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MILITARY STANDARD

RELIABILITY PROGRAM REQUIREMENTS

FOR

SPACE AND MISSILE SYSTEMS

AMSC F3161

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DEPARTMENT OF THE AIR FORCE
Washington, D.C. 20330

Reliability Program Requirements for Space and Missile Systems

MIL-STD-1543A (USAF)

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FOREWORD

The reliability achieved by military systems is directly dependent upon the emphasis put on reliability during the initial design, fabrication, and test of such hardware. Government and contractor management emphasis on reliability throughout the system life cycle will assist in achieving the desired levels of system/cost effectiveness. The reliability program requirements herein have been established to aid in the timely and economical attainment of system reliability as an integral part of the acquisition process.

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MILITARY STANDARD

RELIABILITY PROGRAM REQUIREMENTS FOR SPACE AND MISSILE SYSTEMS

1. SCOPE

1.1 Purpose. This standard establishes uniform reliability program practices and procedures for use during design, development, fabrication, test and operation of space and missile systems.

1.2 Application. This standard applies to all prime, associate and subtier contractors involved in the design, development, fabrication, test and initial operation of equipment for space and missile systems applications. The contractor(s) and the contractor's subtier contractors' requirements documentation shall reflect the requirements of this standard. The contractor(s) requirements documentation shall be subject to review and disapproval of the procuring activity. This standard may be limited to new developments or major modifications at the prerogative of the procuring activity.

1.3 Relationship to other requirements. This standard is intended to complement the requirements of MIL-Q-9858 and Parts, Materials, and Processes (PMP) control and standardization requirements.

1.3.1 Integration with other activities. The reliability program effort shall be closely coordinated with the design engineering and test programs as well as configuration management and integrated logistic support. The reliability program shall also be closely integrated with the related disciplines of quality assurance; maintainability; human engineering; system safety; and parts, materials, and processes control to preclude duplication of effort and produce integrated cost effective results.

2. REFERENCED DOCUMENTS

The following documents, of the issue in effect on the date of invitation for bid or request for proposal, form a part of this standard to the extent specified herein:

Military Specifications

MIL-Q-9858	Quality Program Requirements.

Military Standards

MIL-STD-280	Definitions of Item Levels, Item Exchangeability, Models, and Related Terms.
DOD-STD-480	Configuration Control, Engineering Changes, Deviations, and Waivers.
MIL-STD-721	Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors and Safety.
MIL-STD-756	Reliability Prediction.
MIL-STD-1521	Technical Reviews and Audits for Systems, Equipment, and Computer Programs.

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MIL-STD-1556 Government/Industry Data Exchange Program.

Other Documents

MIL-HDBK-217 Reliability Prediction of Electronic Equipment.

(Copies of specifications, standards, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer).

3. DEFINITIONS

The definitions of MIL-STD-280, MIL-STD-480, MIL-STD-721, MIL-STD-1521, and MIL-STD-1556 are applicable to this standard. The definitions of Appendix B, paragraph 30, and the following definitions also apply:

3.1 Assessment. A critical appraisal including qualitative judgments about an item, such as importance of analysis results, design criticality, and failure effect.

3.2 Item. Use the definition in MIL-STD-280.

3.3 Level of indenture. An identifiable portion of a completed configuration item (CI) defined by the level of assembly completed. For example, a printed circuit board is a lower level of indenture than a component unit or black box. A CI is defined as comprising one or more lower indenture level items.

3.4 Critical items. Critical items are those items which require "Special Attention" because of complexity, application of state-of-the-art techniques, the impact of potential failure or anticipated reliability problems. An item is to be considered critical if it meets any of the following criteria:

a. A failure of the item would critically affect system operation or cause the system to not achieve specified objectives.

b. A failure of the item would prevent obtaining data to evaluate accomplishment of mission objectives.

c. The item has stringent performance requirement(s) in its intended application relative to state-of-the-art techniques for the item.

d. The item is a single point failure.

e. The item is stressed in excess of recommended derating criteria.

f. The item has a known operating, shelf life or environmental exposure limitation, such as vibration, thermal or propellant, which warrants controlled surveillance under specified conditions.

g. The item is known to require special handling, transportation, storage, and/or test precautions.

h. The item is difficult to procure and/or manufacture relative to state-of-the-art techniques.

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i. The item has exhibited an unsatisfactory operating history.

j. The item does not have sufficient history of its own, or similarity to other items having demonstrated high reliability, to provide confidence in its reliability.

k. The item's past history, nature, function or processing has a deficiency warranting total traceability.

3.5 Single point failure. Any piece part, assembly, component, or element of construction, such as printed circuit board layout; the failure of which would result in irreversible degradation of item mission performance below contractually specified levels, such as failure of an item in operation which could be catastrophic to a mission objective.

4. GENERAL REQUIREMENTS

The prime, associate, and subtier contractors shall implement and maintain a reliability program that is planned, scheduled, integrated, and developed in conjunction with other design, development, and production functions in accordance with the requirements of this standard and the procuring activity approved reliability program plan. The contractor shall establish and maintain an internal system of directives, procedures, instructions, specifications and manuals to implement the requirements of the reliability program. The program level of effort shall be adequate to fulfill the contractual quantitative and qualitative reliability requirements.

4.1 Quantitative requirements. The minimum acceptable item reliability shall be as stated in the CI specification. Quantitative hardware reliability requirements for all major items shall be stated in the appropriate section of each item specification. The quantitative values not defined by the procuring activity and those to be allocated by the contractor from the major item specification requirements shall be established by the contractor through item level trade-off analysis prior to the Preliminary Design Review (PDR) and shall be updated for the Critical Design Review (CDR) and subsequent formal reviews.

4.2 Reliability testing and demonstration. The contractor shall implement and maintain a reliability test and demonstration program that is planned, integrated, and developed with the system and/or equipment test program; such as performance and flight testing, item testing, and maintainability demonstration to avoid duplicate testing. This program shall include the requirements of this standard and receive procuring activity approval prior to implementation. The program shall include all reliability testing and demonstration to be performed for the program. Tests shall be designed to make maximum use of reliability data from all sources. Unless otherwise specified by the contract, the contractor shall analytically demonstrate the achievement of minimum acceptable hardware reliability requirements at the Physical Configuration Audit (PCA). The analytical methods, assumptions and piece part failure rates to be used shall have specific approval of the procuring activity. The contractor shall use the results of program tests, Failure Mode and Effect Analyses (FMEA's), and item failure reports to qualitatively evaluate the demonstration results as part of the assessment of the item predictions.

