# FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

*A Special Bibliography from the NASA Scientific and Technical Information (STI) Program*

FEBRUARY 2000

Failure Modes and Effects Analysis (FMEA) is a bottom–up analytical process which identifies process hazards.

This sampler bibliography contains references to documents in the NASA STI Database. Selections are based on major concepts and NASA Thesaurus terms, including 'failure analysis' and 'failure modes.' An abstract is included with most citations, followed by the applicable subject terms.

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**19810039879**

**Current and future concepts in FMEA**

Sevcik, F., Ketron, Inc., USA; Jan 1, 1981; 8p; In English; Annual Reliability and Maintainability Symposium, January 27-29, 1981, Philadelphia, PA; See also A81-24251 09-38; Copyright; Avail: Issuing Activity

The goal of the Failure Modes and Effects Analysis (FMEA) is to anticipate, identify and avoid failures in the operation of a new system while the system is still on the drawing board. The recent occurrence of failures in some new systems in operation has had disastrous effects on many lives. These events prompted the author to evaluate the documented problems and to seek improvements in FMEA procedures and their application. The result was surprising. While a great number of procedures exist, not one single FMEA procedure could be found as an all encompassing document. Each FMEA procedure was different. It is believed that the recent disasters could have possibly been avoided if a good FMEA procedure had been applied during development. A simple, complete FMEA procedure is proposed.

AIAA

*Failure Analysis; Failure Modes; Performance Prediction; Reliability Analysis; Reliability Engineering; System Failures*

**19810058863**

**Maintainability applications using the matrix FMEA technique**

Herrin, S. A., ESL, Inc., USA; IEEE Transactions on Reliability; Aug 1, 1981; R-30, pp. Aug. 198; In English; p. 212-217; Copyright; Avail: Issuing Activity

The Matrix Method of Failure Modes and Effects Analysis (FMEA) provides an organized and traceable analysis from the piece-part failure-mode through all indenture levels to system-level failure effects. This paper describes a methodology for reversing the buildup process for maintainability analysis. The output of this reverse process identifies each system-failure effect individually and the related indentured, lower-level composition of contributing sources of failure. The results of this technique provide source data for identifying different levels of ambiguity for fault isolation, evaluating test point adequacy, formulating replacement level criteria, developing maintenance diagnostic charts and procedures, validating maintenance concepts, and segregating most-probable faults for spare parts requirements.

AIAA

*Airborne Equipment; Electronic Equipment Tests; Failure Analysis; Failure Modes; Maintainability; System Failures*

**19850023205** Hughes Aircraft Co., Ground Systems Group., Fullerton, CA, USA

**Automated FMEA (Failure Modes and Effects Analysis) techniques** ***Final Report, Apr. 1982 - Mar. 1984***

Goddard, P. L., Hughes Aircraft Co., USA; Davis, R., Hughes Aircraft Co., USA; Dec 1, 1984; 172p; In English

Contract(s)/Grant(s): F30602-82-C-0072

Report No.(s): AD-A154161; RADC-TR-84-244; Avail: CASI; A08, Hardcopy; A02, Microfiche

The techniques traditionally in use for Failure Modes and Effects Analysis (FMEA) have been fragmented in approach and not fully automated. These limitations can result in FMEA's being performed which are inconsistent in quality and approach. The Advanced Matrix FMEA Technique is presented as a standardized FMEA technique, and the automation of this technique is discussed. Additionally, the results of research into component failure modes to support FMEA are presented. The purpose of the study was to determine the feasibility of standardizing and automating FMEA techniques for electronics and to develop such techniques. FMEA is a bottom-up, inductive, failure analysis technique. This analysis, which is normally performed by reliability engineers, is used to support multiple disciplines. The analysis output supports reliability, maintainability, testability, logistics, and safety activities. The analysis starts with a single point, low-level failure and proceeds upward through the hardware under analysis to define the failure effect at each level.

DTIC

*Automatic Control; Failure Analysis; Failure Modes*

**19850067376**

**Automated FMEA - Status and future**

Dussault, H. B., USAF, Rome Air Development Center, USA; Jan 1, 1984; 5p; In English; Annual Reliability and Maintainability Symposium, January 24-26, 1984, San Francisco, CA; Sponsored by IEEE, AIAA, ASME; See also A85-49526 24-38

Contract(s)/Grant(s): F30602-82-C-0072; Avail: Issuing Activity

If Failure Modes and Effects Analyses (FMEAs) are to provide meaningful and useful results, techniques which are both standard and automated must be developed. A survey of current FMEA techniques and automation tools is presented. The feasibility and practicality of developing a standardized, automated FMEA technique is addressed. The framework for a computerized technique, based upon matrix FMEA and consistent with the guidance provided in MIL-STD-1629A, is discussed. The technique provides: a functional top-down FMEA during early development phases; a top-down and bottom-up approach when equipment/system hardware elements and their configuration have been defined; and information which can be used for maintainability, testability, and logistics studies. The paper addresses the specifics of this procedure and its application.

