity state, that is the reason for non-availability, is determined and recorded and the simulation passes to the next activity. If the activity is available the major function Boolean expansions are solved to identify the relevant equipment functions.

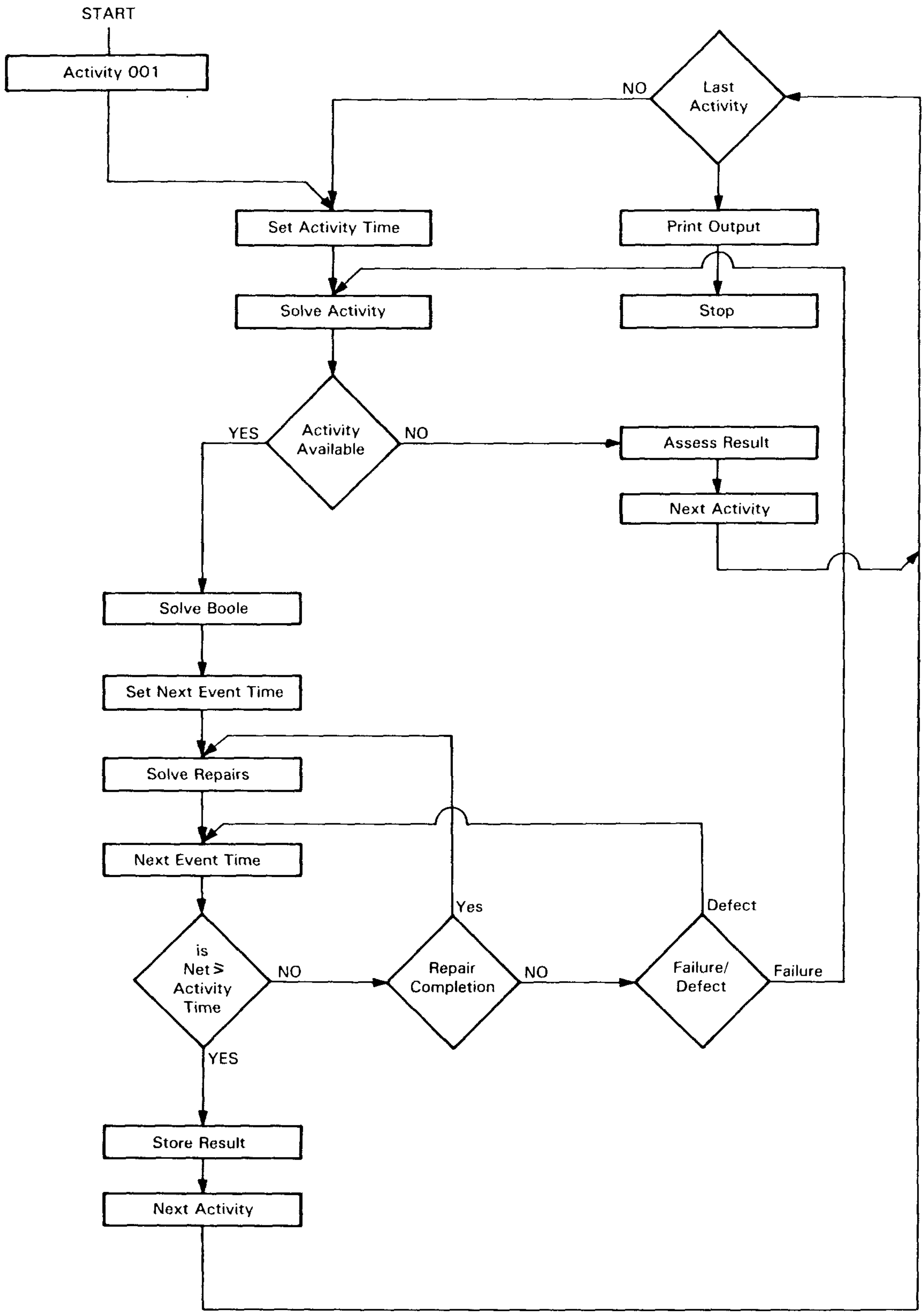


FIG 5—SIMULATION MODE FLOW CHART

The next event time for each equipment is then updated to take into account the extent to which they are at risk and the equipment functions ranked by next event times.

Then the repair queue and number of free repairmen are checked, and repairmen allocated where possible. For equipment newly under repair, repair times are established by sampling, next event times calculated for the equipment, and the equipment added to the next event time ranking.

If the shortest event time is longer than the activity time the activity is a success, the result is stored, and the simulation passes to the next activity. If it is not, the equipment data is checked to establish whether the event is a completed repair, a defect or a failure. If a repair, the cycle is repeated. If the event is not a repair a random number is used to decide whether the event is a failure or a defect.