4.3 Design reviews. For new design or redesign, the contractor's reliability personnel shall participate in procuring activity, subcontractor PDRs and CDRs and internal design review(s), such as pre-PDR, post-PDR or pre-CDR of an item. Results of these design reviews shall be recorded and shall be available to the procuring

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activity for detailed examination at the contractor's or subcontractor's facilities during the term of the contract. Procuring activity, subcontractor PDRs and CDRs, and internal design reviews and design audits should include: (1) a review of current reliability estimates and achievements for each mode of operation, (2) a review of potential design or manufacturing problem areas, (3) an analysis of mode(s) and effect(s) of failure, (4) a sensitivity analysis including worst-case effects on the item design, (6) the effects of engineering decisions and trade-offs upon the item reliability, (7) a thorough assessment of the item reliability at that point in time, including a listing of those items not meeting derating requirements, (8) a review of test requirements and results, (9) a review of program schedule compatibility, and (10) procedures to assure that decisions made as a result of design reviews are reflected in the design of the item. The contractor shall follow-up design review decisions, action items and agreements to assure that the design reflects the results of such decisions. The contractor shall notify the procuring activity of any design reviews at least five working days prior to the review. The procuring activity reserves the right to have representative(s) attend the internal and subcontractor reviews as an observer.

4.3.1 Design trade-offs. Whenever design trade-offs are performed, or engineering change proposals are generated, the contractor shall define the effects of the proposed change(s) on the entire system. The details of the trade-offs involving system reliability and the results of any design change on reliability shall be evaluated, recorded and reflected in the reliability analysis.

4.4 Critical items. The contractor shall establish and maintain an effective method for identification, control and test of critical items from initial design through final acceptance. The method(s) the contractor uses for critical item control shall be described in the contractor's formal policies and procedures to assure that all affected personnel such as design, purchasing, manufacturing, inspection, test, handling are aware of the essential and critical nature of such items. Periodic reviews at PDR, CDR, Functional Configuration Audit (FCA), and PCA, as a minimum, shall be used by the contractor and the procuring activity to determine if additions or deletions to the critical item list and control plan(s) and procedures are warranted, and to assess the effectiveness of the critical item controls and tests. Each critical item control method and plan to be used shall be subject to on-going review and evaluation by the procuring activity. (See 5.7.1)

4.5 Reliability test and evaluation. The contractor shall identify to the procuring activity items which are candidates for reliability evaluation or life tests. As a minimum, these shall include items that have limited documented history of previous usage to support the life requirements of the program. Reliability evaluation or life tests shall be performed as directed by the procuring activity. The contractor's reliability evaluation or life test plans shall be included in the Program Test Plan and be detailed with sample sizes, test duration, confidence level, test conditions and accept/reject criteria as a minimum. The FMEA shall be used as an aid in the design of the test plans and procedures. Test results shall be used to ascertain the item's capability to comply with program reliability requirements.

4.5.1 Development and qualification testing. The results of contractor's functional and environmental testing of items during the design and development phases shall be analyzed to estimate achieved reliability, to provide confidence in the predicted reliability and to provide feedback to support design changes that impact reliability. A log

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book shall be maintained for each item identified on the program equipment listing to record its operating times during assembly, test, and operation. The development testing program shall be used to confirm the following factors, down to the piece part level: adequacy of item selection, safety margins, parameter drifts with time, failure modes, and establishment of human performance operation and maintenance variability criteria.

4.5.2 Statistical methods. The contractor shall use statistical analysis to extract usable design and management information from the discrepancy and failure reports, failure analysis records, and corrective action records. The contractor shall make use of statistical planning and analysis in the test program. This may include application of such methods as design of experiments, analysis of variance and other methods applicable to design, development, production, and operational phases.

4.6 Circuit and item stress analysis. During the development and design phase the contractor shall perform sensitivity analyses which relate the parts stress to circuits, modules, components, subsystems and system performance as they are influenced by parametric variations, environmental effects, radiation effects and input and output limits, due to such factors as operating points, aging and initial tolerances. The sensitivity analyses shall account for worst-case part stress and include all derating factors in the approved derating criteria, such as part derating, part end-of-life and part stresses due to application effects. Analysis shall be performed for steady state and known transient conditions occurring during turn-on, turn-off and performance state change. Worst-case operations shall be included for:

a. Maximum input signal variation.

b. Maximum line voltage variations and line transients.

c. Maximum part parameter variation.

d. Maximum performance demands.

e. Maximum and minimum temperatures.

f. Fail safe provisions.

g. Redundancy provisions.

h. Radiation effects, as applicable.

These analyses shall be scheduled and performed as an integral part of the design effort and be presented at design reviews. The contractor shall correlate the results of these analyses with the FMEA. Results of these analyses shall be available for procuring activity review prior to item CDR.

5. DETAILED REQUIREMENTS

5.1 Design for reliability. The contractor shall give preference to hardware and hardware designs that have performed successfully in the intended actual mission environment. Non-proven designs shall be validated by analysis and test as part of the design process. Standard derating criteria, including radiation effects as applicable, shall be established for use by designers and deviations to the criteria shall require joint

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approval of the contractor's system engineering, parts engineering, and reliability managers. The contractor shall use part standardization and minimization, stress derating, redundancy, fault isolation, single point failure minimization and stress-strength analysis in his design. These program peculiar criteria shall be developed for and used by the designers.

5.1.1 Stress derating guidelines. The contractor's part and component derating criteria for design in response to 5.1 shall be consistent with part derating policy developed to comply with applicable parts, materials, and processes management provisions.

5.1.2 Design guidelines for redundancy The contractor will assure optimum application of all redundancy techniques (active, passive, and graceful degradation). Single point failures will not be permitted for mission critical components, except as provided in Appendix B, 50.7.3. Design for redundancy will utilize independent paths of operation or communication and provide for a high degree of assurance of effective successful operation during intermittent failure modes.

5.2 Failure mode and effect analysis (FMEA). The contractor shall perform a FMEA in accordance with Appendix B.

5.3 Reliability analysis. The contractor shall perform a reliability analysis of the system as an integral part of the overall system engineering analysis in order to optimize the balance between effectiveness, schedule, and total resources. Criteria for the analysis shall include operational and support concepts and requirements and environmental conditions of use. The results of these reliability analysis shall be used during design, development, and test to evaluate the achievement of the reliability design requirements. The contractor shall not compromise reliability related criteria such as maintainability, quality assurance, safety or parts control in an attempt to exceed contractually specified performance criteria.

