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Superseding ARP5890A

(R) Guidelines for Preparing Reliability Assessment Plans for Electronic Engine Controls

RATIONALE

This document has been reviewed by the E-36 committee as part of the recommended Five-Year update plan. Additions were made to reflect new developments and publications in the field.

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1. SCOPE

This document establishes guidelines for a Reliability Assessment Plan (herein also called the Plan), in which Electronic Engine Control manufacturers document their controlled, repeatable processes for assessing reliability of their products. Each Electronic Engine Control manufacturer (the Plan owner) prepares a Plan, which is unique to the Plan owner.

This document describes processes that are intended for use in assessing the reliability of Electronic Engine Controls, or subassemblies thereof. The results of such assessments are intended for use as inputs to safety analyses, certification analyses, equipment design decisions, system architecture selection and business decisions such as warranties or maintenance cost guarantees.

This Guide may be used to prepare plans for reliability assessment of electronic engine controls in which, typically, the impact of failure is high, the operating environment can be relatively severe and the opportunity to improve the equipment after the start of production is limited. In this and similar industries, accurate estimates of expected equipment reliability are necessary prior to the start of production. This guide was initially produced in response to the recognized need for alternative reliability assessment and prediction methods in the wake of the decline in the availability of mil-spec parts and the declining use of military specifications and handbooks.

Since the original publication of this document, a more advanced approach to handbook prediction has been developed, re-introducing this assessment method as a more viable option. This re-issue describes recent handbook advances while also highlighting a number of emerging reliability risks resulting from advances in electronic component development.

The approach to reliability assessment in this Guide:

- Encourages the equipment manufacturer (the Plan owner) to consider all relevant information regarding equipment reliability which may include the effects of design and manufacturing process as well as component selection issues. This is in contrast to more traditional methods that focus on component reliability as the most significant contributor to the equipment reliability.
- Encourages the equipment manufacturer to define and use the processes that are most effective for the manufacturer's own equipment. This guide does not attempt to prescribe a set of acceptable data, algorithms, methods, or equations to be used in reliability assessment, but rather to provide a 'toolbox' of complementary assessment methodologies based upon a number of current practices.
- Describes a continuous process, in which a reliability assessment can be updated as more information becomes available during the equipment life cycle. This information may be used to improve both the reliability of the equipment and the effectiveness of the assessment process.

Reliability assessment results should be viewed as objective evidence that it is expected the product reliability requirements and goals will be satisfied, by the proposed design. As such, they may be used, for example, to authorize advancement to the next step in product development, or to authorize progress payments, or to proceed with delivery and acceptance of products. Reliability assessment results should never be used to support a claim that the reliability requirements, goals, or expectations have been satisfied, in the face of clear evidence to the contrary from in-service experience.

Traditional approaches to reliability assessment, including Handbook Predictions and Durability Analysis described herein, primarily address unreliability resulting from hardware defects within the equipment. It is not the intention of the ARP to provide methods and processes to specifically address software and system reliability issues, but it is recognized that system and software design errors contribute to product unreliability and that the use of Similarity Analysis, for instance, can encompass these sources of unreliability.

This SAE Aerospace Recommended Practice (ARP) is intended as a guide towards standard practice and is subject to change to keep pace with experience and technical advances.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. Unless otherwise specified, the latest issue of the reference shall apply. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP4754	Certification Considerations for Highly-Integrated or Complex Aircraft Systems
ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
ARP6338	Process for Assessment and Mitigation of Early Wearout in Life-limited Microcircuits
ARP6379	Processes for Application-Specific Qualification of Electrical, Electronic, and Electromechanical Parts and Sub-assemblies for use in Aerospace, Defense, and High Performance Systems
870050	Denson, W. and Priore, M., "Automotive Electronic Reliability Prediction," SAE Technical Paper 870050, 1987, doi:10.4271/870050.

2.1.2 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel 732-981-0060, www.ieee.org.

IEEE 1413	Standard Methodology for Reliability Predictions and Assessment for Electronic Systems and Equipment
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2.1.3 International Electrotechnical Commission Publications

Available from International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +44-22-919-02-11, <http://www.iec.ch/>.