If it is a failure the activity logic is solved to establish whether the activity can still be performed without the associated equipment function. If the event is a defect the next longer event time is selected and activity success reconsidered.

Capacity

The simulation mode is particularly useful in the context of a multi-system ship or installation coupled with a multi-activity mission. The resulting model can become very large and the capacity of the computing suite becomes important. The limiting factors are summarized in TABLE VII. So far these limits have been more than adequate for any modelling task undertaken or envisaged.

TABLE VII—*Model capacity*

100	Components per Equipment.
2000	Equipments.
120	Equipments per Major Function.
60	Redundant Equipments per Major Function.
2000	Redundancy Options per Major Function.
480	Major Functions.
46	Major Functions per Dependency Chart.
60	Dependency Charts per Model.
150	Major Functions per Mission Activity.
995	Activities per Mission Chart.
10	Mission Charts per Model.

Whilst one would not contemplate developing a modelling procedure of this scope and scale to undertake small scale modelling tasks, the procedure is very flexible and it is possible to use it for very simple models. In fact it has been used successfully in concept design for the quick modelling of some 34 simple plant and activity variants as well as in detail design for modelling a complex vessel, complete but without its weapons.

Examples

For the purpose of illustrating the suite's capabilities, two much simplified examples are presented. The first is of a single system type, where a design and one option are analyzed in the analytical mode. The second is a multi-system model used here to show how mission events can be simulated taking due account of the interdependency between systems, including closed loops.

Single System Model

FIG. 6 shows a simple schematic representation of an equipment cooling system where clean cooling water is pumped through the equipment by two clean water pumps, the heat being removed from the system through two dirty water cooled heat exchangers, each with its own dirty water pump. The system can be sided through hydraulically operated cross-connection and isolating valves, and non-return valves. A facility exists for make-up.

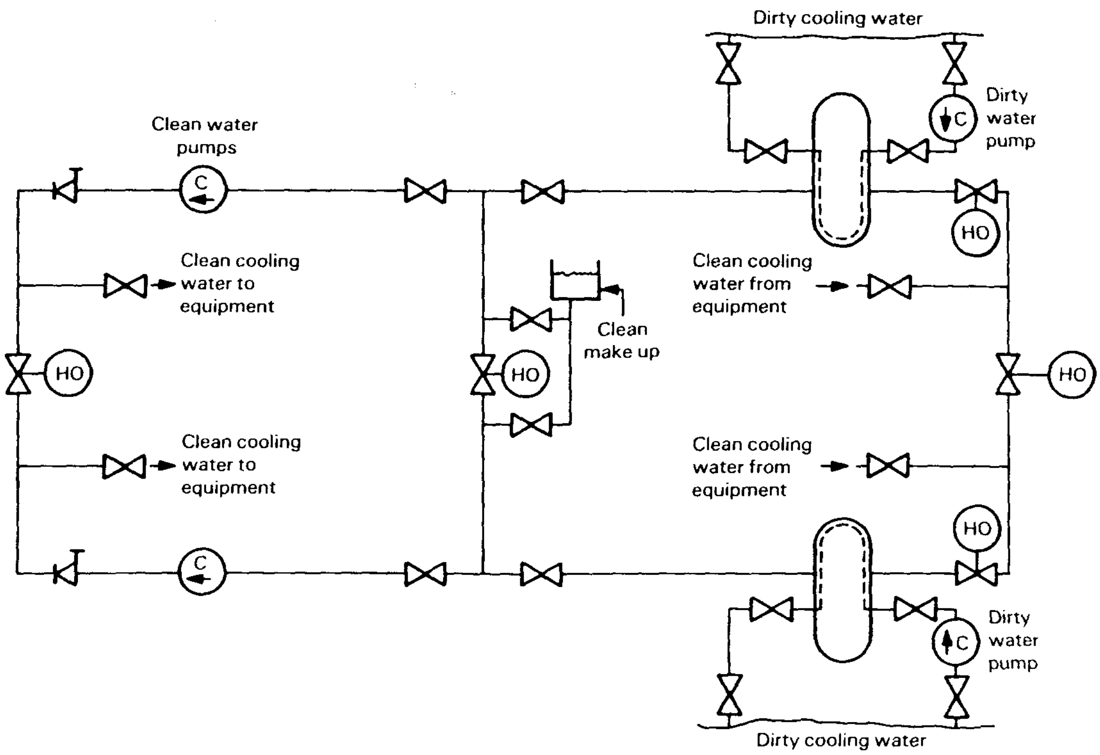


FIG. 6—COOLING WATER SYSTEM WITH TWO CLEAN WATER PUMPS

A steady state analysis of this system will include the results presented in TABLE VIII. Of particular interest are the Instantaneous Availabilities and Mean Downtimes for the different modes of operation. Instantaneous Availabilities indicate the availability to meet rapid changes in demand at a particular time, important in both warship and commercial plant operation.