5.4 Reliability modelng and prediction.

5.4.1 Reliability modeling. The contractor shall develop and maintain a reliability mathematical model based on design schematics and drawings for each configured item required to perform the mission functions. A reliability block diagram shall be developed and maintained for the system with associated allocations and predictions for all items in each reliability block. Allocations and predictions shall be made down to the component level as a minimum and shall include probability of success with associated failure rate. The reliability block diagram shall be keyed and traceable to the functional block diagram, schematics and drawings. Switching circuit physical locations shall be clearly identified. The current reliability prediction determined by use of the updated mathematical model shall be presented during item design reviews along with the current parts counts. Nomenclature of items used in reliability block diagrams shall be consistent with that used in block diagrams, drawing and schematics, weight statements, power budgets and specifications. The reliability mathematical model shall be capable of being readily updated with information resulting from reliability and other relevant tests as well as changes in item configuration, mission parameters and operational constraints. Inputs and outputs of the reliability mathematical model shall be compatible with the input and output requirements of the system, subsystem and component level analysis models.

5.4.2 Reliability predictions. The contractor shall perform reliability predictions for all items using the methods defined in the approved reliability program plan. Predictions shall account for and differentiate between each mode of item operation as

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defined in the item specification and the reliability program plan. The probability that the system will operate within specified limits at some point in time shall be computed for the total mission profile including any subphases. The contractor shall perform these predictions for the associated reliability block diagram using methods contained in MIL-STD-756, MIL-HDBK-217 or alternatives established prior to contract go-ahead and/or failure rate data approved by or provided by the procuring activity.

Results of the FMEAs shall be reflected in the predictions. Items excluded from the predictions as mission non-essential shall have substantiating FMEAs which verify that the item failure cannot cause mission failure. Prior to such exclusions from the predictions, an assessment shall be made and approval shall be obtained from the procuring activity. Usage of operational duty cycles of less than 100 percent shall require prior approval of the procuring activity and be clearly identified in all analyses and predictions.

Failure rates other than those established at or prior to contract go-ahead may be used only upon approval of the procuring activity. When the individual part operating conditions become definitized, the failure rates shall be adjusted for applied stress using MIL-HDBK-217 procedures. The minimum permissible failure rate adjustment factor for standby operation is as specifically agreed to by the procuring activity. Standby failure rate adjustment factor is normally 0.5 for failure rates of one in 10^8 hours or lower.

These reliability predictions will be used by the procuring activity as a basis for determination of contractual compliance with and demonstration of the quantitative reliability requirements and shall be subject to the approval of the procuring activity.

5.4.2.1 Mean mission duration (MMD). The MMD for the system and selected items shall be presented as follows: untruncated, truncated at the end of the expected mission life and truncated at the point in time the contractor estimates wearout or depletion of expendables, e.g., end of useful life, shall occur. The MMD shall be calculated using the following equation:

$$MMD = \int_0^T R(t)dt$$

where R(t) = Mission reliability model function
T = Time at truncation

5.5 Discrepancy and failure recording, analysis and corrective action. The contractor shall maintain and shall require subcontractors to maintain a closed loop system for collecting, recording and analyzing the information derived from all discrepancies and failures that occur at all phases of test, fabrication and inspection commencing with research and development model components. Summary information and charts reflecting discrepancy and failure trends at all levels of inspection shall be developed for review and corrective action.

5.5.1 Problem investigation. The failure and discrepancy recording system shall include procedures for documenting the investigation of the cause of each failure and type of discrepancy. Failure analysis shall be conducted to the lowest level of hardware necessary to identify the failure cause and mechanism and shall begin with an on-the-spot review by reliability and quality engineering and the responsible test engineer prior to removal of the failed hardware from the test set-up. Parts failure analysis shall be performed by parts engineers.

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5.5.2 Corrective action. The contractor's failure and discrepancy recording system shall include provisions to assure and verify that effective corrective actions; appropriately coordinated with design engineering, quality assurance and manufacturing; are taken on a timely basis to reduce or prevent repeated failures. The methods and responsibilities for corrective action shall include initiating, assigning, follow-up, and close out functions. The contractor shall establish and maintain an automatic suspense audit procedure to review all open reports, analyses, and corrective action suspense dates and report all delinquencies to the Failure Review Board (FRB) and the procuring activity at prescribed time intervals (5.5.3). Closeout shall not be accomplished until corrective action is implemented. All failures will be resolved prior to flight.

5.5.3 Failure review board (FRB). A FRB shall be established and maintained to review failure trends, significant failures, delinquent corrective actions, and assure adequate corrective actions (5.5.2). The FRB shall meet regularly, normally monthly, after development testing is started. The FRB shall review data on all failures from all levels of inspection and testing including subcontractor qualification and acceptance test failures. All failure occurrence information shall be available to the FRB. Minutes of FRB activity shall be recorded and kept on file for detailed examination by the procuring activity during the term of the contract. Contractor FRB members shall include representatives from design engineering, reliability, parts engineering and quality engineering as a minimum. The procuring activity reserves the right to appoint a representative to the FRB as an observer.

5.5.4 Failure and discrepancy data collection and recording. Commencing with testing of advanced development model components, failure and discrepancy data collection and recording shall be equivalent to that for qualification, production of components and higher indenture level items (5.5.4.1). The contractor shall maintain logs of significant events, discrepancies and failures on research and advanced development hardware prior to component level testing. These logs shall be used to complete the history of each such item.

5.5.4.1 Qualification and production hardware. Qualification and production system hardware discrepancy data collection and recording shall start at the module functional test level for manufactured items. Qualification and production piece part discrepancies at receiving inspection shall be integrated into the data collection and recording system. Discrepancies occurring at all levels of test and inspection shall be recorded and shall require corrective action in accordance with an established policy based on criticality and trends. Failures occurring at all levels of test and inspection after power is applied to qualification and production hardware shall be recorded separately and each shall require investigation for cause and corrective action. An unscheduled adjustment, other than a calibration made during other maintenance actions because of convenience, shall be defined as a failure for recording purposes. Analysis and recording of failures shall differentiate between but not be restricted to those that occur in development, qualification and acceptance test; those due to equipment failure; and those due to human error in designing, processing, handling, transporting, storing, maintaining and operating the equipment. The data collection and recording system shall provide visibility for recurrence control based on causes as well as hardware configuration at all levels of assembly. Failures occurring during test at subcontractors' facilities shall also be integrated into the contractor's data gathering, recording, problem investigation and corrective action system.