AIAA

*Automatic Test Equipment; Computer Aided Design; Failure Analysis; Failure Modes; Reliability Analysis; Technology Assessment*

**19860037657**

**Improved methods for computerized FMEA**

Lind, J. A., Ford Aerospace and Communications Corp., USA; Jan 1, 1985; 4p; In English; See also A86-22376; Copyright; Avail: Issuing Activity

Conventional narrative or tabular FMEAs are formatted to either allow tracing from a design element to its effects or from an effect to the design elements causing that effect. The tabular FMEAs generally do not provide full traceability between the effects and the failure modes of a design. The matrix FMEA technique was introduced to provide full traceability between effects and design element failure modes by use of a cross referencing matrix. for small FMEAs the matrix is adequate, but for FMEAs with a large number of effects, failure modes and/or design elements, the matrix becomes inadequate. A tabular FMEA format has been developed that overcomes the problems of the matrix FMEA approach for large FMEAs and also provides additional capability for addressing causes, preventive measures, criticality, and other data. A computerized system for the preparation of FMEAs, FMECAs, and Product Design FMEAs using this tabular format is described.

AIAA

*Failure Analysis; Failure Modes; Matrix Methods*

**19860037658**

**Hardware/software FMEA applied to airplane safety**

Van Baal, J. B. J., Nationaal Lucht- en Ruimtevaartlaboratorium, Netherlands; Jan 1, 1985; 6p; In English; See also A86-22376; Copyright; Avail: Issuing Activity

Recent changes in the nature of airplane systems have created the need for a systematical and analytical methodology for system safety assessment. Such a methodology is briefly explained. A try-out on a software controlled digital avionics system

is described. Special attention is paid to the analysis of the software components of the system. From this work it is concluded that the same methodology can be applied to both software and hardware. Two conditions that have to be met to perform a successful hardware/software safety assessment are described.
AIAA
*Aircraft Safety; Avionics; Computer Programs; Failure Analysis; Failure Modes; Hardware*

**19870044265**
**Problems with failure modes and effects analysis for digital avionics**
Hecht, Herbert, SoHar, Inc., USA; Jan 1, 1986; 6p; In English; See also A87-31451; Copyright; Avail: Issuing Activity

The provisions of the MIL-STD-1629A standard for Failure Modes and Effects Analysis (FMEA) are discussed with respect to their applicability to digital avionics equipment, and problem areas are highlighted. It is noted that current practices usually circumvent rather than correct deficiencies, and that they introduce duplication and uncertainty into the application of FMEA-related information in the design of digital equipment. An approach in which an individual FMEA is restricted to one hierarchical level, and in which a built-in feedback mechanism identifies and corrects its own deficiencies by identifying FMEA problem areas as part of the normal reporting system, is proposed.
AIAA
*Avionics; Digital Electronics; Failure Analysis; Failure Modes; Mission Planning*

**19880019986** Boeing Computer Support Services, Inc., Huntsville, AL, USA
**Failure modes and effects analysis automation**
Kamhieh, Cynthia H., Boeing Computer Services Co., USA; Cutts, Dannie E., Boeing Computer Services Co., USA; Purves, R. Byron, Boeing Aerospace Co., USA; NASA, Marshall Space Flight Center, Second Conference on Artificial Intelligence for Space Applications; Aug 1, 1988, pp. p 169-176; In English; See also N88-29351 23-61; Avail: CASI; A02, Hardcopy; A06, Microfiche

A failure modes and effects analysis (FMEA) assistant was implemented as a knowledge based system and will be used during design of the Space Station to aid engineers in performing the complex task of tracking failures throughout the entire design effort. The three major directions in which automation was pursued were the clerical components of the FMEA process, the knowledge acquisition aspects of FMEA, and the failure propagation/analysis portions of the FMEA task. The system is accessible to design, safety, and reliability engineers at single user workstations and, although not designed to replace conventional FMEA, it is expected to decrease by many man years the time required to perform the analysis.
CASI
*Automatic Control; Computer Techniques; Data Bases; Failure Analysis; Failure Modes*

**19900002718** NASA Lewis Research Center, Cleveland, OH, USA
**Model 0A wind turbine generator FMEA** ***Final Report***
Klein, William E., NASA Plum Brook Reactor Facility, USA; Lalli, Vincent R., NASA Lewis Research Center, USA; Oct 1, 1989; 8p; In English; 1990 Annual Reliability and Maintainability Symposium, 23-25 Jan. 1990, Los Angeles, CA, USA; Sponsored by ASME
Contract(s)/Grant(s): DE-AB29-79ET-20370
Report No.(s): NASA-TM-102378; E-5117; NAS 1.15:102378; DOE/NASA/20370-23; Avail: CASI; A02, Hardcopy; A01, Microfiche

