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RELIABILITY EVALUATION METHODOLOGY FOR NASA APPLICATIONS

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1. Introduction

Liquid rocket engine technology has been characterized by the development of complex systems containing large number of subsystems, components, and parts. The trend to ever larger and more complex systems is continuing. The liquid rocket engineers have been focusing mainly on performance driven designs to increase payload delivery of a launch vehicle for a given mission. In otherwords, although the failure of a single inexpensive part or component may cause the failure of the system, reliability in general has not been considered as one of the system parameters like cost or performance. Up till now, quantification of reliability has not been a consideration during system design and development in the liquid rocket industry. Engineers and managers have long been aware of the fact that the reliability of the system increases during development, but no serious attempts has been made to quantify reliability. As a result, a method to quantify reliability during design and development is needed. This includes application of probabilistic models which utilize both engineering analysis and test data.

Classical methods require the use of operating data for reliability demonstration. In contrast, the method described in this paper is based on similarity, analysis, and testing combined with Bayesian statistical analysis.

2. Reliability Evaluation Process

In general, due to the costly testing of a liquid rocket engine, it is not feasible to establish high reliability based on test only. Traditionally, reliability has been incorporated in the design using safety factor information. But, safety factors do not provide adequate assessments of reliability which takes into consideration all of the available information from historcal data, engineering analysis, and test is needed for reliability evaluation. The following is a description of a reliability evaluation process based on the three above mentioned sources of information.

The reliability evaluation process shown in figure 1 consists of two major steps. The two steps are predicting reliability during design and verifying it during development (segment 1) and certification (segment 2).

The reliability prediction begins with defining reliability requirements, followed by a design selection process which involves evaluating alternative designs to obtain a base design. For a given base design, a preliminary failure mode effects analysis (FMEA) is then performed. FMEA is then used to identify all failure modes relevant to predicting the engine design reliability. The failure modes identified are used with historical database and engineering analysis to predict design reliability.

The predicted reliability is checked against the requirements to determine if the targeted design reliability is met. If target is not met, feasibility of design changes are investigated. If design changes are not feasible, a formal management decision is required.

After the completion of the reliability prediction phase, the process goes into development phase (segment 1) which is the first part of the reliability verification step. The development phase, in general, consists of lower level testing, which includes part and component testing. Some system testing is also done to a limited extent in the development phase. The testing during this phase is mainly intended to verify assumptions and resolve concerns identified during the design reliability prediction phase. Also, a reliability growth and management system is established during this phase to continually evaluate reliability as more testing data becomes available.

Following the development phase, the certification phase (segment 2) emphasize system level testing. The test data obtained during this phase is used to update system reliability predicted earlier. The updated reliability is then compared to the reliability requirement. If reliability requirement is not met, a formal management decision is required. Otherwise, the reliability evaluation process is considered complete with respect to the readiness for flight.

3. Reliability Prediction

The reliability prediction is part of the overall reliability assessment process shown in figure 2. The assessment process consist of predicting reliability using FMEA in conjunction with historical databases and other engineering analyses such as structural analysis. The predicted reliability is then compared to the target value. Failure to meet the target requires management action to reallocate reliability, change the design, change the process, perform additional tests, or simply to accept system reliability as is.

4. Reliability Verification

The reliability verification process discussed in this report is based on predicting reliability during design and verifying reliability during testing (development and certification) as shown in figure 3. During the design phase of the STME, information relevant to the estimation of reliability will be available from different sources at different levels. This information is combined in computing an estimate of the STME reliability. This estimated reliability is updated as test data on the engine become available using Bayesian method as described in figure 4.

Specifically, the reliability verification process uses information from similarity and analysis in the form of a prior and combines this information with the test via the Bayesian analysis to estimate reliability as shown in figure 4.

Referring back to figure 3, other reliability verification is done using DOE and other tools at part and the component level. This includes verifying prediction assumptions and resolving concerns raised during prediction. It should be noted that the prediction process just described also provide a reliability audit trail. This includes complete history of various assumptions used, concerns noted, and data sources.

