Avionics/Electronics Integrity

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Abstract

Modern combat (or commertial) aircraft systems consist of a large number of sophisticated and complex avionics/electronics subsystems. The US Air Force of Productivity, Reliability, Availability and Maintainability (PRAM) reports that 25 to 45 percent of aircraft system failures in the electronics or electromechanical area [Kachmar, 1985]. It is an important issue to achive the required reliability and maintainability for avionics/electronics subsystems in order to guarantee the mission success during the life cycle in a timely and cost effective mannner.

The issuance of USAF Mil-A-87244, "Avionics/Electronic Integrity Program requirements," 1987 demands a new approach called "Avionics/Electronics Integrity Program" (AVIP). The objective of this paper is to give a tutorial presentation on the basic aspects of Avionics/Electronics Integrity efforts in relation to total quality management of avionics/electronics whose performance measures are expressed in terms of reliability, durability, and matainability.

1. Introduction

A number of research efforts have demonstrated that the failures of avionics systems tend to be the result of mechanical, chemical, or thermal modes in the electronic components and/or interconnections between components. The US Air Force of Productivity, Reliability, Availability and Maintainability (PRAM) reports that 25 to 45 percent of aircraft system failures in the electronics or electromechanical area [Kachmar, 1985]. The most commonly occuring failures reported were due to temperature (55 percent), vibration (20 percent), humidity (19 percent), and dust (6 percent). Vibration and thermal environments are the most significant factors to be considered in the operational reliability of avionics system. Reliability assessment of avionics equipment is largely governed by the ability of the designers to evaluate the overall mechanical performance of the system under variety of operating conditions. Accurate prediction of the overall mechanical response of an avionic system requires a knowledge of the conditions leading to the mechanical failure of the individual components in that system. Since the mechanical failure of an avionic electronic component can be induced by one or a combination of loads and environments, it is imperative to recognize and to evaluate all potential failure modes during the design process.

Another incentive for conducting such analysis is the recently adopted Avionics Integrity Program (AVIP), originally initiated by the Aeronautical Systems Division at

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Wright-Patterson Air Force Base, USA. The main goal of this initiative is to develop design criteria with increase the life of avionics systems to two service lifetimes. In general, AVIP requires a defense contractor to define the operational usage of the avionic system in the initial design phase and to understand how the material characteristics used in developing the specific avionics system will be affected by the operational usage.

It is an important issue to achive the required reliability and maintainability for avionics/electronics subsystems in order to guarantee the mission success during the life cycle in a timely and cost effective mannner. The objective of paper is to give a tutorial presentation on the basic aspects of Avionics/Electronics Integrity efforts in relation to total quality management of avionics/electronics whose performance measures are expressed in terms of reliability, durability, and matainability.

2. Product and Process Integrity

Product integrity are established through product performance. True product perfomance is determined in the field by the user. Product integrity is guided by three performance strategy categories; (1) physical (immediate)--mechanical, chemical, and electrical, (2) physical (long term)--reliability and maintainability, and (3) human--physical, mental, and social. The avionics in a modern combat aircraft can be thought of to consist of four primary levels: (1) the component level, (2) the board level, (3) the box level, and (4) the aircraft level. Each level can be thought of to contain at least three critical analysis dimensions: (1) the physical dimension, (2) the electrical dimension, and (3) the manufacturing dimension. The physical dimension includes material and mechanical consideration through the design and specification process that will allow the avionics to function properly when exposed to environmental effects (such as thermal and vibration effects). The electrical dimension includes electrical considerations through the design and specification process that allow the avionics to accomplish signal generation, transmission, reception, and encoding in the presence of various noises and degradation effects. The manufacturing dimension includes process design and specifications which allow for material transformation and fabrication process as well as the assembly and installation of the avionics equipment.Avionics intergrity develops from the net effect of all three dimension, acting over all four levels. Primarily, reliability and maintainability are the measures of avionics integrity. However, performance (and customer satisfaction with the aircraft) in the field environment is the final measure of avionics integrity.Academic literature in the mechnical, electrical, and chemical technical areas, has concentrated on physical performance modeling, usually with a great deal of concern for long-term performance over time or usage (e.g. reliability and durability). Most of these modeling strategies relate to ideal materials and processes, with only limited treatments of material and manufacturing defects common to production materials and processes. This direction is in sharp contrast to reports that suggest that the majority of reliability related problems in electronics are attributable to material and manufacturing defects, both latent and incipient[O'Connor, 1990]. It appers that more focus relative to reliability and durability issues should be placed on the manufacturing or conversion processes (and capabilities) and the product characteristics they generate relative to the applications and environments the product is likely to encounter. The emerging displine of robust design and manufacturing processes is a critical resource area for creating product and process improvement.