The results of Failure Modes and Effects Analysis (FMEA) conducted for the Wind Turbine Generators are presented. The FMEA was performed for the functional modes of each system, subsystem, or component. The single-point failures were eliminated for most of the systems. The blade system was the only exception. The qualitative probability of a blade separating was estimated at level D-remote. Many changes were made to the hardware as a result of this analysis. The most significant change was the addition of the safety system. Operational experience and need to improve machine availability have resulted in subsequent changes to the various systems which are also reflected in this FMEA.
CASI
*Failure Analysis; Failure Modes; Turbine Blades; Wind Turbines*

**19900022036** Carnegie Group, Inc., Pittsburgh, PA, USA
**An expert advisor for FMEA generation**; Report Status Unavailable
Contract(s)/Grant(s): NAS9-18310; RTOP-324-01-00
*Expert Systems; Failure Analysis; Failure Modes*

**19910046441** NASA Lewis Research Center, Cleveland, OH, USA

**Model-OA wind turbine generator - Failure modes and effects analysis**

Klein, William E., NASA Lewis Research Center, USA; Lali, Vincent R., NASA Lewis Research Center, USA; Jan 1, 1990; 4p; In English; See also A91-31032

Contract(s)/Grant(s): DE-AB29-79ET-20370; Avail: Issuing Activity

The results failure modes and effects analysis (FMEA) conducted for wind-turbine generators are presented. The FMEA was performed for the functional modes of each system, subsystem, or component. The single-point failures were eliminated for most of the systems. The blade system was the only exception. The qualitative probability of a blade separating was estimated at level D-remote. Many changes were made to the hardware as a result of this analysis. The most significant change was the addition of the safety system. Operational experience and need to improve machine availability have resulted in subsequent changes to the various systems, which are also reflected in this FMEA.

AIAA

*Failure Analysis; Failure Modes; Turbine Blades; Wind Turbines*

**19910068387**

**Next generation TPS architecture**

Poon, Andrew; Bertch, William J.; Wood, Jay B., General Dynamics Corp., USA; Jan 1, 1990; 11p; In English; AUTOTESTCON ’90; IEEE Systems Readiness Technology Conference, Sept. 17-20, 1990, San Antonio, TX, USA; Sponsored by IEEE; See also A91-53001; Copyright; Avail: Issuing Activity

The authors describe the symptom-model-based (SMB) approach, which correlates the failure symptom with the ambiguity group using historical data and diagnostic knowledge of the specific line replaceable units (LRUs). The SMB approach incorporates three key techniques for developing a next-generation TPS (test program set) architecture. The first technique is model-based diagnosis, which involves isolating the cause of failure based on the defined structure and functions of the components. Several different techniques and levels of detail for modeling an LRU are considered. The second technique is empirical diagnosis, which involves computing the most probable cause of failure using historical data and results from failure modes and effects analysis (FMEA). The third technique is rule-based diagnosis, which uses the knowledge of experts to isolate failures in an expedient manner. The implementation of each of these techniques is evaluated based on the capability to fault isolate to the correct component, the time to fault isolate, and the complexity of the associated TPS structure.

AIAA

*Artificial Intelligence; Diagnosis; Failure Analysis; Failure Modes; Self Tests*

**19920073615**

**Using causal reasoning for automated failure modes and effects analysis (FMEA)**

Bell, Daniel; Cox, Lisa; Jackson, Steve; Schaefer, Phil, Martin Marietta Astronautics Group, USA; Jan 1, 1992; 11p; In English; Annual Reliability and Maintainability Symposium, Jan. 21-23, 1992, Las Vegas, NV, USA; Sponsored by IEEE; See also A92-56201; Copyright; Avail: Issuing Activity

The authors have developed a tool that automates the reasoning portion of a failure modes and effects analysis (FMEA). It is built around a flexible causal reasoning module that has been adapted to the FMEA procedure. The approach and software architecture have been proven. A prototype tool has been created and successfully passed a test and evaluation program. The authors are expanding the operational capability and adapting the tool to various CAD/CAE (computer-aided design and engineering) platforms.