IEC 61508	Functional Safety of Electrical / Electronic / Programmable Electronics Safety Related Systems
IEC 61709	Electronic Components – Reliability – Reference Conditions for Failure Rates and Stress Models for Conversion
IEC 62396	Process Management for Avionics – Atmospheric Radiation Effects
IEC 62239	Process management for avionics – Preparation of an Electronic Components Management Plan

2.1.4 Reliability Information Analysis Center Publications

Available from RIAC, 201 Mill Street, Rome, NY 13440-6916. <http://theriac.org/riacapps/search/>

RiAC EPRD	Electronic Parts Reliability Data
RiAC VZAP	Electrostatic Discharge Susceptibility Data
RiAC 217Plus™	Integrated Software Tool for Assessing System and Component Reliability

2.1.5 U.S. Military Publications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

MIL-HDBK-217 Reliability Prediction of Electronic Equipment

MIL-HDBK-87244 Avionics/Electronics Integrity

2.1.6 Other Publications

ANSI / VITA 51.1-2008 Reliability Prediction MIL-HDBK-217 Subsidiary Specification

British Telecom Handbook "Handbook of Reliability Data for Components used in Telecommunications Systems", British Telecom, Materials and Components Centre, 1987

British Telecom "Handbook for Reliability Data", Issue 5 (HRD5)

Centre National D'Etudes des Telecommunications (CNET) Handbook

UTE-C 80811 FIDES Reliability Methodology for Electronic Systems

GEIA-STD-0005-1 Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder

GEIA-STD-0005-2 Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High performance electronic Systems

GEIA-HB-0005-2 Technical Guidelines for Aerospace and High performance electronic Systems Containing Lead-free Solder and Finishes

ISBN 0-471-78617-9 Lead Free Electronics: Edited by Ganesan and Pecht

JESD47G - JEDEC Solid State Technology Association - Stress-Test-Driven Qualification of Integrated Circuits

Siemens Standard SN29500

Technical Reference SR-332 "Reliability Prediction Procedure for Electronic Equipment", Telcordia Technologies

2.2 Plan Terms, Definitions and Abbreviations

The Plan author should make every effort to prevent ambiguous or inconsistent statements within the Plan by the utilization of consistent terms and definitions. Abbreviations and acronyms should be spelled out and compiled if used frequently. The list below provides some examples, from this ARP, which may be of use to the author in the production of the Plan.

BITE: Built-in test equipment

BPSG: Boron Phosphate Silicate Glass

DURABILITY ANALYSIS: An analysis of the equipment's responses to the stresses imposed by operational use, maintenance, shipping, storage, and other activities throughout its specified lifecycle in order to estimate its expected life.

ELECTRONIC COMPONENTS: Electrical or electronic devices that are not subject to disassembly without destruction or impairment of design use. They are sometimes called parts, or piece parts. Examples are resistors, diodes, etc.

ELECTRONIC ENGINE CONTROL: Primarily LRU (EEC) but not excluding possible application to other elements of the control system.

ELECTRONIC EQUIPMENT: An item, e.g., end item, sub-assembly, line-replaceable unit, shop replaceable unit, or system, designed by the Plan owner.

FEA: Finite Element Analysis

FFOP: Failure-Free Operating Period

FMEA: Failure Mode and Effect Analysis

FMECA: Failure Mode Effect and Criticality Analysis

FRACAS: Failure Reporting, Analysis and Corrective Action System

FTA: Fault Tree Analysis

LIFE-CYCLE: A period of time extending from the equipment concept design phase through to the end of in-service support and disposal.

LOTC: Loss Of Thrust Control

LRU: Line Replaceable Unit

MFOP: Maintenance-Free Operating Period

MTBF: Mean Time Between Failures

MTBUR: Mean Time Between Unscheduled Removals

NBTI: Negative Bias Temperature Instability

OEM: Original Equipment Manufacturer

PCB: Printed Circuit Board

RELIABILITY: The ability of an item to perform a required function under stated conditions for a stated period of time.

SIMILARITY ANALYSIS: The structured comparison of the elements of the equipment being assessed with those of predecessor equipment for which in-service reliability data are available.

SRU: Shop Replaceable Unit

SSA: System Safety Assessment

TBBD: Time Dependent Dielectric Breakdown

TLD: Time Limited Dispatch

TTF: Time to Failure

3. RELIABILITY ASSESSMENT PLAN FOR ELECTRONIC ENGINE CONTROLS

3.1 Plan Content

A Reliability Assessment Plan for Electronic Engine Controls, prepared in accordance with this Guide, should record the processes used to satisfy the provisions of 3.1.1 through 3.1.5, shown schematically in the Assessment Diagram of Figure 1.