The purpose of imposing product (or process) intergrity program on avionics/electronics is to assure and improve system effectiveness, capability and operational suitability by enhancing reliability, mainatainability and durability. Many of the tools used in the product and process integrity activities outlined in Figure 1[Kolarik, 1992].

3. Overview of Avionics Integrity Program(AVIP)

The specification which details the AVIP requirements is US Mil-A-87244, "Avionics/Electronics Integrity Program Requirements", July, 1986. The avionics integrity demands fall in many categories:

(1) sevice life,
(2) design usage (application focused)
(3) environment,
(4) materials,
(5) design criteria (including margin and derating),
(6) strength,
(7) durability and economic life (including expected opearting life, failure free operating period, and low and high cycle fatigue),
(8) damage tolerance,
(9) life management (including maintenance, inspection, testability, and quality control).

Pictorial overview of avionics integrity program flow is shown in figure2. The AVIP time schedule for contactors is divied into the following 5 stages:

(1) design information (Draft Request For Proposal/Request For Proposal),
(2) preliminary planning (Requst For Proposal/Contact Award/Systems Requirement Review),
(3) design and manufacturing development (Systems Requirement Review/Critical Design Review),
(4) compliance verification and production (Critical Design Review/Low Rate Initial production),
(5) life management (Full Scale Production).

US Mil-Std 810 (Environmental Test Methods and Engineering Guidelines) and US Mil Hdbk 217 (Reliability Prediction of Electronic Equipment), along with US Mil-A-87244 (Avionic/Electronic Integrity Program Requirements) serve as the major source material for the AVIP initiative.

US Mil-A-87244 serves as a shell for the AVIP initiative, without providing specific guidance in either defining requirements or requirement verification. The emphasis is to towards more physical based quantitative requirements and less acturial based calculation, as encouraged by US Mil-Hdbk 217. Its emphasis on defining the opeational, environmental usage of avionics system in the initial design phase and understanding how the material characteristic used in developing specific avionics system will be affected by operational environmental usage.