TABLE VIII—*Major function availability predictions for a two-pump system on a 100 day mission*

Funct. Ref.	*Function Title*	A_{ss}	A_{inst}	*Reliability*	*Mean Downtime* (hours)		
					Repair	*Non-Repair*	*Total*
1	2 DW Pumps, 2 CW Pumps	0·9933	0·9687	0·2786	9·62	17·94	27·44
2	2 DW Pumps, 1 CW Pump	0·9935	0·9886	0·3049	9·34	3·54	12·85
3	1 DW Pump, 2 CW Pumps	0·9977	0·9776	0·5062	3·32	14·53	17·82
4	Side 1 only	0·9947	0·9823	0·4974	7·62	9·01	16·58
5	Side 2 only	0·9946	0·9822	0·4975	7·76	9·01	16·72

The Mean Downtimes show the average loss of availability for the period of operation analyzed, in hours, both for failures repairable during the period, and those not repairable. These need some interpretation—the non-repairable downtimes for Function 1 are more likely to indicate a loss of that service for say 720 hours every fortieth period of operation. The 2400 hours period of operation chosen is arbitrary and any period can be chosen.

TABLE IX—*Sensitivity (% change in Instantaneous Availability for 10% equipment MTBF change)*

Equipment Ref.	*Equipment Title*	*Major Function Reference*				
		1	*2*	*3*	*4*	*5*
A	Cooler (Side 1)	0·043	0·043	0·000	0·043	—
B	Cooler (Side 2)	0·043	0·043	0·000	—	0·043
C	DW Pump Starter	0·000	0·000	0·000	0·000	0·000
D	CW Pump (Side 1 or Side 2)	0·102	0·102	0·102	0·102	0·102
E	HO Valves	0·000	0·000	0·000	0·020	0·020
F	DW Pump (Side 1 or Side 2)	0·010	0·010	0·010	0·010	0·010

Given that these availabilities may not be acceptable, it is necessary to determine the main problem areas. The sensitivity analysis shown in TABLE IX helps here, the analysis indicating the percentage change in an activity's Instantaneous Availability for a 10% change in equipment MTBF or MART. From this we can see that for this example the clean water pumps are worthy of attention.

Many options lie open to the designer at this stage, including the introduction of stand-by equipment. One such option is illustrated in FIG. 7 which shows a third clean water pump and extra hydraulically operated valves to permit sided operation.

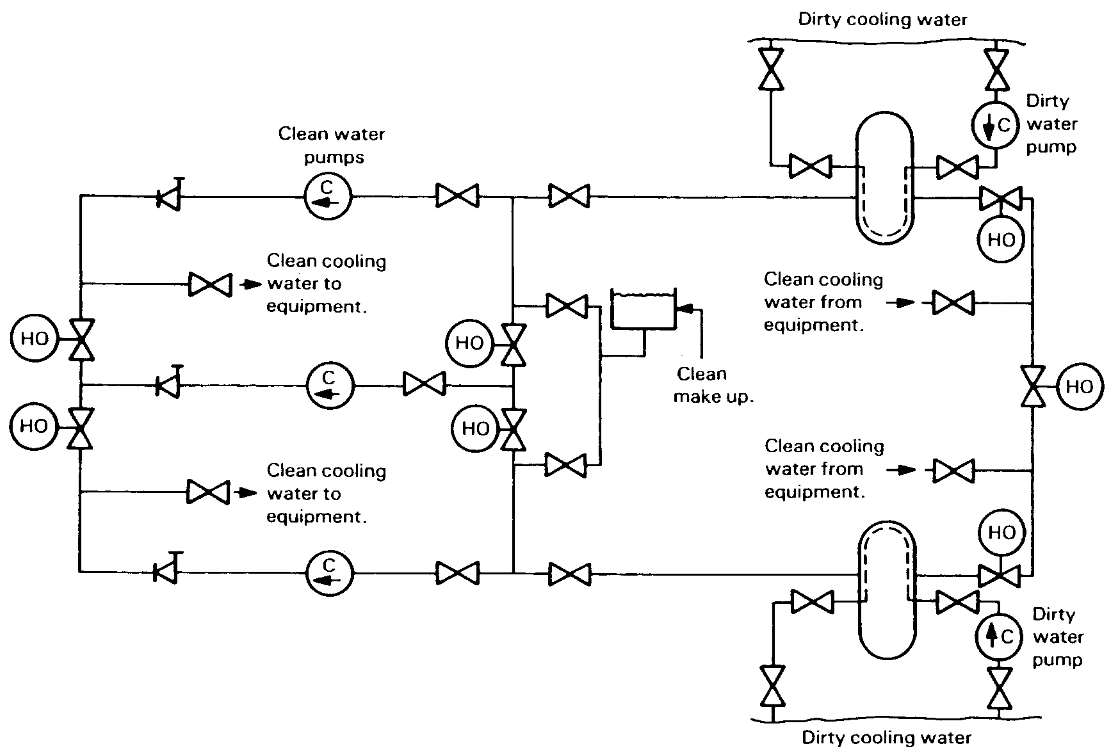


FIG. 7—COOLING WATER SYSTEM WITH THREE CLEAN WATER PUMPS

TABLE X—*Major function availability predictions for a three-pump system on a 100 day mission*