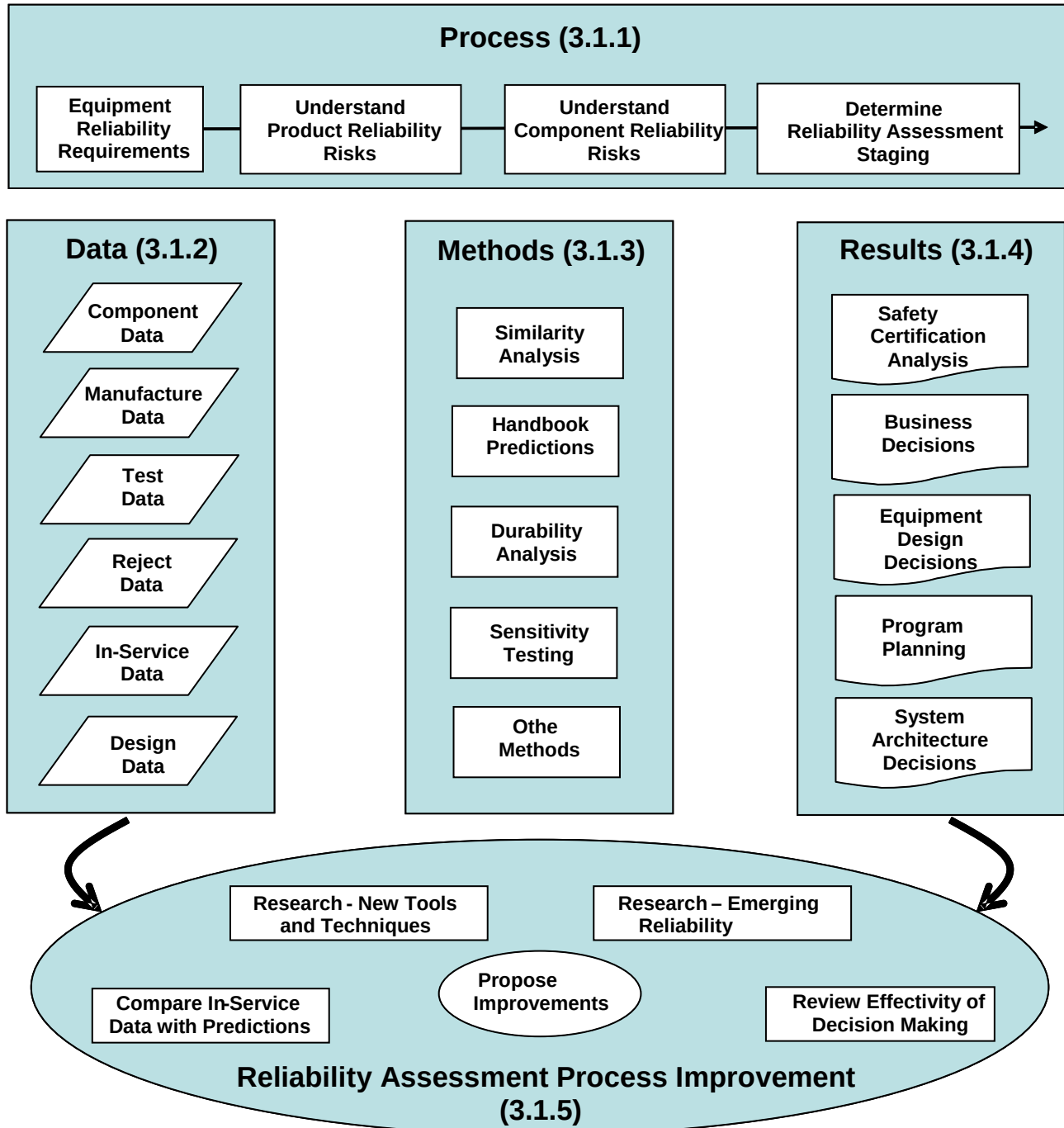


Figure 1 - Reliability assessment diagram

Detailed descriptions of the reliability assessment process should be included in the Plan owner's document. The Plan should show how the sub-processes of 3.1 fit together to form the entire reliability assessment process. Use of a diagram similar to that of Figure 1 is recommended to communicate the major elements of the Plan.

To avoid duplicating descriptions of processes that may already be documented elsewhere, the Plan owner may refer to other documents in the Plan owner's-controlled document system as described in 3.6.

3.1.1 Process

Reliability assessments depend upon a correct understanding of the reliability requirements and should be conducted according to a documented, controlled, and repeatable process that combines those data and methods that are appropriate to the product type and its life-cycle stage (e.g., design, qualification, in-service, etc.).