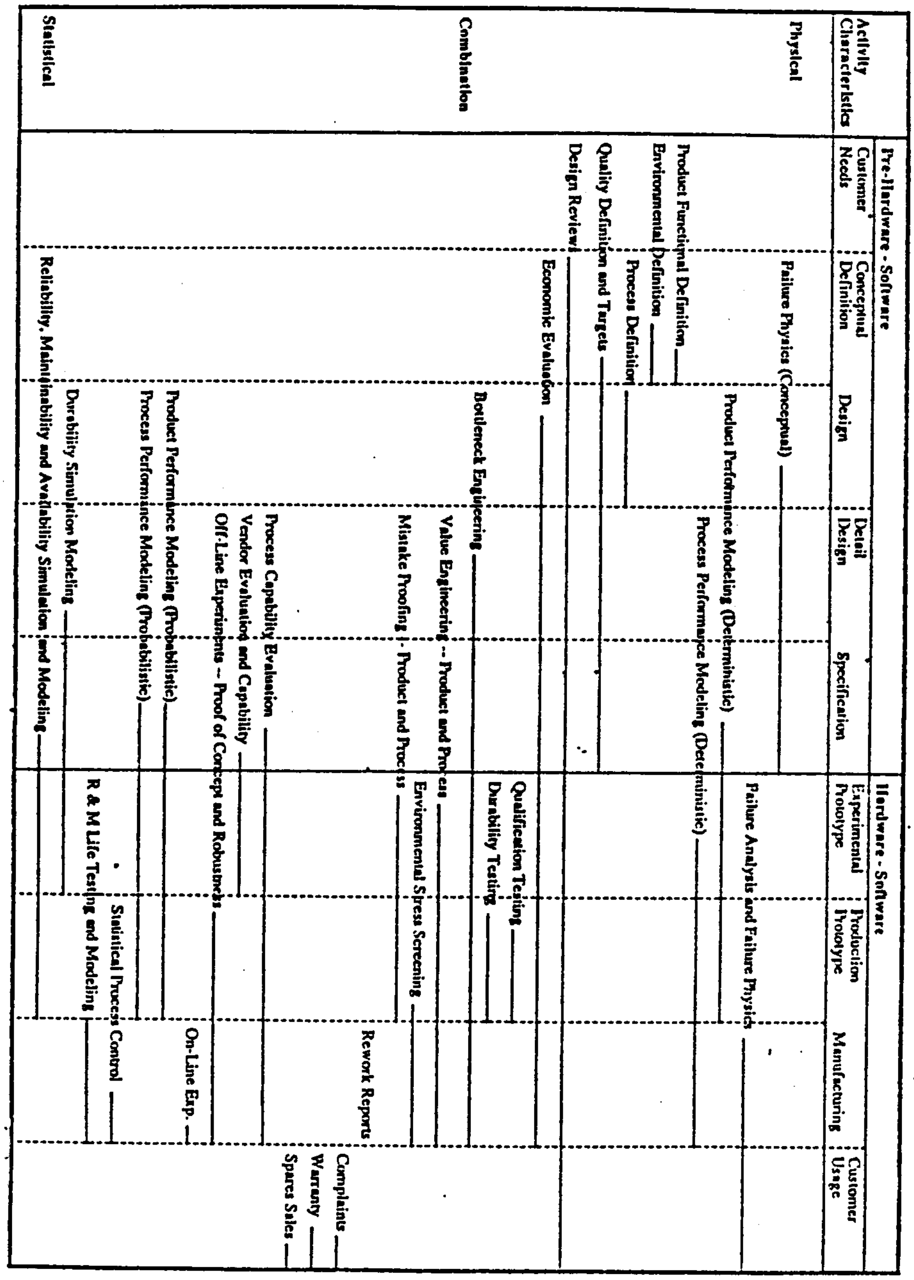

Figure 1: Product and Process Integrity Strategy [Kolarik, 1992]

