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NASA TECH BRIEF

Design and Sparing Techniques to Meet Specified Performance Life

In the conceptual phase of a program or project, often only a gross description of what is wanted is available. Whether the device be a space system or clean room, some requirement for life span and permissible down time is generally specified.

A cost-effective and proven technique which has been developed can be implemented, even before the system is designed, to determine the major subsystems, their required reliability, required switchable and maintenance spares as a function of time, and required redundant functional systems. While these determinations can be approximated by the use of conventional reliability, maintainability, availability, and logistics models, this conventional approach generally requires more information than that readily attainable and is time consuming and costly.

The new technique starts with the general description of what is wanted, defines in block diagram form (model) what operational needs must be met, and then defines the functional systems required to satisfy the operational needs. Thus far the technique is similar to a truncated reliability model, but the method of calculation is much simplified by use of a Poisson distribution approach to failure probability. The method of attacking the problem involves calculating the probability that the number of available spares is equal to or greater than the number of failures during the period of interest. System parameters, namely, redundant subsystems, spares, maintenance time, subsystem reliability, down time, operating time, etc., are compatibly adjusted to obtain the desired system characteristics, including cost and weight.

The Poisson distribution formula is applied:

$$P(x) = e^{-U}\frac{U^x}{x!}$$

where P(x) is the probability that exactly x failures will occur when U failures are expected.

The accumulated form, C(x), of this distribution also gives the probability that the number of failures will be equal to or less than x:

$$C(x) = \sum_{r=0}^{x} e^{-U}\frac{U^r}{r!}$$

where r is the index of summing.

Utilizing published tables of the Poisson distribution, the number of redundant or spared items to provide the required probability of success for any combination of failure rate and time can be determined.

The initial approach is to select arbitrary probabilities of mission success (or successful operation for a given period of time) and test these in the model to arrive at reasonable allocations of reliability and overall success of the operation. This approach is iterated until satisfactory results are obtained.

Notes:

1. The technique would be of value in situations where the penalty associated with improper performance of a system, at some time or for some period, must be weighed against the penalties of cost resulting from redundant systems, spares, maintenance, and weight. Examples of applications of the technique are: determining, in advance, the cost of warranties on automobiles; estimating trade-offs between the cost of spares and down time of machines and other equipment; determining required availability and corresponding sparing and maintenance of a manufacturing facility; and studying trade-offs between availability and logistics weight for field or flight equipment.

(continued overleaf)

2. No further documentation is available. Inquiries may be directed to:

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No patent action is contemplated by NASA.

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