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5.5.5 Notices of suspect parts, materials, and processes (PMP) specifications. When the adequacy of a program PMP is suspect, the contractor shall have procedures for: (1) recording the suspected deficiency with supporting evidence; (2) failed part diagnoses and analysis of those PMP suspected to be deficient; (3) notifying the procuring activity and other subtier contractor members (normally within ten days) after the suspected deficiency has been confirmed or when it has been concluded that a PMP specification is suspect. The contractor shall participate in Government/Industry Data Exchange Program (GIDEP) to the extent necessary to generate ALERTS and receive ALERTS from the GIDEP Operations Center and shall have procedures for responding to notices of suspect PMP specification deficiencies received by the contractor either internally or from the procuring activity and other government agencies. The contractor shall notify the procuring activity of the usage of any suspect PMP specification, describe its location and usage in the system, and state the effects its failure or usage would have on the system. The contractor shall be capable of locating specific supplier lots and performing further analysis and corrective action as required.

5.5.6 Failure impact planning. The contractor shall estimate the number of failures expected during the program by program phase. The basis for this estimate shall be defined. Scaled data from other program experience may be used with detailed backup data. This estimate shall be established early in the program, prior to PDR, and shall include the total number of failures expected at the module level and above, as well as the expected number of failure analyses required. This estimate shall be updated at CDR. These estimates shall not relieve the contractor from performing failure analysis in excess of the contractor's estimates.

5.6 Integrated equipment. Where other items such as government furnished equipment are to be integrated, known or estimated reliability predictions and analyses for these items shall be used in the contractor's reliability predictions and other analyses. When such empirical data are not available, reliability related problems introduced by inclusion of such items shall be identified to the procuring activity.

5.7 Maximum preacceptance operation. The contractor shall establish and maintain a current list of items having criticality limited useful life, total operating time or operating cycles. The derivation of the maximum allowable operating time or cycles of operation shall be clearly defined along with the elements of data and computational methods used. The contractor shall maintain a record for each such item that contains its total operating time or number of equivalent operating cycles, starting with and including its initial functional testing, whether at the contractor's or supplier's facility. These operating time records shall become part of the acceptance documentation.

5.7.1 Critical items list. The contractor shall establish and maintain a current list of critical items. The list shall contain all critical items which have not been dispositioned or removed by the procuring activity (see 3.4, 4.4, and Appendix B, 50.7).

5.8 Effects of testing, storage, shelf-life, packaging, transportation, handling, and maintenance. The contractor shall establish, maintain and implement procedures to determine by test and analysis, or estimation, the effects of repeated exposure to testing, storage, shelf-life, packaging, transportation, handling and maintenance on the design and reliability of a product. The results of this analysis shall be used to support design trade-offs, definition of allowable test exposures, retest after storage decisions, special handling or storage requirements and refurbishment plans.

6. NOTES

6.1 Tailored application. Each time this standard is used, the procuring activity

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should review each paragraph for program applicability, required deviations or supplementary requirements. Such addenda to this standard should be included in the Request for Proposal and subsequent contract. Particular attention should be given to program tailoring regarding the requirements of paragraphs 3.3, 4.3, 5.2, 5.4.2, 5.5, 5.6, 5.7, and 5.8.

6.2 Data requirements. The data normally required for delivery under this standard are listed in Appendix G.

Custodian:
Air Force - 19

Preparing activity:
Air Force - 19
(Project No. RELI-F022)

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APPENDIX A

APPLICATION GUIDANCE FOR IMPLEMENTATION OF MIL-STD-1543

10. GENERAL

10.1 Scope. This appendix provides guidance for the selection of reliability tasks as they apply to various acquisition phases, and is not to be construed as mandatory.

10.2 Purpose. This appendix is to be used to tailor the standard in the most cost effective manner that meets established program objectives.

20. REFERENCED DOCUMENTS

Not applicable.

30. DEFINITIONS

30.1 Tailoring. The process by which the individual requirements (sections, paragraphs, or sentences) of the selected specifications and standards are evaluated to determine the extent to which each requirement is most suitable for a specific material acquisition and the modification of these requirements, where necessary, to assure that each tailored document invoked states only the minimum needs of the Government.

30.2 Acquisition phases:

30.2.1 Conceptual (CONCEPT) phase: The identification and exploration of alternative solutions or solution concepts to satisfy a validated need.

30.2.2 Demonstration and validation (VALID) phase: The period when selected candidate solutions are refined through extensive study and analyses; hardware development, if appropriate: tests; and evaluations.

30.2.3 Full-scale engineering development (FSED) phase: The period when the system and the principal items necessary for its support are designed, fabricated, tested, and evaluated.

30.2.4 Production (PROD) phase: The period from production approval until the last system is delivered and accepted.

40. GENERAL APPLICATION REQUIREMENTS

40.1 Procuring activity responsibility. The procuring activity shall assure that tailored reliability requirements are applied in contracts, statements of work, or request for proposals, as applicable. (Reference 40.2).

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40.2 Tailoring constraints. Tailoring of the standard to meet program systems based on complexity, criticality, quantity, and category of equipment; program type, magnitude, and funding; and life cycle cost.

40.3 Application matrix for program phases. Table I provides a guideline summary of reliability tasks generally included in a reliability program for particular program phases, depending on the program objectives. This matrix will not be construed as covering all procurements situations but shall be used as general guidance when tailoring a reliability program to specific objectives.

50. TASK/PHASE OBJECTIVES

50.1 Reliability program objectives:

a. CONCEPT phase: To provide a framework that insures awareness of reliability considerations when conceptual decisions are being made. This may be integrated within other design planning but should be clearly defined as having impact on operational success.

b. VALID phase: To identify critical parameters that impact reliability. This identification should be required either by test or by analysis. A formal reliability program is required only if the system or equipment criticality or total acquisition cost suggests its need. Usually, the updating of reliability requirements within the design plan is sufficient. Updating can include test monitoring, failure analysis, and corrective action feedback.

c. FSED phase: A fully developed program does not necessarily contain all tasks of the standard but it should be capable of being independently evaluated to determine the effectiveness of the task in providing design assurance.

d. PROD phase: To maintain design integrity. Design changes and critical or special processes require evaluation and monitoring. The results of failure analysis, process trends and field feedback should be considered during the production phase.