3.1.1.1 Equipment Reliability Requirements

A description of the process that the Plan owner will use to capture and interpret the equipment reliability requirements, reach agreement upon them with the customer and record them should be included. A standard format, such as that shown in Figure 2 is recommended for defining and reporting reliability requirements. Such a format may be used by the Plan owner to communicate reliability requirements to the purchaser of the equipment, regulatory agencies or any other entity holding a stake in the reliability of the equipment, including internal customers.

The primary sources for reliability requirements will be customer requirements specifications and regulatory agency regulations in conjunction with internal technical and business objectives.

Where reliability requirements from these sources are specified as tangible and unambiguous, then Figure 2 should include traceability to the original requirement.

For those reliability objectives that require further clarification, Figure 2 may be used to define and agree upon a set of derived requirements. These requirements should be based upon well-defined reliability metrics, such as MTBF, TTF or MFOP, and should record the agreed interpretation of the requirement with any assumptions. Traceability from the derived requirement to the original higher level, less tangible, reliability objective should be provided.

The form of Figure 2 may be used to record test, analysis and in-service data. The form may then provide an ongoing indication of the predicted versus actual reliability performance of the equipment, as it progresses through the design and development cycle and into revenue service. Figure 2 may also be used to provide traceability from the original reliability requirement to each test and analysis activity carried out to verify that the equipment performance will meet its specified requirements.

3.1.1.2 Understand Product Reliability Risks

The Plan owner should provide sufficient evidence to demonstrate a good understanding of the failure mechanisms most likely to manifest themselves at the product level. This knowledge may be determined from maintenance records for existing products, currently in service operation, or from data acquired from product test and qualification. At the most basic level it is important to distinguish between failures mechanisms characterized by the infant mortality, wear out and the useful life elements of the bathtub curve. This distinction is necessary to ensure the most appropriate analysis methods for reliability assessment are selected.

As an example, if a manufacturing process failure dominates In-Service returns for a previous product, it is likely that this product will demonstrate infant mortality, as represented by a decreasing failure rate model. Alternatively, it may be that endurance testing of the new product has highlighted a wear-out mechanism. In this case an increasing failure rate model may be more appropriate.

In the majority of cases, however, product failure will not be dominated by a single mechanism but by a combination of failure modes, each with their own characteristic.

Over the service life of the product, this combination of failure mechanisms will appear at a random [or constant] rate, indicating the 'useful life' period. It is for this reason that a constant failure rate model is predominately used as the underlying assumption for reliability assessment.

However, in making this judgment it is important to consider the context in which the assessment results may be used for decision making. While a constant failure rate model may provide a good indicator of comparative reliability over a long period of time, a warranty threshold may be best defined using a decreasing failure rate model, as this can better represent the impact of those failure mechanisms that display infant mortality. Likewise, if the assessment results are being used to determine an overhaul period or maintenance schedule, then an indication of specific wear out issues would be best provided to the decision maker, using increasing failure rate model.

In some cases, a review of maintenance records may indicate that the product failure rate is inconsistent with its removal rate. This skew can often be caused by ineffective maintenance systems or troubleshooting practice, where products are incorrectly removed from the aircraft system and are subsequently tested to confirm no fault is present. Product removals where the root cause of failure cannot be confirmed following test are typically called No Fault Found events and, for some systems, can often account for a high proportion of the total product removals. If product removal rate is agreed as an important requirement, then the assessment should include failures of the wider system in order to estimate the likely removal rate for the product concerned.

Since the initial issue of this document, an increased risk to reliability performance has been introduced with the use of lead free solders.

3.1.1.2.1 Lead Free Solder

Following the implementation of RoHS (Removal of Hazardous Substances) legislation within the EU, the use of Lead within electronic equipment has been prohibited. At the time of publication however, the Aerospace industry has been granted an exemption from the RoHS legislation, but it is unlikely that this exemption will remain into the future. In the short term, therefore, the Aerospace industry has not been mandated to manufacture products with non-lead based solder. However, the commercial electronic industry (e.g., computers and mobile phones), dominate the market need for electronic components and they must comply with RoHS legislation. This has consequently had an impact on component termination finishes which have, in the main, been converted from tin-lead to pure tin. The main impact of tin solder on reliability is the well-known propensity for pure tin to spontaneously form whiskers. These whiskers can vary in length from a few microns to several millimeters. This effect introduces the possibility of short circuits being formed between adjacent unconnected circuit elements. Mitigation strategies to minimize the impact of whiskers on product reliability must therefore be considered, if pure tin termination finishes are to be used.