AIAA

*Causes; Computer Aided Design; Failure Analysis; Failure Modes; Reliability Engineering*

**19920073632**

**A blackboard model of an expert system for failure mode and effects analysis**

Russomanno, David J., Intergraph Corp., USA; Bonnell, Ronald D.; Bowles, John B., South Carolina University, USA; Jan 1, 1992; 8p; In English; Annual Reliability and Maintainability Symposium, Jan. 21-23, 1992, Las Vegas, NV, USA; Sponsored by IEEE; See also A92-56201; Copyright; Avail: Issuing Activity

The design of an expert system to assist in performing a failure mode and effects analysis (FMEA) is approached from a knowledge-use-level perspective to provide a thorough understanding of the problem and insight into the knowledge and expertise needed to automate the FMEA process. A blackboard model is a conceptual model that provides the organizational principles required for the design of an expert system without actually specifying its realization. In the blackboard model of an intelligent FMEA, the system is functionally decomposed into a set of knowledge sources, each containing the knowledge associated with

a subfunction of the FMEA process. The conceptual model derived can be used to evaluate attempts to automate the FMEA process, and it can serve as the foundation for further research into automating the FMEA process. An example is presented illustrating the interaction among the knowledge sources in the blackboard model to construct a FMEA for a domestic hot water heater.
AIAA
*Expert Systems; Failure Analysis; Failure Modes; Reliability Engineering*

**19930012469** Technical Research Centre of Finland, Electrical and Automation Engineering Lab., Espoo, Finland
**Analysis of failure and maintenance experiences of motor operated valves in a Finnish nuclear power plant**
***Moottoritoimisten venttiilien vika- ja korjaustietojen analysointi ydinvoimalaitoksessa***
Simola, Kaisa, Technical Research Centre of Finland, Finland; Laakso, Kari, Technical Research Centre of Finland, Finland; Jan 1, 1992; ISSN 1235-0605; 202p; In English; Sponsored by Ministry of Trade and Industry and Nordic Industrial Fund
Report No.(s): VTT-TIED-1322; ISBN 951-38-4054-9; Copyright; Avail: CASI; A10, Hardcopy; A03, Microfiche

Eight years of operating experiences of 104 motor operated closing valves in different safety systems in nuclear power units were analyzed in a systematic way. The qualitative methods used were Failure Mode and Effect Analysis (FMEA) and Maintenance Effects and Criticality Analysis (MECA). These reliability engineering methods are commonly used in the design stage of equipment. The successful application of these methods for analysis and utilization of operating experiences was demonstrated.
ESA
*Failure Analysis; Failure Modes; Maintenance; Nuclear Power Plants; Safety Devices; Valves*

**19930017833** NASA Lewis Research Center, Cleveland, OH, USA
**Reliability studies of integrated modular engine system designs**
Hardy, Terry L., NASA Lewis Research Center, USA; Rapp, Douglas C., Sverdrup Technology, Inc., USA; Jun 1, 1993; 19p; In English; 29th; Joint Propulsion Conference and Exhibit, 28-30 Jun. 1992, Monterey, CA, USA; Sponsored by AIAA
Contract(s)/Grant(s): RTOP 468-02-11
Report No.(s): NASA-TM-106178; E-7774; NAS 1.15:106178; AIAA PAPER 93-1886; Avail: CASI; A03, Hardcopy; A01, Microfiche

A study was performed to evaluate the reliability of Integrated Modular Engine (IME) concepts. Comparisons were made between networked IME systems and non-networked discrete systems using expander cycle configurations. Both redundant and non-redundant systems were analyzed. Binomial approximation and Markov analysis techniques were employed to evaluate total system reliability. In addition, Failure Modes and Effects Analyses (FMEA), Preliminary Hazard Analyses (PHA), and Fault Tree Analysis (FTA) were performed to allow detailed evaluation of the IME concept. A discussion of these system reliability concepts is also presented.
Author
*Engine Design; Failure Analysis; Failure Modes; Fault Trees; Modularity; Propulsion System Configurations; Reliability Analysis; Rocket Engine Design*

**19930065762** NASA Lewis Research Center, Cleveland, OH, USA
**Reliability studies of Integrated Modular Engine system designs**
Hardy, Terry L., NASA Lewis Research Center, USA; Rapp, Douglas C., Sverdrup Technology, Inc., USA; Jun 1, 1993, pp. 18 p.; In English; 29th; AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, June 28-30, 1993, Monterey, CA, USA; Sponsored by AIAA; Previously announced in STAR as N93-27022
Report No.(s): AIAA PAPER 93-1886; Copyright; Avail: Issuing Activity

A study was performed to evaluate the reliability of Integrated Modular Engine (IME) concepts. Comparisons were made between networked IME systems and non-networked discrete systems using expander cycle configurations. Both redundant and non-redundant systems were analyzed. Binomial approximation and Markov analysis techniques were employed to evaluate total system reliability. In addition, Failure Modes and Effects Analyses (FMEA), Preliminary Hazard Analyses (PHA), and Fault Tree Analysis (FTA) were performed to allow detailed evaluation of the IME concept. A discussion of these system reliability concepts is also presented.
*Engine Design; Failure Analysis; Failure Modes; Fault Trees; Modularity; Propulsion System Configurations; Reliability Analysis; Rocket Engine Design*