50.2 Reliability program plan objectives:

a. CONCEPT phase: (Reference 50.1a).

b. VALID phase: To provide assurance that all requirements are planned and scheduled. Depending on the criticality and category of equipment, the program plan could be developed as a separate entity or with other test and design planning.

c. FSED phase: To establish a clearly identified reliability organization with the necessary authority to influence the achievement of reliability program milestones. A fully developed and controlled program, which include reporting of status and problem areas to all levels of managements, should be administered by the reliability organization. It is highly desirable that a single reliability contact point be established for all procuring activity interfaces.

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TABLE I. Application of Matrix for Mission Essential Equipment

MIL-STD-1543 REQUIREMENTS	PARA NO	CONCEPT	VALID	FSED	PROD
RELIABILITY PROGRAM PLAN					
MANAGEMENT					
Management Organization and Control	4.0	P	P	F	P
Subcontractor Control	1.2	(-)	P	F	F
Program Reviews	4.3	(-)	P	F	F
DESIGN AND EVALUATION					
Design Techniques	5.1	P	P	P	C
Reliability Analysis	5.3/5.6	P	P	F	C
Parts Reliability	5.1.1	P	P	F	C
Critical Items List	5.7.1	P	P	F	C
Effects of Storage, Shelf Life Packaging and Transportation	5.8	(-)	(-)	F	F
Design Review	4.3	(-)	P	F	C
Quantitative Reliability	4.1	P	F	F	F
Stress Analysis	4.6	P	F	F	P
Reliability Prediction	5.4	P	F	F	C
FMEA	5.2	P	P	F	C
Failure Impact Projection	5.5.6	(-)	P	F	F
Limited Life Items	5.7	(-)	P	F	F
TESTING PLANS					
Test Plans	4.5	N/A	P	F	P
Dev Testing	4.5.1	N/A	P	F	N/A
Reliability Demo	4.2	N/A	P	P	P
FAILURE DATA	5.5	N/A	F	F	F
PRODUCTION RELIABILITY	5.5	N/A	N/A	F	P

CODE DEFINITION:

(-) - Not generally required but may have partial implementation on some programs.
P - Partial implementation required.
F - Full implementation required.
C - Full implementation on hardware design changes.
N/A - Not applicable.

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d. PROD phase: To continue functions of the reliability organization to the extent necessary to administer the defined reliability activities.

50.3 Reliability management objectives

50.3.1 Reliability organization:

a. CONCEPT phase: To identify an individual or organizational element responsible for administration of the reliability program.

b. VALID phase: To assure proper emphasis and coordination of program reliability activities. The reliability organization should participate in the establishment and preliminary assessment of the reliability goals and begin the identification of critical items and potential problems.

c. FSED phase: To establish a clearly identified reliability organization with the necessary authority to influence the achievement of reliability program milestones. A fully developed and controlled program, which includes reporting of status and problem areas to all levels of managements, should be administered by the reliability organization. It is highly desirable that a single reliability contact point be established for all procuring activity interfaces.

d. PROD phase: To continue functions of the reliability organization to the extent necessary to administer the defined reliability activities.

50.3.2 Management organization and control objectives:

a. CONCEPT phase: To establish general engineering management control of the program effort.

b. VALID phase: To extend the authority and control established during the conceptual phase. Hardware is usually available and management and control can be focused on its improvement and testing. The application of more formal management procedures and control should be implemented including the tasks identified in the standard.

c. FSED phase: Those details identified in the standard should be expanded and discussed in detail in the contractors reliability program plan. Particular attention should be given to the identification of engineering tasks and the establishment of realistic program milestones.

d. PROD phase: To continue the implementation of program tasks that are outlined in the program plan is essential in the phase. The major effort of management and control is to prevent degradation of reliability and should be centered around design changes and the monitoring of operational failure data.

50.3.3 Subcontractor and supplier reliability program objectives. This requirement is applicable to all program phases in which system elements are to be procured or may be procured from subcontractors and/or suppliers. This effort is intended to minimize the risk of not achieving the overall system

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reliability requirement(s) by assuring the appropriately tailored methods/ provisions made by the prime contractor for allocating requirements to subcontractors, source selection of subcontractors and surveillance of subcontractors are consistent with reliability program plan requirements.

50.3.4 Program reviews objectives. Program reviews are not tailorable by program phase but should be planned and scheduled as appropriate for the procuring activity to review its status and results achieved.

50.4 Reliability design and evaluation objectives

50.4.1 Design techniques

a. CONCEPT phase: To be considered to the extent necessary to support design.

b. VALID phase: To emphasize those techniques which involve basic design characteristics that could have a significant impact on the reliability of the final design. Because of the fluidity of the design in this phase, caution is advised against prematurely requiring application of techniques which may have to be repeatedly revised during the design evolution. Tasks which fall into this category include but are not limited to such techniques as worst-case analysis and parameter variance analysis.

c. FSED phase: The final baseline design destined for production should be subjected to reliability design analysis through application of appropriate design techniques. Therefore, in this phase, maximum application of such techniques is suggested consistent with a cost-benefit evaluation of each technique and the potential impact on system performance, reliability, producibility, and ultimate life-cycle cost.

d. PROD phase: To be restricted to only those cases where design modifications are implemented or where necessary to support engineering failure investigations.

50.4.2 Reliability analysis. The depth of this task becomes increasingly more complex as the program progresses through development. This task is applicable to CONCEPT, VALID, FSED phases; it has limited applicable to the PROD phase except as appropriate when changes in function occur.

50.4.3 Parts reliability objectives:

a. CONCEPT phase: To be limited to participation in system trade-off decisions involving state-of-the-art components or critical component applications.

b. VALID phase: To continue involvement in component application trade-offs and development of design application criteria. Planning should be developed for full implementation during full scale development.

c. FSED phase: Fully applicable.

d. PROD phase: Applicable only to unique parts problems and design changes which are identified during this phase.

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50.4.4 Reliability critical items objectives:

a. CONCEPT phase: Restricted to system element consideration.

b. VALID phase: To establish a control mechanism within design planning where critical items are identified.

c. FSED phase: Fully applicable.

d. PROD phase: To continue critical item controls as defined in the critical item program previously developed.