Lead free solders are generally comprised of tin, silver and copper, in various proportions; typically around 3% silver and 0.5% copper with the balance made up from tin. The alloy designation is generally abbreviated to SAC plus a number, where the number represents the silver and copper content; e.g., SAC305 contains 3% silver and 0.5% copper. These alloys are more brittle than conventional tin-lead solder and as a consequence are not as resistant to shock and vibration. The thermal cycle performance of solder joints made using SAC solder is very dependent on the test regime used so prediction of in-service performance and life expectation cannot be easily assessed with any confidence.

Furthermore, SAC alloys melt at a higher temperature than conventional tin-lead solder and thus a higher degree of thermal damage to both PCBs and electronic components may occur during assembly, consequently affecting the reliability performance of the product.

RELIABILITY REQUIREMENTS REPORT					
Equipment ID No.: _____		Date: _____			
Equipment Name: _____		Equipment Manager: _____			
		Reliability Engineer: _____			
Requirement Reference	Reliability Metric	Required Value	Actual / In-Service Performance	Test Reference	Analysis Reference
Requirements Interpretation and Assumptions					
Summary of Environmental and Operating Conditions					
Summary of Type and Level of Maintenance					

Figure 2 - Reliability requirements report form

3.1.1.2.2 Current Research into Lead Free Soldering

Extensive research into the reliability of lead free solder joints and tin whisker formation is being carried out at academic institutions throughout the world. The Centre for Advanced Life Cycle Engineering (CALCE) at the University of Maryland is at the forefront of research in the USA along with the National Physical Laboratory (NPL) in the UK. Current research focus is on both solder joint life and reliability and reliability prediction, on the understanding of tin whisker formation and perhaps more importantly on the mitigation of tin whiskers to prevent their formation impacting on unit functionality and reliability. In the Aerospace and Defense industry, research is being coordinated by the PERM (Pb-free Electronics Risk Management) consortium who are authors to the GEIA standards and handbook referenced below.

3.1.1.2.3 Recommended Reading

Useful publications which contain additional technical information are listed below:

ISBN 0-471-78617-9: Lead Free Electronics: Edited by Ganesan and Pecht

GEIA-STD-0005-1: Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder

GEIA-STD-0005-2: Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High performance electronic Systems

GEIA-HB-0005-2: Technical Guidelines for Aerospace and High performance electronic Systems Containing Lead-free Solder and Finishes

3.1.1.3 Understand Component Reliability Risks

The Plan owner should identify the types of electronic component that will be used within the equipment, particularly those with little service pedigree or high technological risk. The Plan owner should provide sufficient evidence to demonstrate a good understanding of the reliability risks associated with the specific components or technologies selected for use within the equipment design. This should include a reasoned argument as to the most appropriate data and analysis methods for carrying out an effective assessment.

Since the initial issue of this document, a significant risk to reliability performance has developed from a continued reduction in IC feature size; this is particularly noticeable in IC processes which fall below 1 micron. A reduction in feature size below this value has been shown to significantly increase the wear out mechanisms within the IC while also increasing the threat posed by Single Event Effects (SEE). These issues are briefly described in 3.1.1.3.1 and 3.1.1.3.2 respectively.

It is recommended that the Plan owner assess the feature size of all electronic components (particularly memory), within their proposed design, in order to determine whether they may pose a threat to product reliability. If this is the case the most appropriate means to assess this threat may then be selected.

3.1.1.3.1 Single Event Effects

Cosmic Rays that interact with the Earth's atmosphere produce a flux of high energy secondary neutrons. These secondary neutrons can produce Single Event Effects, SEE, within submicron electronic devices. The effects can be observed at sea level but at aircraft altitudes the high energy secondary neutron flux is much higher; over two decades higher at 40000 feet altitude. The type of SEE may vary from simple upset (change of state) for a memory to more permanent events including latch up and burn out. Very low energy thermal neutrons are produced by interaction of the high energy neutrons with the aircraft; these can produce SEE in vulnerable devices with boron 10 (the unstable isotope of boron in boron doped silicon) in the BPSG passivation (used as an insulator between metal layers).