**19950019625** Finnish Centre for Radiation and Nuclear Safety, Helsinki, Finland

**Reliability analysis of software based safety functions**

Pulkkinen, U., Technical Research Centre of Finland, Finland; May 1, 1993; 65p; In English

Report No.(s): DE95-606516; STUK-YTO-TR-53; Avail: CASI; A04, Hardcopy; A01, Microfiche

The methods applicable in the reliability analysis of software based safety functions are described in the report. Although the safety functions also include other components, the main emphasis in the report is on the reliability analysis of software. The check list type qualitative reliability analysis methods, such as failure mode and effects analysis (FMEA), are described, as well as the software fault tree analysis. The safety analysis based on the Petri nets is discussed. The most essential concepts and models of quantitative software reliability analysis are described. The most common software metrics and their combined use with software reliability models are discussed. The application of software reliability models in PSA is evaluated; it is observed that the recent software reliability models do not produce the estimates needed in PSA directly. As a result from the study some recommendations and conclusions are drawn. The need of formal methods in the analysis and development of software based systems, the applicability of qualitative reliability engineering methods in connection to PSA and the need to make more precise the requirements for software based systems and their analyses in the regulatory guides should be mentioned.

DOE

*Checkout; Computer Programs; Failure Analysis; Failure Modes; Fault Trees; Petri Nets; Qualitative Analysis; Quantitative Analysis; Reliability Analysis; Reliability Engineering; Software Reliability*

**19960039760**

**Using failure mode and effects analysis in new glaze introduction**

Marchant, David D., Lenox China Manufacturing Div, USA; Stangle, Timothy K.; Ceramic Engineering and Science Proceedings; May 1995; ISSN 0196-6219; 16, 3, pp. 159-164; In English; Copyright; Avail: Issuing Activity

Failure modes and effects analysis (FMEA) tool has been found to be effective in organizing the conversion of a glaze formulation and process of a plant. It is effective in helping to identify weaknesses in the implementation of the process by addressing process weaknesses before the actual implementation. This tool provides a methodical examination of potential failures due to a change in a process. It helps to recognize and evaluate potential failure modes and causes associated with manufacturing, identifies action to eliminate or reduce the potential failure, and documents the process. In this paper, FMEA tool is described and examples of its uses are presented.

Author (EI)

*Ceramics; Failure Analysis; Failure Modes; Glazes; Industrial Management; Industrial Plants; Manufacturing*

**19980053939**

**Combining functional and structural reasoning for safety analysis of electrical designs**

Price, C. J., Univ. of Wales, UK; Snooke, N.; Pugh, D. R.; Hunt, J. E.; Wilson, M. S.; Knowledge Engineering Review; Sep, 1997; ISSN 0269-8889; Volume 12, no. 3, pp. 271-287; In English; Copyright; Avail: Issuing Activity

Increasing complexity of design in automotive electrical systems has been paralleled by increased demands for analysis of the safety and reliability aspects of those designs. Such demands can place a great burden on the engineers charged with carrying out the analysis. This paper describes how the intended functions of a circuit design can be combined with a qualitative model of the electrical circuit that fulfills the functions, and used to analyze the safety of the design. FLAME, an automated failure mode and effects analysis system based on these techniques, is described in detail. FLAME has been developed over several years, and is capable of composing an FMEA report for many different electrical subsystems. The paper also addresses the issue of how the use of functional and structural reasoning can be extended to sneak circuit analysis and fault tree analysis.

Author (EI)

*Failure Analysis; Failure Modes; Structural Analysis; Computer Techniques; Network Analysis; Artificial Intelligence; Human-Computer Interface*

**19980060342**

**Redundancy verification analysis - An alternative to FMEA for low cost missions**

Sincell, Jeffry, Worst Case Associates, Inc., USA; Perez, Reinaldo J., JPL, USA; Noone, Patrick, JPL, USA; Oberhettinger, David, Logicon Syscon, Inc., USA; 1998, pp. 54-60; In English; Copyright; Avail: Aeroplus Dispatch

