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Failure Mode and Effect Analyses		

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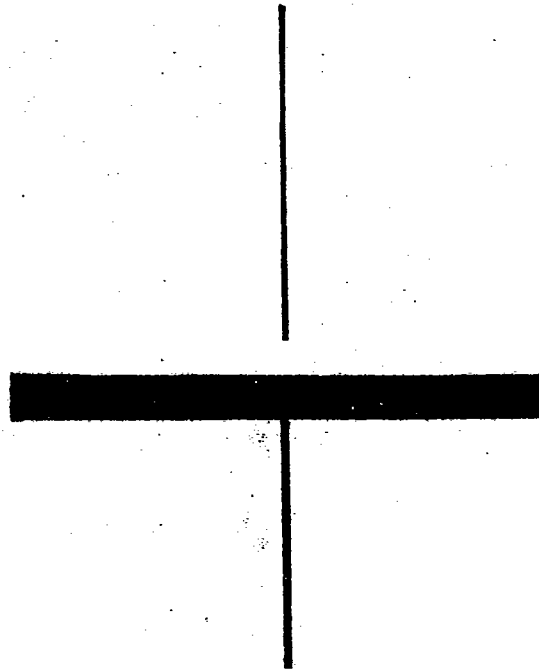
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Failure Mode and Effect Analyses



NOVEMBER 1971



Prepared by the

G-41 Committee on Reliability

Engineering Department

ELECTRONIC INDUSTRIES ASSOCIATION

2001 Eye Street, N.W., Washington, D.C. 20006

FAILURE MODE AND EFFECT ANALYSES

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PREPARED BY THE
FAILURE MODE AND EFFECT ANALYSES
TASK GROUP
G-41 COMMITTEE ON RELIABILITY
November 1971

ELECTRONIC INDUSTRIES ASSOCIATION
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FOREWORD

This Bulletin presents concepts, techniques, and procedures for performing Failure Mode and Effect Analyses. Technical and functional interfaces with associated disciplines of maintainability analysis, safety analysis, and systems effectiveness are described so as to develop a broad understanding of the objectives of performing Failure Mode and Effect Analyses.

This Bulletin has been published by the Electronic Industries Association in the belief that the approach will interest and benefit those responsible for Failure Mode and Effect Analysis development and use, and contribute to the timely acquisition of effective electronic systems.

This Bulletin was prepared for the Electronic Industries Association G-41 Reliability Committee under the Chairmanship of E. D. Karmiol by a special task group (69-001) consisting of:

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Section I

Introduction

This Reliability Bulletin is provided as a guide for engineering and management personnel concerned with Failure Mode and Effect Analyses (FMEA).^{*} In addition, it provides information concerning technical and functional relationship of Failure Mode and Effect Analyses to associated disciplines, as for example, Maintainability, Safety, and System Effectiveness Analyses. This Bulletin covers requirements, concepts, interface, procedures and reports of FMEA. This Bulletin should contribute to greater utilization of FMEA results and to the understanding and appreciation of the purpose of FMEA on the part of engineering and management personnel.

Failure Mode and Effect Analysis is the study of a system, or portion thereof and working inter-relationships of its elements, to determine ways in which failures can occur (failure modes), effects of each potential failure on the system element in which it occurs and on other system elements, and the probable overall consequences (criticality) of each failure mode on the success of the system's mission. Criticalities are usually assigned by categories, each category being defined in terms of a specified degree of loss of mission objectives or degradation of personnel safety. Although it is recognized that the human element can be, and frequently is a major influence in both causing as well as avoiding failures, this aspect is not specifically treated in this Bulletin.

Reporting of Failure Mode and Effect Analyses is an important action critical to communications of data to and from personnel performing related analyses and planning of design and development, evaluation, testing, quality assurance, logistics and operations.

^{*}In this Bulletin, the term "FMEA" is considered to include failure mode and effect studies for criticality analysis, sometimes called "FMECA".

Section II

Requirements

Requirements for FMEA originate from the need to understand hardware behavior and its implication regarding system use. These requirements are sometimes self-imposed and sometimes contractually specified. Because the need for Failure Mode and Effect Analyses (FMEA) may vary widely from case to case depending upon established objectives, nature of the project, and the extent to which other related analyses are called for, the customer should request a FMEA plan as part of the proposal package. This would present the prospective contractor's thoughts concerning his use of FMEA as a technique to do an adequate job of engineering the system to perform as desired by the customer. This desired performance would be stated by the customer in his request for bids as end requirements, such as the reliability wanted under certain conditions for a specified period of time. FMEA is a design tool that the contractor should apply as appropriate to a project. It should not become a customer requirement in the sense of FMEA carried out in a prescribed pattern for its own sake.