Work has been carried out to characterize the atmospheric radiation environment and there are several models that are available to calculate the secondary neutron flux at any flight location directly. However, a nominal value has been defined within the IEC technical specification 62396 which may be scaled for different locations. In order to assess the SEE tolerance of avionics equipment it is necessary to identify the potentially SEE sensitive parts and determine their SEE tolerance, this information can then be used to assess the impact at equipment and system level. IEC TC62396 provides a comprehensive means of assessing the impact of SEE on product reliability.

- IEC 62396-1 Process management for avionics – Atmospheric radiation effects
Part 1: Accommodation of atmospheric radiation effects via single event effects within avionics electronic equipment
- IEC 62396-2 Process management for avionics – Atmospheric radiation effects
Part 2: Guidelines for single event effects testing for avionics systems
- IEC 62396-3 Process management for avionics – Atmospheric radiation effects
Part 3: Optimising System Design to accommodate the Single Event Effects, SEE of Atmospheric Radiation
- IEC 62396-4 Process management for avionics – Atmospheric radiation effects
Part 4: Guidelines for designing with high voltage aircraft electronics and potential single event effects
- IEC 62396-5 Process management for avionics – Atmospheric radiation effects
Part 5: Guidelines for assessing thermal neutron fluxes and effects in avionics
- IEC 62396-6 Process management for avionics - Atmospheric radiation effects
Part 6: Extreme space weather and potential impact on the avionics environment and electronics
- IEC 62396-7 Process management for avionics - Atmospheric radiation effects
Part 7: Management of SEE analysis process in avionics design
- IEC 62396-8 Process management for avionics Atmospheric radiation effects
Part 8: Assessment of proton, electron, pion, muon fluxes and single event effects in avionics systems

3.1.1.3.2 Wear-Out of Sub-micron Electronic Devices

Reliability assessment for semiconductor devices with feature sizes above 0.5 micron have been successfully performed using a constant failure rate assumption for many years. However, with reducing feature sizes below 0.5 micron the internal stresses within the devices (power per unit volume, voltage and current) has greatly increased. This is predominantly because the device voltage and currents have not reduced in proportion with the geometric feature size reductions. At device feature sizes of about 0.1 micron the increased stresses and resulting degradation mechanisms may impact both the reliability and operating life in the application environment. For this reason, consideration must be given to potential wear out within its operational life, which suggests that an increasing failure rate model may best represent the reality.

Academic and industry consortia have carried out detailed investigation of potential degradation mechanisms and have concluded that four mechanisms dominate the behavior; Hot carrier injection [HCI], time dependent dielectric breakdown [TDDB], negative bias temperature instability [NBTI] and electro-migration [EM]. During operational usage, these devices will, as a population, degrade away from their initial characteristics. The time at which the devices fail intrinsically in the given application will depend on a complex function of a large number of factors which include feature size, deployment, environmental and application electrical stresses. However, effective derating as part of the design process, may enable such parts to meet operational requirements

Investigation of these effects in devices with geometric feature sizes below 0.2 micron has been carried out by the Aerospace Vehicle Systems Institute as part of projects AFE17 and AFE71. The following references are recommended for further reading.

SAE ARP6338 - Process for Assessment and Mitigation of Early Wear Out of Life-limited Microcircuits

IEC TS 62239 - Process management for avionics – Electronic Components Management Plan

AFE17 - Aerospace Vehicle Systems Institute, Methods to Account for Accelerated Semiconductor Device Wear Out

AFE71 - Aerospace Vehicle Systems Institute, Reliability Prediction Software using FARBS and MaCRO

JESD47G - JEDEC Solid State Technology Association - Stress-Test-Driven Qualification of Integrated Circuits

3.1.1.4 Reliability Assessment Staging

The Plan should include a schedule that defines at which phases of the equipment life cycle the Plan owner will conduct reliability assessments. The intent is to define a progressive process in which the Plan owner will update the reliability assessment as more data become available throughout the design and development of the equipment. Following the equipment's entry into service, any updates to the reliability assessment will be determined by prior agreement between the supplier and purchaser of the equipment.

It is recommended that the reliability assessment process be continually updated as data become available throughout the equipment life cycle.

3.1.2 Data

Data used in reliability assessment should be obtained from credible and relevant sources and should be controlled, updated, accessed, and used according to consistent processes. Data may be obtained from equipment, sub-assembly or component testing, in-service performance, and other relevant data sources. A process that defines how the accuracy and completeness of the data are determined should be included in the Plan.

To avoid duplicating descriptions of processes that may already be documented elsewhere, the Plan owner may refer to other documents in the Plan owner's controlled document system to record the data management system.