50.4.5 Effects of storage, shelf life, packaging, transportation, handling, and maintenance objectives:

a. CONCEPT phase: Not applicable.

b. VALID phase: Not applicable.

c. FSED phase: Fully applicable. Requirements and controls should be specified and developed.

d. PROD phase: To implement controls and procedures established in the development phase.

50.4.6 Design reviews objectives. Design review is not tailorable. The frequency of contractual or internal review should be analyzed in terms of benefit to the program.

50.4.7 Quantitative reliability:

a. CONCEPT phase: Will only be applicable when mission requirements are defined in Program Management Plan.

b. VALID phase: Fully applicable.

c. FSED phase: Fully applicable.

d. PROD phase: Requires evaluation for specific engineering changes made during production to assure no degradation to system reliability.

50.4.8 Stress analysis:

a. CONCEPT phase: Restricted to known critical elements in early system design.

b. VALID phase: Fully applicable.

c. FSED phase: Fully applicable.

d. PROD phase: Applicable only to Engineering Change Proposals.

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50.4.9 Reliability prediction:

a. CONCEPT phase: Limited to only functional levels of design. Details are not normally defined at this stage of development.

b. VALID phase: Fully applicable.

c. FSED phase: Fully applicable.

d. PROD phase: Reliability Prediction is restricted to significant Engineering Change Proposals.

50.4.10 Failure mode and effects analysis (FMEA):

a. CONCEPT phase: FMEA is restricted to functional levels of design.

b. VALID phase: FMEA is restricted to functional levels of design and system determined to be critical.

c. FSED phase: Fully applicable.

d. PROD phase: FMEA is restricted to Engineering Change Proposals.

50.4.11 Failure impact projection:

a. CONCEPT phase: Not applicable.

b. VALID phase: Restricted to expected high frequency failures.

c. FSED phase: Fully applicable.

d. PROD phase: Fully applicable.

50.4.12 Limited life items:

a. CONCEPT phase: Not applicable.

b. VALID phase: Restricted to major functional areas.

c. FSED phase: Fully applicable.

d. PROD phase: Fully applicable.

50.5 Reliability testing and demonstration objectives

50.5.1 Reliability test plans:

a. CONCEPT phase: Not applicable.

b. VALID phase: Necessary when a reliability development test (test analyze and fix) is to be performed.

c. FSED phase: See 50.5.2c and 50.5.3c.

d. PROD phase: See 50.5.2d and 50.5.3d.

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50.5.2 Development testing:

a. CONCEPT phase: Not applicable.

b. VALID phase: Consideration of a test analyze and fix approach to reliability testing to uncover weaknesses in design approaches that were not previously detected by engineering analysis or testing. This testing consists of a sequence of testing, analyzing all failures, incorporating corrective action, and retest, and provides a basis for program decisions.

c. FSED phase: A dedicated test analyze and fix approach to reliability testing should be imposed during this phase of acquisition cycle. This test should be designed, utilizing dedicated samples and sufficient test time, to uncover design deficiencies not detected during previous testing or analyses.

d. PROD phase: Not applicable.

50.5.3 Reliability demonstration by analysis/test:

a. CONCEPT phase: Not applicable.

b. VALID phase: Not applicable.

c. FSED phase: To provide confidence that the equipment design meets or exceeds program objectives. The test units used for this demonstration/ analysis shall be the best available representation of the production configuration. The test/analysis will also serve to confirm the effectiveness of corrective actions and provide a statistical assessment of program status for the production decision process.

d. PROD phase: To provide confidence by sampling and combining the equipment test to assure that the equipment reliability continues to meet or exceed program objectives and was not degraded to an unacceptable level by the production process.

50.6 Failure data objectives:

a. CONCEPT phase: Not applicable.

b. VALID phase: To impose a formal failure reporting and correction active system (FRACAS) to varying degrees depending on the expected volume of failures for the particualr program and the criticality of major system components. If a reliability development test is imposed, the greatest benefit can be derived from failures encountered during that testing program through the use of a FRACAS system.

c. FSED phase: To obtain maximum benefit from failures encountered during any formal qualification or acceptance testing. Contractor procedures may be used prior to formal qualification or acceptance testing.

d. PROD phase: To obtain maximum benefit from failures encountered during any manufacturing tests or acceptance tests. Provision should be made by the procuring activity to insure that the user provide adequate failure information to assist the corrective action process.

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50.7 Production reliability objectives:

a. CONCEPT phase: Not applicable.

b. VALID phase: Not applicable.

c. FSED phase: In this phase, this effort could prove beneficial if the anticipated production process is expected to significantly impact the reliability of the equipment and the follow on product contract is expected to be awarded to the developing contractor. Control specification should be prepared for identified critical processes.

d. PROD phase: In this phase, the procuring activity should be prepared to reprocure the equipment using the same reliability as used in previous production requirements.

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APPENDIX B

FAILURE MODES AND EFFECTS ANALYSIS FOR SPACE AND LAUNCH VEHICLE SYSTEMS

10. GENERAL

10.1 PURPOSE. The material of this appendix is a mandatory part of this standard (refer to 5.2) and establishes requirements for the performance of a Failure Modes and Effects Analysis (FMEA). It also provides criteria and amplifying examples to be used in performing FMEA for spacecraft, launch vehicle, and reentry systems, and for integrated combinations thereof, so as to assure completeness, usefulness, and timeliness of FMEA efforts and to assure achievement of FMEA objectives. Rather than specifying detailed methodologies, techniques, and formats, this appendix describes FMEA content and end results including critical item list and single point failure mode (SPFM) records. This is intended to foster timely identification of potential weaknesses and needed reliability improvements and to foster interface and interchange with other program activities such as system safety, instrumentation, test, and other reliability analyses.

10.2 APPLICATION. This appendix is intended to be applied throughout programs which invoke reliability requirements of this standard. It should be applied as early as possible in the development cycle for early identification of needed concept and design changes so they can be implemented at least cost. This appendix may be applied to other programs where appropriate and may be tailored as needed for particular contracts consistent with program reliability requirements.

20. REFERENCED DOCUMENTS

The referenced documents of Section 2 of this standard apply to this appendix to the extent specified herein.

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30. DEFINITIONS

The definitions below apply for this Appendix as well as those of Section 3 of this standard.