Funct. Ref.	Function Title	A_{ss}	A_{inst}	Reliability	Mean Downtime (hours)		
					Repair	Non-Repair	Total
1	2 DW Pumps, 2 CW Pumps	0·9932	0·9883	0·2716	9·77	3·56	13·30
2	2 DW Pumps, 1 CW Pump	0·9932	0·9883	0·2916	9·77	3·56	13·30
3	1 DW Pump, 2 CW Pumps	0·9976	0·9975	0·5299	3·46	0·11	3·57
4	Side 1 only	0·9965	0·9941	0·5365	5·04	1·78	6·81
5	Side 2 only	0·9964	0·9940	0·5366	5·18	1·78	6·95

An analysis of this arrangement is shown in TABLE X and indicates the effect of the changes incorporated.

The results presented are fictitious, but they are representative of the sort of differences the modelling method detects and the sort of comparative study a designer may wish to do where availability is a critical requirement.

Multi-System Models

Most plants are a compendium of many such individual systems. For development purposes a twenty-system model has been conceived which is representative of the sort of systems and system interdependencies one might expect to find in warship plants.

A selection of outputs limited to the rows of direct interest are shown in TABLES XI to XIV. The consideration here is to analyze mission results to identify mission failures and any significant shortfall in availability. The contributory causes of each can then be found and corrective action decided. There are two paths to follow, the first concerned with the causes of mission failure and the other with the causes of low availability.

The Mission Failure Analysis (TABLE XI) indicates the critical mission activity, the equipment causing the failures and the reason each leads to non-availability. The extent of the overall non-availability can be found in the Failed Equipment Performance Analysis (TABLE XII). The equipment

TABLE XI—*Typical mission failure analysis for 100 day mission*

% of Missions	Failed Activity	Failed Equipment	Reason for Non-Availability	Mean Time
27	High Speed Manoeuvre	Fuel Boost Pump	Not Repairable	90 days
8	General Passage	Navigational Equipment	No Spares	70 days
20	Various	Various	Various, including Under Repair & Failure Not Detected	Various

% of Successful Missions = 45%

TABLE XII—*Failed equipment performance analysis*

Failed Equipment	Availability		Mean Downtime (hours)		Mission End States			
	Mean	Usage	Repair	Non-Repair	UP	DAR	DNR	EMR
Fuel Boost Pump	0·9761	0·7485	0·050	57·40	73	1	26	0

UP: serviceable
DAR: down and repairable
DNR: down not repairable
EMR: emergency repaired

TABLE XIII—*Group function availability analysis*

Group Function	Availability		Mean Downtime (hours)		Mission End States			
	Mean	*Usage*	*Repair*	*Non-Repair*	*UP*	*DAR*	*DNR*	*EMR*
General Passage	0·9938	0·8505	2·8	12·0	50	20	30	0

TABLE XIV—*Major function availability analysis*

Major Function	Availability		Mean Downtime (hours)		Mission End States			
	Mean	*Usage*	*Repair*	*Non-Repair*	*UP*	*DAR*	*DNR*	*EMR*
Main Propulsion	0·9996	0·9080	1·0	0·0	100	0	0	0
Navigation	0·9943	0·9912	1·8	12·0	50	20	30	0

data is then analysed for individual failures, failures repaired, failures not repaired and why, spares used or not available, and whether repairmen are available. If a solution cannot be found here the operating and test pattern of the associated major function would be examined to see if these could be improved and finally whether additional redundancy would be the best answer.

The second path starts with the Availability Analysis which reveals the critical group function (TABLE XIII). The Mission Chart Dependency Statement (not illustrated) displays the composition of the group function and leads to the major functions which are possible causes. Examination of the identified major functions (TABLE XIV) enables the culprit to be identified. For the purposes of this paper the major function is shown to be main propulsion and from the outputs we can discover whether the function has been a major contributory factor in the group function low availability. The Major Function Dependency Statement equally leads to possible equipment causes. Thereafter deeper analysis of the equipment data would be used as before to formulate possible corrective actions.

Conclusions

The Ship Availability Model is a powerful tool that can provide a great deal of information of a management, engineering, operational and logistics nature related to availability. This information is predictive and hence permits corrective action to be taken before situations involving heavy penalties arise.

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Reference

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