Redundancy verification analysis (RVA) is a promising technique for verifying internal redundancy within electronic assemblies, as well as 'cross-strap' redundancy between them, in cost or schedule constrained spacecraft development projects. RVA tracks a signal from its source to the end of the signal path, through all the subsystems along the way, including software. When performed in conjunction with a worst case analysis, RVA may obviate the need for a system-level failure mode and effects

analysis, providing a detailed examination of the actual workings of system hardware, software, and interfaces. Demonstrated by JPL on the Mars Global Surveyor project, use of RVA is consistent with NASA's emphasis on 'faster-better-cheaper' spacecraft design and development.
Author (AIAA)
*Spacecraft Electronic Equipment; Redundancy; Failure Analysis; Failure Modes; Fault Tolerance; Spacecraft Reliability*

**19980060405**

## FMEA For multiple failures

Price, Christopher J., Univ. of Wales, UK; Taylor, Neil S., Univ. of Wales, UK; 1998, pp. 43-47; In English; Copyright; Avail: Aeroplus Dispatch

Failure mode and effects analysis (FMEA) usually only considers single failures in a system. This is because the consideration of all possible combinations of failures in a system is impractical for any but the very simplest example systems. Even if simulation is used to automate the work of producing an FMEA report, consideration of all possible combinations of failures is not possible, and even if it were possible, an engineer could not be expected to spend the time needed in order to read, understand, and act on all of the results. This paper shows how to use approximate failure rates for components to select the most likely combinations of failures for simulation, and how to prune the resulting report to such an extent that it is practical for an engineer to study and act on the results. The strategy outlined in the paper has been applied to a number of automotive electrical subsystems, and the results have confirmed that the strategy described here works well for realistically complex subsystems.
Author (AIAA)
*System Failures; Failure Modes; Circuit Reliability; Failure Analysis*

**19980087674**

## Effective techniques of FMEA at each life-cycle stage

Onodera, Katsushige, Hitachi, Japan; 1997, pp. 50-56; In English; Copyright; Avail: AIAA Dispatch

The Failure Mode and Effects Analysis (FMEA) is a widely used analytical tool. It is especially useful in the conduct of reliability, maintainability, and safety analyses. Such analyses are commonly used to identify failures of significant consequence and those affecting system performance. An investigation of some 100 FMEA applications revealed that the FMEA technique is useful in virtually every stage of the modern industrial process. Although FMEAs were most frequently used in the initial design and development stages of a project, they were also of value in the manufacturing stage. In support of manufacturing, FMEAs contributed in deriving the optimum construction method and schedule. Even after construction of the plant, FMEAs were again found to add value in the analyses of day-to-day plant operations and maintenance activities, or the use stage. The continuous application of the FMEA process over the life-cycle of a project is ensured by the preparation of the individual FMEA worksheets for each stage. Examples of such worksheets are presented and discussed in this paper. FMEAs are evaluated by either of two methods: Criticality or Risk Priority Number (RPN). The elements which comprise the Criticality and RPN method are also presented in this paper.
Author (AIAA)
*Failure Modes; Life Cycle Costs; Failure Analysis; Safety Factors*

**19980120575**

## FMEA automation for the complete design process

Montgomery, Thomas A., Ford Motor Co., USA; Pugh, David R., Univ. of Wales, UK; Leedham, Steve T., Ford Motor Co., UK; Twitchett, Steve R., Jaguar Cars, Ltd., UK; 1996, pp. 30-36; In English
Contract(s)/Grant(s): SERC-GR/H96973; Copyright; Avail: Aeroplus Dispatch

Performing an FMEA during the design stage is a valuable technique for improving the reliability of a product. Unfortunately, the traditional brainstorming approach is also very tedious, time consuming, and error prone. Automating the process promises the generation of a more complete, consistent FMEA worksheet in a fraction of the time currently required. However, to be truly valuable, this automation must follow the product though the entire design cycle at each level of design: architecture, subsystem, and component. This paper presents an FMEA automation approach that spans the entire design cycle for electrical/electronic circuits. Brainstorming is replaced by computer simulation of failure modes and their effects. Qualitative simulation is used in the early (architectural) stages when design detail is not available. As the design progresses, the qualitative simulation gives way to quantitative simulation. Throughout, the information required to perform the FMEA is gleaned from that used to understand

the nominal behavior of the circuit; thus the relief from brainstorming is not offset by a new modeling burden. Sample results from software supporting this approach are presented.
Author (AIAA)
*Automation; Failure Modes; Failure Analysis; Computerized Simulation; Circuits; Electronic Equipment*

**19980120576**

**FMEA/CIL implementation for the Space Shuttle new turbopumps**

Littlefield, Milton L., Pratt & Whitney, USA; 1996, pp. 48-52; In English; Copyright; Avail: Aeroplus Dispatch