3.1.2.1 Data Sources and Types

The data sources that the Plan owner may use as inputs to reliability assessment processes should be described. As a general rule, data from the Plan owner's equipment and component manufacturers are highly preferred over data obtained from general industry sources, provided that the population of data is sufficient to carry out a credible statistical analysis. Specific data captured directly from the Plan owner's equipment and component suppliers is preferred over general industry data because specific failure rate information for an LRU, sub-assembly or piece part will implicitly reflect the design and manufacturing process capability for the individual equipment supplier.

If sub-assembly or component level data is being used, an evaluation of the interaction of components in the design needs to be included to ensure failure modes included in the data are applicable and potential failure modes are not overlooked.

A description of the process, based upon sound statistical evidence, that defines how the Plan owner selects the most appropriate data source for the particular assessment application should be included in the Plan.

Examples of data from the Plan owner's equipment include:

1. Qualification test data from components and sub-assemblies;
2. Quality assurance test data from component and sub-assemblies;
3. In-service data from similar equipment and similar applications;
4. In-service data from components and sub-assemblies in similar equipment and similar applications;
5. Manufacturing and Statistical Process Control data from similar equipment, components, and sub-assemblies;

6. Development test data from engineering (e.g. highly accelerated life test (HALT) data);
7. Environmental stress screening, functional test, and acceptance test data from production;
8. Test and rework data from non-OEM facilities such as third-party repair and overhaul facilities.

Examples of data from other sources are:

1. Data from component manufacturers;
2. Data from industry and consortia databases;
3. Data from handbooks.

The types of information may include:

1. Maintenance action (Diagnostics activity, Scheduled/Non-scheduled, repaired, replaced, removed for use on other aircraft);
2. Fault indication and confirmation (BITE data, cockpit warnings/observed effects);
3. Failure effect or criticality (including loss of function and any effects of secondary damage);
4. Failure mode;
5. Failure mechanism;
6. Failure site;
7. Operating and environmental conditions to which the LRU is nominally subjected and those at which the failure occurred;
8. Hours and Cycles of the equipment or sub-assembly in which the failure occurred (including aircraft duty cycle, i.e. operating versus non-operating, powered hours);
9. Corrective actions for the failure;
10. Failure analysis results, including root cause;
11. Total population exposure time or cycles (possessed, operating, or flight);
12. Trending and prognostic data.

It is essential to select data that will enable calculation of appropriate reliability metrics.

3.1.2.2 Data Collection, Storage, and Retrieval

A description of the processes the Plan owner will use to collect, store and retrieve reliability assessment data should be included in the Plan. The data are usually integrated into a larger database, as opposed to a separate reliability assessment database. If this is done properly, all relevant data, including lessons learned, are available to design and manufacturing personnel for use on current and future equipment. When using field data for the purposes of reliability assessment it is crucial to understand the accuracy of the data and the integrity of the data collection process itself. For example, when using field data to predict a critical failure rate, such as LOTC, for a safety analysis, it is necessary to ensure that source data is current, complete and provided by a collection process that will focus on capturing all pertinent data.

Limitations in both the scope of recording and accuracy of reporting data must be understood. Clearly for the purposes of data analysis, equipment's failure rate would be seen as zero if the level of its test coverage is insufficient to detect particular faults. The same optimistic analysis would result if faults were detected but were not reliably reported. Confidence in data is critical when determining unit safety as it often involves two failures, one of which, may be dormant.

When defining the scope of the data collection process, the Plan owner should consider the ability of the process to detect and record those failures that subsequent data analysis may be used to predict. A description of those processes that ensure controlled, repeatable data collection should be included in the Plan. Further data management information is described in ATA Specification 2000.

3.1.3 Methods

Reliability assessments should be conducted using documented, controlled, and repeatable methods and techniques which may include analyses and/or testing. These methods should undergo some form of validation. The Plan should include the results of validation carried out to indicate the accuracy and limitations of each method. This information may be used to determine the applicability of an assessment method to a particular reliability assessment activity. Continued validation of each assessment method will be available in the form of in service data. Current correlation between predicted and actual reliability performance can be provided to justify the selection of a particular method for any subsequent assessment, taking credit for any proven process improvements. Guidelines for managing reliability assessment validation and improvement are detailed in 3.1.5.