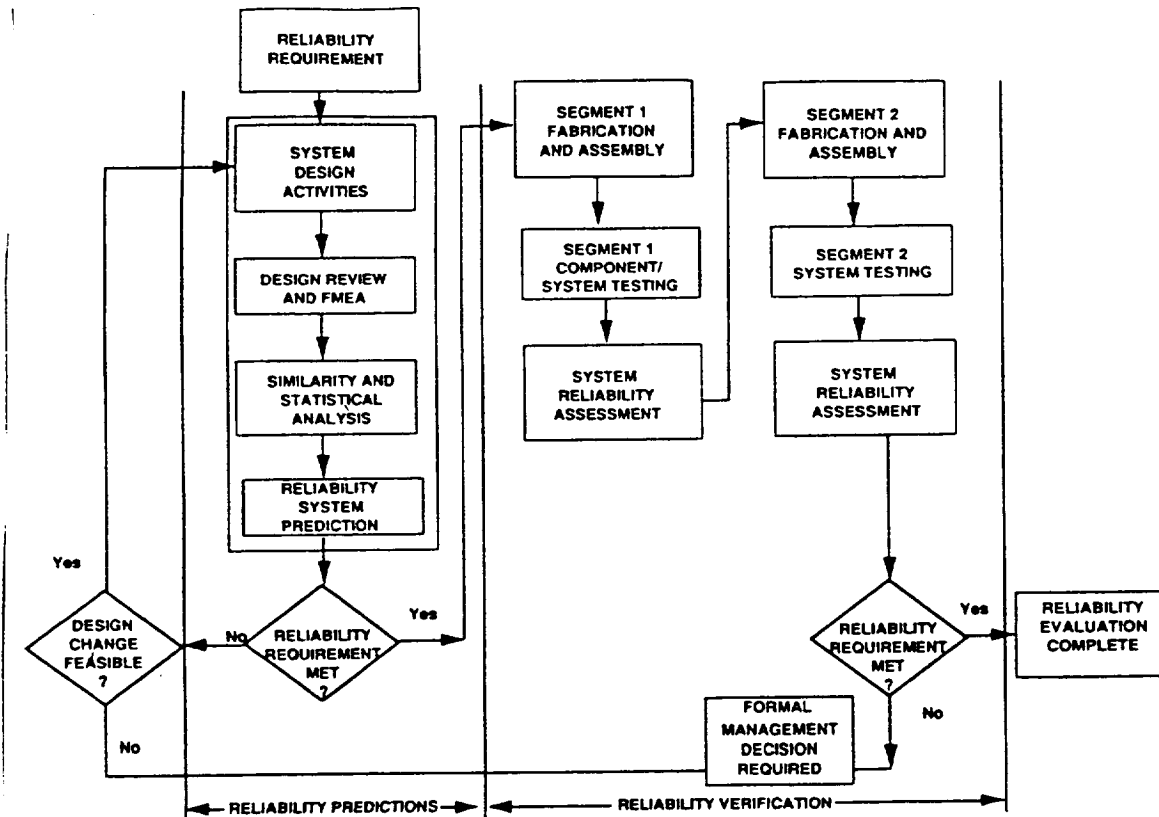


FIGURE 1: RELIABILITY EVALUATION PROCESS

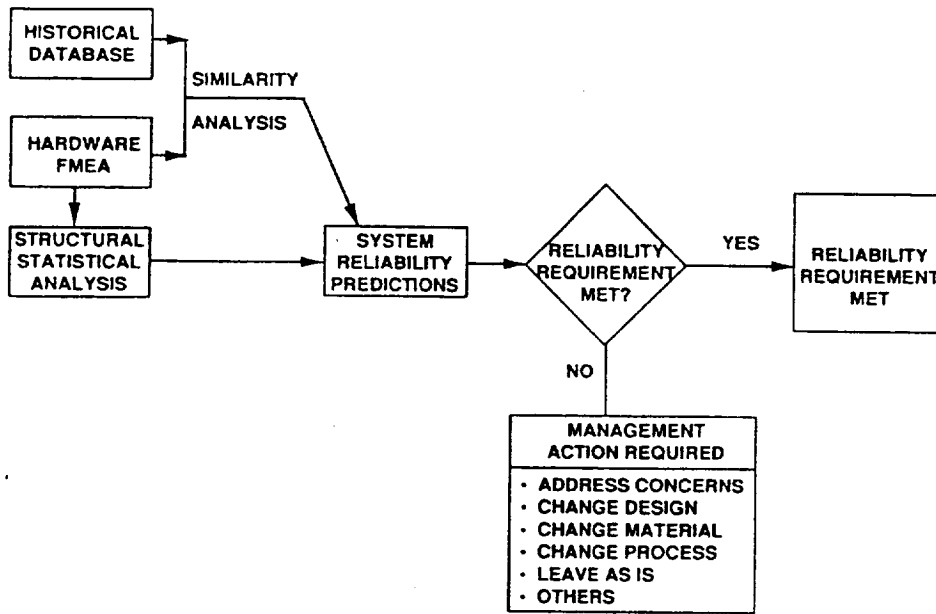