To satisfy a reliability requirement which necessitated the implementation of the Space Shuttle High Pressure Oxidizer Turbopump (HPOTP) Failure Mode Effects Analysis (FMEA) and Critical Items List (CIL), Pratt & Whitney (P&W) developed a plan that emphasized the utilization of existing systems and the standardization of subcontractor reporting documentation. Prior to acceptance testing of the first flight HPOTP, an audit of the quality assurance records for all CIL required inspections was performed to determine if the inspections had been made and accepted by quality assurance. 99.9 percent of the CIL inspections were verified as being successfully completed, far exceeding the 90 percent NASA verification requirement. Essential to the success of CIL implementation were the analytical procedures used to identify and ensure the test/inspectability of the inspections, testing, and process controls (CIL characteristics) performed to minimize the probability of critical part failures.
Author (AIAA)
*Failure Modes; Failure Analysis; Turbine Pumps; Space Shuttles; Spacecraft Equipment; Reliability*

**19980120589**

**A combined analysis approach to assessing requirements for safety critical real-time control systems**

Goddard, Peter L., Hughes Aircraft Co., USA; 1996, pp. 110-115; In English; Copyright; Avail: Aeroplus Dispatch

The combined Petri net and FMEA based approach to requirements analysis of safety critical embedded real time control systems developed by Hughes has been proven to provide a method of identifying incomplete, inconsistent, and incorrect requirements which may impact safety. This analysis method is applicable early in the design process, allowing requirement changes to be identified and implemented with minimal cost and schedule impact. It has been applied to several real world systems with positive results; missing, inconsistent, and incorrect requirements were identified in all cases. The approach is expected to be able to be implemented with minimal training of existing analysis personnel. Some training in Petri nets may be needed.
Author (AIAA)
*Real Time Operation; Safety; Failure Modes; Failure Analysis; Control Systems Design; Petri Nets*

**19980155995**

**Functional reasoning in a failure modes and effects analysis (FMEA) expert system**

Russomanno, David J., Integraph Corp., USA; Bonnell, Ronald D., South Carolina, Univ., Columbia; Bowles, John B., South Carolina, Univ., Columbia; 1993, pp. 339-347; In English; Copyright; Avail: Aeroplus Dispatch

An Expert System for Failure Mode and Effects Analysis (XFMEA) must provide a full spectrum of assistance that the reliability and design engineer can exploit. The goal is not only to automate the collection and storage of data and facilitate the generation of reports, but also to provide assistance in the reasoning process. This paper addresses functional FMEA methodology in the design of an expert system; specifically, the issue of representing the knowledge of how systems work is approached from a functional perspective. A knowledge base, organized around a functional representation, provides the inference procedure with a focus of attention directed toward expected goals and guides the reasoning process in determining the effects of a system's failure modes The functional representation described includes relationships to more detailed schemes, including numerical techniques and qualitative simulations of the causal behavior of systems. A functional representation is domain-general, in that functional primitives provide a language that is more general than any one system being modeled. The blackboard framework is proposed as a comprehensive problem-solving architecture for integrating the functional approach with other simulation and representation techniques.
Author (AIAA)
*Failure Modes; Expert Systems; Functional Analysis; Failure Analysis*

**19980206187** Alabama Univ., Industrial Engineering Dept., Tuscaloosa, AL USA

**An Independent Evaluation of the FMEA/CIL Hazard Analysis Alternative Study**

Ray, Paul S., Alabama Univ., USA; Oct. 1996; 8p; In English; See also 19980206153; No Copyright; Avail: CASI; A02, Hardcopy; A04, Microfiche

The present instruments of safety and reliability risk control for a majority of the National Aeronautics and Space Administration (NASA) programs/projects consist of Failure Mode and Effects Analysis (FMEA), Hazard Analysis (HA), Critical Items List (CIL), and Hazard Report (HR). This extensive analytical approach was introduced in the early 1970's and was implemented for the Space Shuttle Program by NHB 5300.4 (1D-2. Since the Challenger accident in 1986, the process has been expanded considerably and resulted in introduction of similar and/or duplicated activities in the safety/reliability risk analysis. A study initiated in 1995, to search for an alternative to the current FMEA/CIL Hazard Analysis methodology generated a proposed method on April 30, 1996. The objective of this Summer Faculty Study was to participate in and conduct an independent evaluation of the proposed alternative to simplify the present safety and reliability risk control procedure.

Author

*Hazards; Risk; Safety; NASA Programs; Failure Analysis; Reliability Analysis; Failure Modes; Assessments*

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**Study of FMEA Automation Technique for Airborne Power System**

Songhua, Shen, Beijing Univ. of Aeronautics and Astronautics, China; Ying, Li, Beijing Univ. of Aeronautics and Astronautics, China; Rui, Kang, Beijing Univ. of Aeronautics and Astronautics, China; Journal of Beijing University of Aeronautics and Astronautics; Dec. 1997; ISSN 1001-5965; Volume 23, No. 6, pp. 805-809; In Chinese; No Copyright; Avail: Issuing Activity, Hardcopy, Microfiche

Advances in an automatic quantitative analysis method of failure modes and effects analysis with system transient simulation in the system design stage take a airborne power system as a case in point. by use of the method, every possible failure mode of elements and devices in the system is accounted to the system transient model and system is simulated. Then simulation results of the failure states, and the cruel level of every failure mode effect is determined in numerical quantities. Therefore, the automation of failure modes and effects analysis is realized.

