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Reliability based design with FMEA AND FTA

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ABSTRACT: *Reliability based design is the methodology for finding designs that are characterized with a low probability of failure. Assessing reliability of projects during design phase reviews requires a critical look at equipment details to determine if reliability has been built into the design for meeting performance goals required by the project. Failure modes effect analysis (FMEA) is an analysis tool for evaluating reliability by examining expected failure modes to find the effects of failure on equipment or systems. Fault tree analysis (FTA) is a deductive reliability analysis tool for evaluating reliability driven by top level views of what will fail and searches for root causes of the top level event. FTA considers experience and biases such as "every time we build a plant for this product we have these types of failures—". FTA provides both reliability assessments and fault probability perspectives.*

Keywords- *FMEA, FTA, Reliability, Reliability assessment.*

I. INTRODUCTION

Design and development are system engineering processes. Design synthesis that achieves high reliability involves a process that can be thought of as an iteration of design (design and redesign), where relevant failure modes are identified and removed. Reliability of a system arises from its resistance to failure, so during the design and development phase, an effective design process eliminates the system failure modes that would be encountered in the field. The removal of failure modes requires vigilant, informed, and sustained engineering

Reliability metrics should be chosen based on the type of system under consideration (i.e., one-T shot systems or repairable systems), the support concept, and the system's use. systems are expendable systems that only get used once and are then replaced, for example an automotive air bag is a one-shot system. The reliability may be characterized by a single probability (e.g., 99.9% reliability when 999 out of 1000 air bags fired and deployed properly when voltage was applied). Alternative reliability characteristics might be storage reliability and reliability under conditions before use (i.e., vibration conditions of transportation).[1]

II. DEVELOP RELIABILITY PROGRAM PLAN

System operational availability is a consequence of actual system Reliability assessment performance in the field, combined with the logistics support provided. Targeted levels of Reliability assessment are more likely to be achieved when designers accurately anticipate and accommodate the operational, environmental and support factors applicable to the fielded system. Designers rely on and consider the documentation that is supplied within the contractual context from earlier life cycle phases. This documentation includes:

• Operational Concept documentation

• Logistics and Maintenance Support (Concept) documentation

• Life cycle environmental information

These documents provide the constraints and boundaries within which the design must operate and be sustained. The support and maintenance concepts are typically refined during this phase, as a result of gaining a better understanding of the technology, the technical solution, and operational constraints.

Successful and efficient reliability program management comes from the ability to identify and tailor relevant "value-added" tasks that address the stated or implied needs of the customer while minimizing overall system or product life cycle costs. Knowing and understanding the needs of the customer serves as the basis for establishing realistic reliability and integrated design requirement. Building inherent reliability into the design

and ensuring that it is maintained throughout the development, manufacture and use of the product/system is the primary objective of an effectively managed RPP. An effective RPP provides an overall cost benefit, particularly in terms of Life Cycle Cost (LCC). An effective program may include analysis tasks that supersede unnecessary tests, or may use a test strategy that has a more significant impact on inherent product reliability than analytical methods. In either case, the improved product/system reliability should be pursued at optimal cost.[2]

III. RELIABILITY DESIGN AND DEVELOPMENT TECHINQUES.

There are a number of techniques used within the systems engineering process to develop and assure the Reliability assessment performance of the system. These include the following techniques described subsequently.

∑ General Reliability assessment Design Considerations.

∑ Reliability assessment.

∑ Failure Modes and Effects Analysis (FMEA).

∑ Fault Tree Analysis (FTA).

3.1 General Reliability assessment Design Considerations.

In general, the following basic techniques should be in the forefront of designers' minds during the design and development process as methods that will normally improve the reliability performance of items under design.

• Simplify the design
• Implement redundancy judiciously

• Design for fault-tolerance

• Improve the design by eliminating the failure modes

• Adopt a modular design approach
.
• Use robust design techniques

3.2 Reliability assessment.

Assessment is the continuing process of determining the value of the level of Reliability assessment being achieved at any point in time. The ability to make an

assessment, and the quality of the assessment, depends on the information available Assessments are needed throughout the development of a system, and often are stated in what appear to be very "accurate" terms, it must always be remembered that reliability is probabilistic concepts and that operational availability is a function of not only reliability and maintainability but of many other factors.

Limitations of Assessment : All assessments will have limitations. They may be caused by insufficient sample size, inadequate testing under required conditions (both technical and operational), or immature system functionality. Limitations should be clearly identified and reported as part of an assessment as well as their effects on test results, parameter estimates, and any inferences on requirements compliance.[1]

3.2.1 Reliability Modelling.

Reliability assessment modelling is a very powerful and informative tool and very useful for activities in addition to its utility as an assessment tool. Reliability model presents a clear picture of functional

interdependencies and provides the framework for developing quantitative product level reliability estimates to guide the design trade-off process.

There are several basic reliability and availability models used when analyzing a system.

Fig. 1 Basic Series Model

When redundancy is introduced between the components, the reliability models become more complex. The active redundancy model is used for simplest redundant system, which consists of two independent components that can still achieve system success as long as one component is functioning. Fig. 2 shows a dual redundant system.