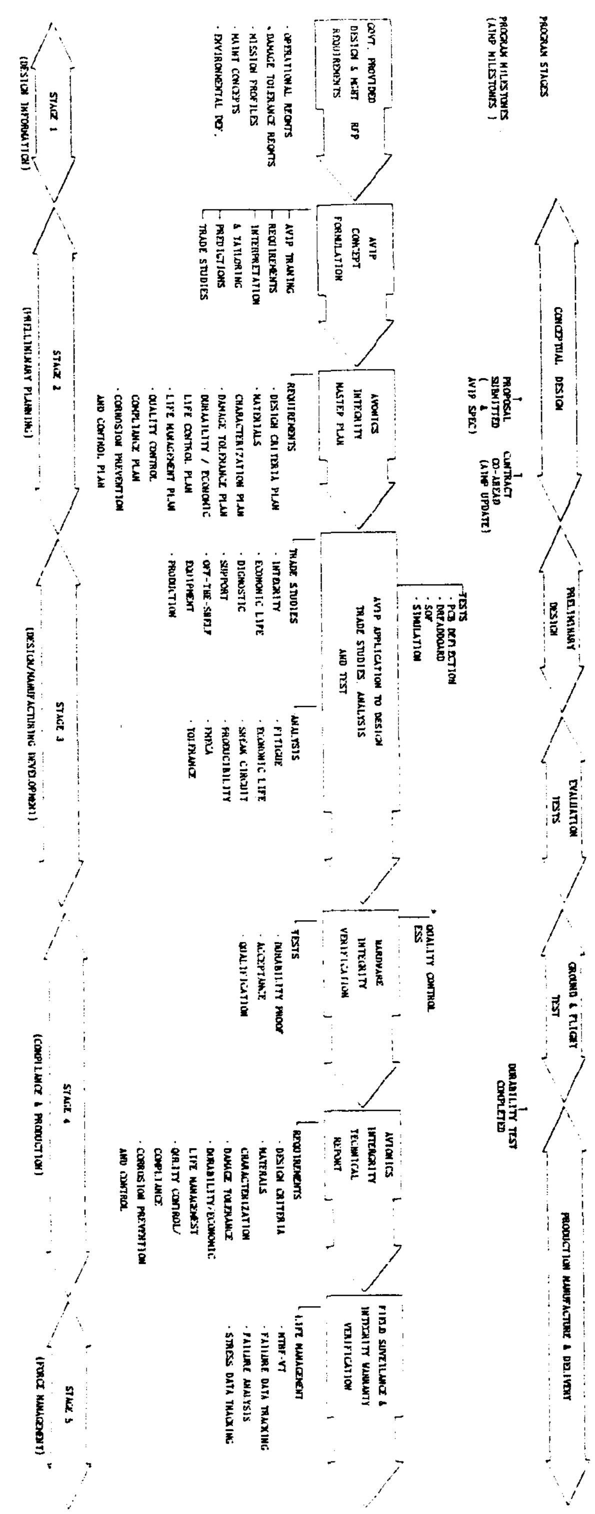

Figure 2: Pictorial Overview of Avionics Integrity Program Flow

Most US Mil-Std/Hdbk reliability work is aimed at MTTF measures. Failure Free Operating Period(FFOP) quantiles appear to be useful in avionics/electronics. If knowledge of the failure distribution is available, FFOP quantiles can be readily computed. However, most statistical fits are subject to question in the distribution tails, unless the data used for fitting contain a number of failures, including rare events in the tail areas.

Much of the trade literature (both military and commertial product based) reference US Mil-Std 810, when defining and characterrizing environmental conditions and planning test programs. This AVIP specification specifies the process that measures the effectiveness of avionics system early in the design phase through analysis and test. These, in turn, translate into specific requirement for durability, reliability, maintainability, fault dection and isolation, and supportability. AVIP specification requires the avionics/electronics designer/manufacturer to confront the issue of how the equipment will perform, over time , under the real situations of operational environmental usage. It guided us a better understanding of the factors that cause elecronic assemblies to failure. Main factors of cause of avionics/electronics failure are low cycle fatigue (thermal stress), high cycle fatigue(vibration stress). The AVIP approach put emphasis on early development analyses, establishment of sound and verifiable design criteria, design margins, performing trade-offs studies, and peforming engineering and field tests to understnad material and part characteristics and to identify failure modes and defects. These are followed by durability testing to identify failure modes and to verify the life requirements under application usage and environment.

4. Reliability and Durability

Reliability (also termed survivability in the literature) is clearly defined in the technical literature as the probability that a componet, subsystem, or system will function or perform as intended, for a specified amount of time or usage, under specified environmental conditions. Durability on the hand is not clearly defined in the literature. The clear quantitive defintion and measureability are absolute essentials if a critical quality characteristic of a product or process (such as reliability or durability) is to be improved. Hence, a clear and quantitative definition of durability is necessary in order to measure the durability of avionics/electronics.

The AVIP approach to avionics/electronics reliability prediction is the deterministic approach rather than probabilistic approach such as in MIL-HDBK-217. This AVIP approach is based on the premise that all electronic hardware have a cause rather than being randomly occurring events over which there is little control. These failures ultimately result from mechanical, chemical, thermal, vibration and/or metalluragical stress, as with structural fatigue failures in aircraft. Thus, the probability of failure is a function of the inherent strength of the part or assembly and the load applied to it. Techniques for the prediction and control of the failure that were developed for aircraft structures are being applied to avionics/electronics hardware. This concept of avionics integrity has been termed durability. Durability is measured in terms of Minimum acceptable Failure Free Lifetime(MFL) and Failure-Free Operating Period (FFOP).

Mil-A-87244 approaches durability and avionics integrity in an open-ended fashion, where by the contractor must define requirements and determine verification in the nine categories previously listed. It is expected that avonics durability will be proven in physical tests to prior to full scale field deployment. By using pre-prototype modeling and analysis tools, it is neeed to accomplish to: 1) decrease the desin to deployment cycle time, 2) reduce engineering change orders, 3) increase field reliability and maintainability, and 4) decrease life cycle costs.

5. Summary & Conclusion

This paper presents avionics integrity concept on avionics/electronics with a fundamentals and insight into the process of achieving required reliability, maintainability, durability, and safety. The AVIP details the operational usage, installed environments, requirements for design criteria, requirements for verification of meeting design criteria, and provisions for life mangement.

The key to succes in avionics integrity efforts requires integrated approaches based on proven technology which appears in the literature relative to design, material, manufacturing, quality control, thermal and vibration environments, test, risk, and life management. The AVIP efforts should directed as a continuous improvement tool rather than qualification tool. Also, it must link together the technical, risk, and economic issues involved in defining, designing, manufacturing, and supporting avionics/elecronics.

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