Author

*Failure Modes; Failure Analysis*

**19990012185**

**Integrative use of QFD and FMEA in planning process** ***Integrative Nutzung von QFD und FMEA bei Entwurfsprozessen***

Krusche, Thomas; Dilger, Elmar; Strasser, Michael; ZWF Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb; Oct, 1997; ISSN 0947-0085; Volume 92, no. 10, pp. 507-510; In German; Copyright; Avail: Issuing Activity

An improvement in attention to quality aspects while a product is being created is achieved by providing an integration model comprising important parts of both preventive quality assurance methods QFD and FMEA. The model ensures methodical cohesion by rigorous parallel application of the functional and component aspect within the development process. It ensures that customer demands are met, that there is constant development documentation and that risk analysis is simplified.

Author (EI)

*Failure Analysis; Failure Modes; Quality Control; Planning; Product Development; Models; Assessments; Risk*

**19990056042**

**A modified FMEA tool for use in identifying and addressing common cause failure risks in industry**

Childs, Joseph A., Texas Instruments, Inc., Dallas, USA; Mosleh, Ali, Maryland, Univ., College Park; 1999, pp. 19-24; In English; Copyright; Avail: AIAA Dispatch

The nature of common cause failures (CCFs) is explored in the context of existing analytical techniques. Failure Modes and Effects Analysis (FMEA) is described as a means for accomplishing early risk assessment in the context of an existing analysis framework. Cause and coupling factor taxonomies are refined to fit the FMEA methodology. This modification allows consideration of CCF risks. Blending this methodology with the standard FMEA process enables a seamless prioritization of single failure and CCF risks for further studies and actions. An example is provided to illustrate the use of this new tool.

Author (AIAA)

*Failure Analysis; Failure Modes; Computer Techniques; Industries*

**19990074063**

**How to use FMEA to reduce the size of your quality toolbox**

Vandenbrande, Willy W., Quality Solutions Consult, Belgium; Quality Progress; Nov, 1998; ISSN 0033-524X; Volume 31, no. 11, pp. 97-100; In English; Copyright; Avail: Issuing Activity

The failure mode effects analysis (FMEA) has been proven to be a useful and powerful tool in assessing potential failures and preventing them from occurring. When introducing a new process, the classical process FMEA can easily be adapted to the study of potential environmental risks. Using a new table for scoring severity, the environmental priority number can be calculated in the same way as the risk priority number. The scoring table is specifically designed to assess the severity of the environmental impact related to a failure mode/cause combination. Occurrence and detection are scored in exactly the same way as in the FMEA process.

EI

*Failure Analysis; Failure Modes; Assessments; Risk; Environmental Surveys; Computation; Quality Control*

**19990077710**

**Failure mode and effect analysis on ITER heat transfer systems**

Pinna, T., ENEA, Italy; Caporali, R.; Cambi, G.; Burgazzi, L.; Poucet, A.; Porfiri, M. T.; Fusion Engineering and Design; Sep 03, 1998; ISSN 0920-3796; Volume 42, Pt C, pp. 431-436; In English; 1997 4th International Symposium on Fusion Nuclear Technology. Part C, Apr. 6-11, 1997, Tokyo, Japan; Copyright; Avail: Issuing Activity

The complexity of the ITER (International Thermonuclear Experimental Reactor) plant and the inventories of radioactive materials involved in its operation require a systematic approach to perform detailed safety analyses during the various stages of the project in order to demonstrate compliance with the safety requirements. The failure mode and effect analysis (FMEA) methodology has been chosen to perform the safety analysis at system level for ITER. The main purposes of the work are: to identify important accident initiators, to find out the possible consequences for the plant deriving from component failures, identify individual possible causes, identify mitigating features and systems, classify accident initiators in postulated initiating events (PIEs), define the deterministic analyses which allow the possible accident sequences to be quantified, both in terms of expected frequency and radiological consequences, and consequently, to ascertain the fulfillment of ITER safety requirements. This paper summarizes the FMEA performed for the heat transfer systems (HTSs).

Author (EI)

*Failure Analysis; Failure Modes; Fusion Reactors; Thermonuclear Reactions; Heat Exchangers; Nuclear Research and Test Reactors; Accident Prevention*