It is not the intention of this appendix to impose specific equipment groupings within a system and the terms that apply to each such classification or division. The terms and groupings approved for each system should be applied to the FMEA to foster traceability and minimize ambiguity.

30.1 Assembly. A number of parts or subassemblies or any combination thereof joined together to perform a specific function and capable of disassembly. (Examples: audio frequency amplifier, bearing assembly.)

30.2 Circuit and item stress analysis. Analyses which relate parts stress to circuit, module, component/unit, subsystem, and system performance as it is influenced by worst case parameter variations resulting from environmental effects, radiation effects, aging, input and output limits, initial operating points, and initial tolerances.

30.3 Compensating features. Compensating features are special inspections, tests, controls, instructions, drawing notes, or other provisions applied to a single point failure mode item to improve or enhance reliability. See Appendix C for examples.

30.4 Component. An assembly or any combination of parts, subassemblies, and assemblies mounted together, normally capable of independent operation in a variety of situations (e.g., electric motor, electronic power supply, thruster, radio receiver). Note: The size of an item is a consideration in some cases. An electric motor for a clock may be considered as a part inasmuch as it is not normally subject to disassembly. A component is not a part. See equivalent term of unit (30.20).

30.5 Correlated or sympathetic failure. The inability of two (or more) redundant items to perform their function as the result of some single event, thus possibly negating the redundancy and acting as a SPFM (e.g., loss of a raceway containing redundant power leads or a pyrotechnic shock causing parallel relays to chatter).

30.6 Failure. The inability of an item to perform within previously specified limits.

30.7 Failure effect. The consequence of the failure mode including primary and secondary effects.

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30.8 Failure mechanism. The cause of the failure mode.

30.9 Failure mode. The way or manner in which an item fails.

30.10 GIDEP. Government Industry Exchange Program is a program for the collection and dissemination of reliability and other information of interest among government agencies and their industrial contractors. (See MIL-STD-1556).

30.11 GIDEP Alert. A means of rapid dissemination of information relating to a reliability problem which has been encountered, usually concerning parts, materials, or processes.

30.12 Item. A non-specific term used to denote any product, including systems, materials, parts, subassemblies, sets, accessories, etc.

30.13 Part. One piece, or two or more pieces joined together which are not normally subject to disassembly without destruction of designed use (e.g., transistor, integrated circuit, screw, gear, transformer).

30.14 Piece Part Level FMEA. A term from the previous issue of this standard equivalent to component FMEA of 40.2.6.4.

30.15 Pin/fault Analysis. A systematic design evaluation that examines, analyzes and documents all potential inadvertent or spurious closures or openings of current carrying paths and determines the effect of each failure (e.g., analysis of connector pin-to-pin shorts, pin-to-ground shorts, inductive or capacitive coupling, printed wiring-board traces open or short, and harness wiring opens and shorts).

30.16 Reliability Prediction. An analysis which calculates the probability that a system or some portion thereof will operate within specified limits at a given time in its mission profile, and in a specified environment.

30.17 Single Point Failure (SPF). Any piece part, assembly, component, or element of construction, such as printed circuit board layout, the failure of which would result in irreversible degradation of item mission performance below contractually specified levels, such as failure of an item in operation which could be catastrophic to a mission objective. (A SPFM is a single point failure mode.)

30.18 Subsystem. A combination of components which performs an operational function within a system and is a major subdivision of the system.

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30.19 System. A composite of equipment, skills, and techniques capable of performing or supporting an operational role, or both. A complete system includes all equipment, related facilities, material, software, services and personnel required for its operation and support to the degree that it can be considered a self-sufficient item in its intended operational environment. The term system is commonly used in this standard to refer to the highest level of requirements and resource grouping applicable to the particular contract and analysis. The actual analysis for some programs could be at the system segment level (e.g., a space vehicle or a launch vehicle). Guidance in the RFP, contractor's response, definition of the system (40.2.3), and ground rules (40.2.4) should provide early clarification of the scope of the analysis.

30.20 Unit. See equivalent term of component. For the purposes of this appendix the terms may be interchanged; the term commonly used in a particular program should be used to reduce ambiguity.

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40. GENERAL REQUIREMENTS

40.1 Application of the FMEA. The FMEA shall be used for the following purposes:

a. To assure that an organized and exhaustive effort has been made to identify all failure modes, that their mission effects have been determined, and that either corrective or compensating action has been taken, or that the risk to program success associated with no further action is acceptable and approved by the procuring contracting officer.

b. To identify single point failure modes (SPFM) and define their effects.

c. To identify those areas of the design where redundancy for critical functions should be implemented.

d. To identify compensating features for those single point failure modes whose elimination is impractical.

e. To identify redundancy which is not or cannot be tested.

f. As an aid in identifying functions which are not or cannot be tested.

g. As a ranking technique for concentrating program attention on the most serious failure modes.

h. As a basis for establishing and updating a critical items list and critical item control plans (4.4).

i. As an input to reliability modeling, predictions, and assessments.

j. As an iterative design tool to achieve the most reliable design consistent with program objectives.

k. As a design evaluation tool for use in selecting the optimum design from competing design candidates and as inputs to design trade-offs.

l. As a diagnostic tool during mission planning, testing, and operations.

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m. As a criterion for test planning, manufacturing and quality control, instrumentation points, preflight checkout and related program activities.

n. As an aid in determining flight and ground operational constraints and in defining failure indications and recovery actions for orbital operation and contingency plan documents.

o. As an input to maintainability, safety and hazards analysis. Safety, maintainability, and human engineering design and operational criteria shall be developed and implemented as a result of the FMEA.

p. To identify problem areas to be avoided in manufacturing work instructions; in selecting materials, processes, and equipment; and in inspection, test, and control during manufacturing.

40.2 FMEA Requirements. The FMEA shall consist of analyses using techniques selected by the contractor and approved by the procuring contracting officer for accomplishing the purposes cited in 40.1. The major thrust of these analyses shall be identification and elimination or compensation of failure modes for reliability improvement. Emphasis shall be placed on reducing SPFM by design, or where mode elimination is not feasible, on reducing SPFM frequency or impact by compensating features (Appendix C). The analyses of 40.2.6 shall be used to complete the FMEA and SPFM identification. The contractor may utilize additional analyses and techniques as applicable to supplement these analyses.