In deciding on the extent that and the way in which FMEA should be applied to a project, the contractor should consider the specific purposes for which FMEA results are needed, the time phasing with other activities, and the importance of establishing a predetermined degree of probabilistic control over unwanted failure modes and effects. This leads into planning FMEA at specified indenture levels (system, subsystem, component) in qualitative and quantitative terms to relate to the iterative design and development process. Some of the possible applications for FMEA in formulating the FMEA plan are as follows:

- a. Determining need for redundancy, fail-safe design features, further derating, and/or design simplification.
- b. Determining need to select more reliable materials, parts, devices and/or components.
- c. Identifying single failure points.
- d. Identifying critical items for design review, configuration control, and traceability.
- e. Providing the logic model required to quantitatively predict the probability of anomalous conditions of the system.
- f. Disclosing safety hazard and liability problem areas.

- g. Assuring that the test program is responsive to identified potential failure modes and safety hazards.
- h. Establishing allowable use time or cycles.
- i. Pinpointing key areas for concentrating quality, inspection and manufacturing process controls.
- j. Establishing data recording requirements and needed frequency of monitoring in testing, checkout and mission use.
- k. Supporting logistics planning and maintainability analysis. Providing information for selection of preventive maintenance points and development of trouble-shooting guide.
- l. Identifying circuits for worst case analysis. (Failure modes involving parameter drifts frequently require worst case analysis.)
- m. Supporting flight operations activities such as designing fault isolation sequences and alternate-mode-of-operations planning.

The extent to which FMEA activity and results will be reported should be stated in the FMEA plan. This includes specifying whether all elements of the FMEA are to be reported, or whether reporting will be limited to those findings felt to require corrective action. In addition, to avoid subsequent misunderstandings, it is sometimes desirable to specify the reporting format.

Whether the requirement originates from the customer or is self-imposed by the contractor it is important to remember that the objective is to minimize failures. Failure Mode and Effects Analysis, FMEA, is a technique for analyzing a design, evaluating the potential manner in which failures can occur and tabulating results in such a manner that responsible design personnel can consider potential failure modes and their effects (and recommended corrective actions) to determine if it is desirable to allocate resources to remove the potential failure mode.

Section III

Concepts

The basic concept of Failure Mode and Effects Analysis is one of determining what items in an equipment can fail, the modes of failure that are possible for each of these items and the effect of each mode of failure on the complete equipment or any portion thereof.

Within the basic concept there are two primary approaches to accomplishing a failure mode and effects analysis. The two approaches are identified on the basis of the point of departure for starting the analysis. One is the Top-Down Approach, also called the Systems Approach, because the analysis proceeds from the top indenture level (total system or equipment) to successively lower levels. Conversely, the other method is known as the Bottom-Up Approach, also identified as the Parts Approach because here the analysis is initiated at the lowest level.

1. Definitions

For any concept, the failure mode and effects analysis is no exception, a clear understanding of the concept depends on explicit definitions of terms essential to the description of the concept. Terms normally associated with FMEA studies are defined in MIL-STD-721.

2. Description of Analysis Techniques

a. System or Top-Down Technique

As stated earlier, the basic concept involves three aspects: (1) an item failure, (2) the mode of failure, and (3) the failure effect. In the system approach these aspects are considered in the inverse order.

First of all any system or equipment, whatever the top indenture level is, performs certain functions usually identified in terms of specific outputs. These functions or outputs have specified parameters or characteristics of satisfactory performance. These parameters can be measured and, at this level, can often be evaluated subjectively by those who use or operate the equipment. The ultimate failure effects or top level anomalies relating to these outputs are individually identified. Examples would be no transmitter output, low transmitter output, noisy receiver output, low slew rate for search radar, bad parity check in digital system, etc. Each of these amounts to some form of non-conformance with regard to some desired functional output.

The failure effects can occur singularly or in combination. Usually the top-down analysis is performed on the basis of single effects. Fault tree analysis techniques are often used for this purpose. For each possible failure effect that is identified, the system or equipment is analyzed at the next lower indenture level to identify any failure and associated failure mode that could result in the originally identified failure effect. For each of these second level failures the process is repeated by tracing back the functional paths and relationships to the next lower level. The process is iterated until the lowest feasible or desired level is reached. Thus for each ultimate failure effect at the top level, all lower level failures along with the respective modes of failure that can result in this effect become identified. As previously stated the analysis is usually initiated on the basis of a single failure effect. It is not unusual, however, to find that as the analysis proceeds to lower indenture levels, certain failures are identified that produce not only the initial failure effect, but also one or more other effects. This results in identification of a specific multiple failure effect condition.