FIGURE 2: RELIABILITY ASSESSMENT PROCESS

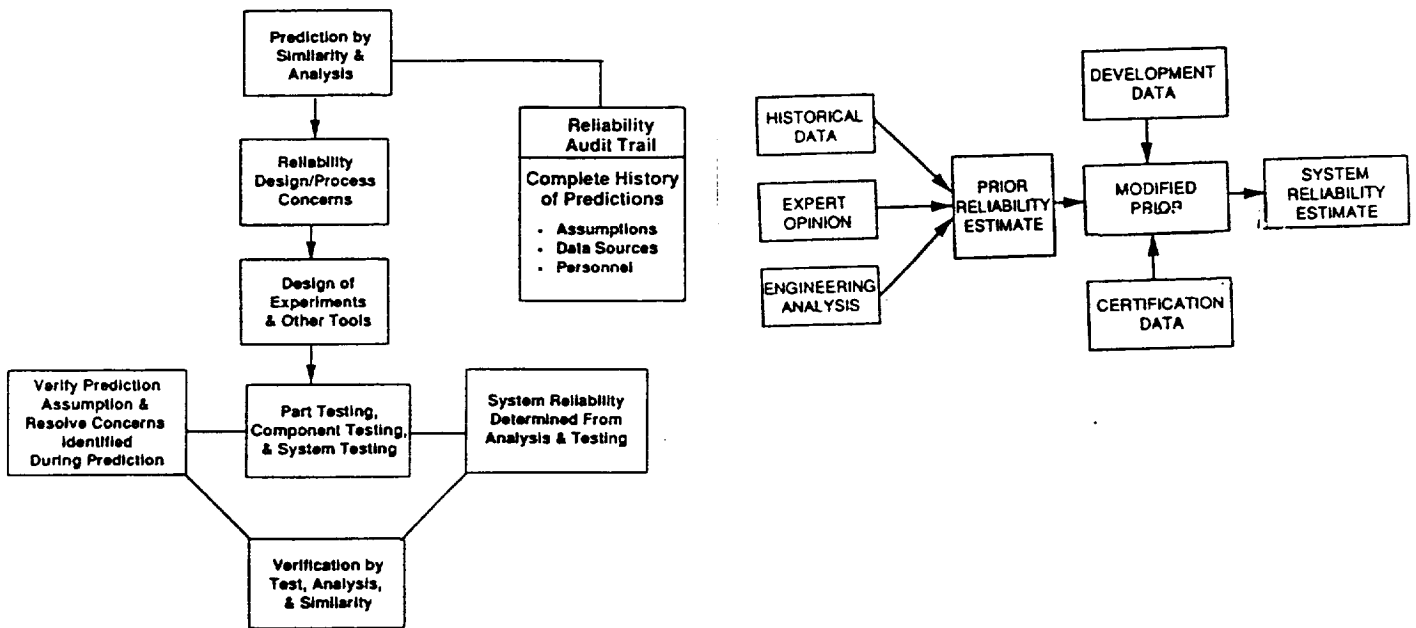


FIGURE 3: RELIABILITY VERIFICATION PROCESS

FIGURE 4: BAYESIAN RELIABILITY PROCESS