A description of all the methods the Plan owner will have available for assessing the expected reliability of a given equipment (including the necessary calculations) using the data described in 3.1.2, should be included. The Plan owner may select the methods described within this section or other methods that the Plan owner intends to have available. The intent is for the Plan owner to document all the analysis and calculation processes that will be available.

More than one method may be applicable to the subject equipment. In fact, it may be advantageous for the Plan owner to apply more than one method to a single product in order to establish a representative reliability assessment. The Plan should include a justification for the selection of the particular assessment method(s). The justification process should be described in the Plan and include sound statistical evidence that can demonstrate that the data source and method are applicable to the assessment application in question.

3.1.3.1 Similarity Analysis

Similarity analysis includes the use of in-service equipment performance data to compare newly designed equipment with predecessor equipment for predicting end item reliability. Appendix A offers guidelines in the form of examples of this method.

Comparisons of similar equipment may be made at the end item, sub-assembly, or component level using the same field data, but applying different algorithms and calculation factors to various attributes, described below. Comparison with similar equipment may also be made at the functional level to provide base failure-rate data for safety analysis or architectural decision making.

Attributes to be compared may include:

1. Operating and environmental conditions (measured and specified);
2. Design features;
3. Design processes;
4. Design team experience with similar designs;
5. Manufacturing processes, including quality control;
6. Manufacturer's experience with similar components and processes;
7. Built in test and fault isolation features;
8. Test and maintenance processes;
9. Components and materials;
10. Date or other measure of technology maturity; and
11. Quality of the reliability assessment processes.

For each of the above attributes, a number of lower level attributes should be compared. As examples, operating and environmental conditions may include steady-state temperature, humidity, temperature variations, electrical power, duty cycle, mechanical vibration, etc.; equipment design features may include number of components (separated according to major component family), number of circuit card assemblies, size, weight, materials, etc. Similarity analysis should include necessary algorithms or calculation methods used to quantify the similarities and differences between the equipment being assessed and the predecessor equipment.

Although the concept of similarity analysis is based very much on locating a 'similar' design, it is finding the critical 'differences' between them, at the appropriate level, that makes the methodology effective. With this in mind it is important that the specific failure modes associated with existing products are reviewed for relevance to a design or technology in a new product.

When an end-item similarity analysis is not possible because no predecessor equipment is sufficiently similar or available for a one-to-one comparison with the newly designed equipment being assessed, then a similarity analysis may be conducted at a lower level (e.g., subassembly, module or component level). The lower level analysis may include the structured comparison of elements of the new equipment with similar elements of a number of different predecessor equipment, for which reliability data are available.

Another means of conducting similarity analysis is to use a more structured approach such as physic-of-failure (PoF) methods, based on finite element analyses of both the predecessor product and the newly-designed product at the equipment, sub-assembly, or piece part level. Generally, the available PoF software employs industry-consensus algorithms, and is updated as new knowledge becomes available. This approach is shown graphically in the flow diagrams of ARP6338 (Figure 3) and ARP6379 (Figure A1).

Figure 3 shows a sample checklist that may be used to facilitate an effective similarity analysis and concise results report.

SIMILARITY ANALYSIS CHECKLIST

The following items are recommended for inclusion in a product reliability assessment report, which uses the similarity analysis method.

GENERAL INFORMATION

- ☐ 1) Analysis Date
- ☐ 2) Analysts Name
- ☐ 3) Approvals – As required
- ☐ 4) Program Phase
- ☐ 5) Usage of Results

REFERENCES

- ☐ 6) Applicable Reliability Assessment Plan Document
- ☐ 7) Reliability Assessment Procedure Document
(Alternately, procedure may be included in the analysis portion of the report document)
- ☐ 8) Predecessor Data Archive

PRODUCT IDENTIFICATION

- ☐ 9) Name of New Product
- ☐ 10) Part Number of New Product
- ☐ 11) Name of Predecessor Product(s)
- ☐ 12) Part Number of Predecessor Product(s)

ANALYSIS

- ☐ 13) Level of Analysis (LRU, SRU, Functional, etc.)
- ☐ 14) Predecessor Product Data Summary(ies)
- ☐ 15) Attributes Compared
- ☐ 16) Basis for Quantifying Attribute Differences
- ☐ 17) Algorithm or Calculation Method(s)

RESULTS

- ☐ 18) Reliability Assessment Metric(s) (MTBF, Failure Rate, etc.)
- ☐ 19) Expected variability of Reliability Metric(s)
- ☐ 20) Reliability Requirement Metric(s) (If applicable)

Figure 3 - Similarity analysis checklist