b. Part or Bottom-Up Technique

The bottom-up approach is started on the basis of failure modes that can occur. In its most complete form, failure modes are identified at the part level which is usually the lowest level of direct concern to the equipment designer. Certainly with regard to the part manufacturer, failure modes and effects do exist for indenture levels within the part from either a function performance concept or a manufacturing routine concept. But for analyses pertaining to equipment and systems, the failure modes of the various parts are tabulated. For each of the part failure modes the corresponding effect on performance at the next higher indenture level is determined. The resulting failure effect becomes in essence the failure mode that may produce a consequential effect at the next higher indenture level. Iteration of the analytical process finally results in establishing the ultimate effect at the equipment or system output or top indenture level. Once the analysis has been performed for all the part failure modes, it will be found that each ultimate end failure effect or combination of effects relates to several and sometimes many different part failure modes rather than to just one. This relationship to the end effect provides the basis for grouping the various part failure modes.

3. Comparison of Techniques

Neither approach stands out as the singular or most appropriate technique that should always be the one that is used. Each has certain advantages or strong points which, in conjunction with the purpose or objective of a particular analysis effort, establish the basis for selecting one in preference

to the other. Sometimes the objective of analysis relates to certain end failure effects that are critical or particularly undesirable occurrences relative to the mission of the system. Here the top-down approach is preferable because it can be applied to the failure effects of interest and others can be bypassed. Thus less time and effort is required. Similarly where all effects are to be analyzed, it is often possible to terminate some of the analytical iteration without going to the lowest level. This is possible because it is sometimes feasible to establish the relative or actual rates of occurrence for the different modes at a module or circuit level. Here again the top-down approach requires less time and effort.

When the primary interest pertains to identifying all the different failure effects that may occur, then use of the bottom-up technique provides a more direct and rigorous analysis. This is particularly true with regard to identifying unanticipated or new end effects. It is especially applicable to disclosing multiple effect conditions which may even turn out to be critical as a result of the particular combination. In using this technique it is sometimes possible to reduce the amount of effort by initiating the analysis at the circuit or higher level. This is particularly feasible where prior knowledge from analyses on similar parts and circuits can be applied. Otherwise there will most likely be some degree of compromise in the rigor of the analysis.

There is another aspect of comparison applicable to both techniques and that is whether the analysis is done on a qualitative or quantitative basis. The latter, of course, requires greater effort than the former and consequently should only be done when the qualitative approach is insufficient to satisfy the objective of the particular analysis. The qualitative technique is sufficient when the desired result is identification of those items that contribute to a particular failure effect. This is most apropos when an effort is being put forth to eliminate an especially undesirable effect. Also when the objective is simply to identify all the failure mode and effects and their relationship or criticality to a mission, then quantification is not necessary. On the other hand when the analysis relates to selective application of limited time or funds for further design effort, quantitative analyses provide a better basis for deciding where the effort will provide the greatest contribution toward increased mission effectiveness.

Section IV

Interfaces

Although a failure mode and effect analysis (FMEA) is an interdisciplinary study, an individual has to be assigned responsibility for it. It involves system and equipment design engineering, reliability data, maintainability, safety, application of probability concepts, and the mathematics of modeling. This section discusses the kinds of information usually needed for FMEA, where it is obtained from, and the types of personnel generally involved.

A FMEA requires a variety of information and personnel as listed in Figure 1. Figure 2 diagrams how these individual pieces of information and tasks organize into a pattern to produce a FMEA.

By its nature, a FMEA tends to be a detailed analysis of an equipment, subsystem, or system. As such, a greater depth of understanding is necessary than with some other types of analyses. Not only is it necessary to understand how the hardware operates and how equipments interface when everything is working properly, but it is also necessary to explore the effects of various types of individual part faults on equipment and system behavior. In electronic systems, this frequently involves circuit analysis.

To examine and analyze the failure tendency of a physical system in this detail usually requires team support for the individual conducting the FMEA with different team members having backgrounds and knowledge concerning design, system and parts reliability, probability and operations research mathematics, thermal analysis, and environmental effects. An equipment or system of any complexity usually results in a computer program analysis, calling for programming skills. For the individual carrying out the FMEA to effectively utilize this team support, he should acquire as full an understanding of system functions as possible prior to engaging in extensive discussions with team members. If he can discuss his FMEA plans based on reasonable system's knowledge, the response and contributions by designers to his FMEA efforts will be markedly greater. For a meaningful FMEA, the analyst has to attract the interest and achieve cooperation from the system and equipment designers.

As shown in Figure 2, knowledge of the system/equipment operation is used to produce a listing of significant failure modes. Where the analysis is quantified, a mathematical model representative of system/equipment behavior is then developed. Individual failure probabilities are then incorporated into the system/equipment mathematical model structure to provide an analysis based on specific failure mode possibilities.