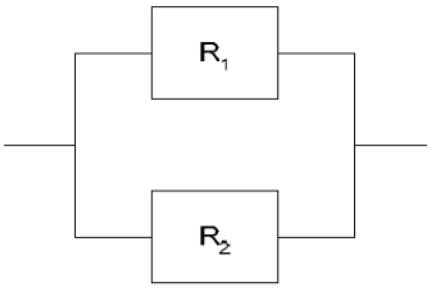

Fig. 2 Dual Redundant System

Standby redundancy is the process in which one unit does not operate continuously, but instead only becomes active when the primary unit fails. When modelling a system with standby redundancy the reliability of the standby and primary units is needed as well as the reliability of the sensing and switching system that controls the system's operation.[2]

3.2.2 Reliability Allocation.

After the system has been drawn in block diagram form, subsystem and component reliability goals and targets are established. This is a common practice in the development of complex systems, particularly when different design teams or subcontractors are involved. Reliability allocation involves setting reliability objectives for components or subsystems in order to meet a system reliability objective and should occur in the initial stages of design or prior to designing major system upgrades. The simplest method for allocating reliability is to distribute the reliability objective uniformly among all the subsystems or components. While uniform allocation is easy to calculate, it is generally not the best way to allocate a reliability objective. The "best" allocation of reliability would take into account the cost or relative difficulty of improving the reliability of different subsystems or components.

3.3 Failure Modes and Effects Analysis (FMEA)

A failure modes and effects analysis (FMEA) is a reliability evaluation and design review technique that examines the potential software failure mode is classified according to its impact on system operating success and failure modes within a system or lower indenture level, to determine the effects of failures on equipment or system performance. Each hardware or software failure mode is classified according to its impact on system operating success and personnel safety. FMEA uses inductive logic (a process of finding explanations) on a "bottom up"

system analysis

It is a procedure in product development and operations management for analysis of potential failure modes within a system for classification by the severity and likelihood of the failures. A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or

processes, enabling the team to design those failures out of the system with the minimum of effort and resources expenditure ,thereby reducing development time and cost resource expenditure, thereby reducing development time and costs. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry. Failure modes are any errors or defects in a process, design, or item, especially those that affect the customer, and can be potential or actual. Effects analysis refers to studying the consequences of those failures.

The outcomes of an FMEA development are actions to prevent or reduce the severity or likelihood of failures, starting with the highest-priority ones. It may be used to evaluate risk management priorities for mitigating known threat vulnerabilities. FMEA helps select remedial actions that reduce cumulative impacts of life-cycle consequences (risks) from a systems failure (fault).

- ∑ Determines the effects of each failure mode on system performance.
- ∑ Emphasizes identification of single-point failures. Provides data for developing fault tree analysis and reliability block diagram models.
- ∑ Provides a basis for identifying root failure causes and developing corrective actions..
- ∑ Aids in developing test methods and troubleshooting techniques.
- ∑ Provides the criteria for early planning of tests to characterize the weaknesses of design .
- ∑ Provides a basis for the safety analysis that is done as part of evaluating the safety characteristics of the design.
- ∑ It is also a basis for operational troubleshooting and for locating performance monitoring and fault-detection devices within the system. [3]

3.4 Fault Tree Analysis (FTA)

A fault tree analysis (FTA) is a systematic, deductive methodology for defining a single specific undesirable event and determining all possible reasons (failures) that could cause that event to occur. It is a top down, deductive failure analysis in which an undesired state of a system is analyzed using boolean logic to combine a series of lower-level events. This analysis method is mainly used in the field of safety engineering and Reliability engineering to determine the probability of a safety accident or a particular system level (functional) failure.

In Aerospace the more general term "system Failure Condition" is used for the "undesired state" / Top event of the fault tree. These conditions are classified by the severity of their effects. The most severe conditions require the most extensive fault tree analysis. These "system Failure Conditions" and their classification are often previously determined in the functional Hazard analysis.[1]

FTA analysis involves five steps:

1. Define the undesired event to study

Definition of the undesired event can be very hard to catch, although some of the events are very easy and obvious to observe. An engineer with a wide knowledge of the design of the system or a system analyst with an engineering background is the best person who can help define and number the undesired events. Undesired events are used then to make the FTA, one event for one FTA; no two events will be used to make one FTA.

2. Obtain an understanding of the system

Once the undesired event is selected, all causes with probabilities of affecting the undesired event of 0 or more are studied and analyzed. Getting exact numbers for the probabilities leading to the event is usually impossible for the reason that it may be very costly and time consuming to do so. Construct the fault tree After selecting the undesired event and having analyzed the system so that we know all the causing effects (and if possible their probabilities) we can now construct the fault tree. Fault tree is based on AND and OR gates which define the major characteristics of the fault tree.

4 Evaluate the fault tree

After the fault tree has been assembled for a specific undesired event, it is evaluated and analyzed for any possible improvement or in other words study the risk management and find ways for system improvement. This step is as an introduction for the final step which will be to control the hazards identified. In short, in this

step we identify all possible hazards affecting in a direct or indirect way the system.

5.Control the hazards identified

This step is very specific and differs largely from one system to another, but the main point will always be that after identifying the hazards all possible methods are pursued to decrease the probability of occurrence.

IV CONCLUSION

1) In a process of reliability based design ,For a given system, models are used to describe the relationship between the system components in order to determine the reliability of the system as a whole.

2) With the help of FMEA ,we can determine of the effect of failures on the system an with Fault Tree Analysis, design changes may be proposed early-on to address concerns over initial system reliability.

3) Reliability based design methodology can bring a reliable product to market using a process focused on designing out or mitigating potential failure modes prior to production release, based on an understanding of the failure, testing to discover issues and statistical analysis methods for reliability prediction.

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