40.2.1 Mission Phases. The FMEA shall be conducted for all phases of a mission including prelaunch, (launch preparation), launch, transfer orbit, orbit injection, acquisition, reacquisition, normal operating modes, orbit changes and reentry, as these phases are defined in applicable system requirements documents.

40.2.2 System Operating Modes. The FMEA shall be conducted for all modes of system operation including normal operating modes, contingency modes, dormant modes, back-up autonomous and nonautonomous modes, ground-controlled modes, and transition between modes as these are defined in applicable system requirements documents.

40.2.3 Definition of System. The system under analysis shall include all contractual items, equipment supplied by subcontractor and associate contractors, and integration activities required by the contract such as those related to

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GFE. Within these boundaries, the contractor shall delineate that which will be encompassed within the FMEA, including the definition of subsystems and components. This delineation shall be subject to approval by the procuring contracting officer (see 30.19).

40.2.4 Ground Rules. The contractor shall establish ground rules for performance of the FMEA in accordance with applicable system requirements documents and subject to approval by the procuring contracting officer. These shall include, but not be limited to, success/failure criteria, primary and secondary mission objectives, operational and environmental stresses, interface factors, assumptions, limitations, and accident risk factors as defined by system safety analyses. (See 30.19)

40.2.5 Failure Modes. All identifiable potential failure modes for each system, subsystem and component shall be analyzed and determinations made of their effects on the end item, the mission, and personnel. Interfaces and isolation techniques for redundant elements shall be analyzed to ensure that the desired redundancy is not negated due to a failure of any interfaces or isolation techniques (especially wiring and other circuit paths). Redundant elements which are not independently testable (e.g., parallel fuses) shall be regarded as potential single point failure modes.

40.2.6 Types of FMEA's.

a. A number of different types of FMEA's are listed in the following subparagraphs. These FMEA's shall be used in conjunction with each other, where the output of one FMEA will be the input to another.

b. In performing the FMEA's specified in 40.2.6.1 through 40.2.6.4 all failure modes as identified in 50.1 and 40.3.2b through 40.3.2e shall be analyzed. The FMEA's shall be performed for the system conditions (mission phases, operating modes, and redundancy effects) specified in 40.2.1, 40.2.2 and 50.2 and shall use the data base of 40.3.3.

40.2.6.1 System Functional FMEA. The contractor shall perform a functional time-independent FMEA as the first part of the analysis followed by a time-dependent analysis. The mission functions of each item shall be classified by criticality to enable prioritization of the action to be taken in performing and using the results of each FMEA. The functional FMEA shall make provisions for different levels of analysis based on the mission phase and function criticality for which the function is

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being analyzed. The contractor shall emphasize FMEA aspects of critical portions of the mission where reliability estimates provide little information, such as launch portion of a satellite and/or missile mission .

40.2.6.1.1 Time-Independent Analysis. The contractor shall develop a functional block diagram of the system or applicable portions. The diagram shall be traceable to the corresponding equipment. All functions shall be identified and if redundant, shall be identified as to how the redundancy is achieved (internal to item or separate item). All system functions including electrical, electronic, mechanical, structural, chemical, ordnance, command and telemetry shall be identified in addition to the redundancy contained in each. Redundancy shall be considered to exist where full system function can be restored at any time after a single failure by using a redundant item. The contractor shall, by search, analysis, or simulation determine the effects on system functions of single failures as specified in 40.2.6b and the requirements of this standard.

40.2.6.1.2 Time-Dependent Analysis. The contractor shall develop a model of the system or applicable portions, traceable to the corresponding equipment, which describes the response of the system to failures where the ability to restore full system function or preserve partial system function by use of redundancy or by other action may depend upon the elapsed time since the failure. Examples of these kinds of failures include those which lead to control instability, cyclic thermal or mechanical stress, or leakage of propellants. The contractor shall, by analysis or simulation, determine the effects on system functions of single failures as specified in 40.2.6b and the requirements of this standard.

40.2.6.2 System Interface FMEA. The contractor shall identify and analyze all of the interfaces between subsystems such as thermal, electrical (including electromagnetic interference (EMI), connectors, and harnesses), mechanical, communication, telemetry, command and control as specified in 40.2.6b and the requirements of this standard. Failures in any one subsystem which cause thermal, electrical, or mechanical damage or degradation to any other subsystem shall be identified. A pin/fault analysis shall be conducted as part of this FMEA.

40.2.6.3 Subsystem Interface FMEA. The contractor shall identify and analyze all of the interfaces between components in a subsystem such as thermal, electrical (including EMI, connectors, and harnesses), mechanical, commmunication, telemetry, command and control as specified in 40.2.6b and the requirements of this standard. Failures in any one component which cause thermal, electrical, or mechanical damage or

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degradation to any other component shall be identified. A pin/fault analysis shall be conducted as part of this FMEA.

40.2.6.4 Component FMEA. As the design progresses, the contractor shall perform a more detailed FMEA, based on the physical layout of the item being analyzed, down to the piece part level in the priority established by the criticality classification of the mission functions. The contractor shall conduct a FMEA to the part level on components as specified in 40.2.6b and the requirements of this standard. The effects of each part failure mode shall be propagated through the analyses required by 40.2.6.1 through 40.2.6.3. A pin/fault analysis shall be performed as part of this FMEA. In addition, an internal interface FMEA shall be performed which analyzes all of the thermal, electrical (including EMI and interconnections), and mechanical interfaces within the component. The component FMEA may be performed by means of special formats, matrices, logic diagrams, or computer programs that may be expanded to include higher levels encompassing the entire system.

a. Critical items and single point failure mode items shall require detailed piece part level (component) FMEAs.

b. Also, a component FMEA shall be performed on each component regardless of whether or not the component or its function is redundant in the system.

40.2.6.5 Product Design/Manufacturing FMEA. The contractor shall conduct a product design/manufacturing FMEA. The contractor shall analyze the manufacturing documentation, such as circuit board layouts, wire routings, connector keying, and hardware implementation of the design to determine if new failure modes have been introduced that were not in circuit schematics. This FMEA shall consider electrical, EMI, thermal, and mechanical failure modes inherent in the manner of fabrication, assembly, packaging, handling, testing, and storage of an item. This FMEA shall be performed initially from design drawings, shall be updated by reference to current manufacturing work instructions, and finally shall be updated by inspection and test of hardware items.

40.2.6.6 Medium Scale Integration (MSI), Large Scale Integration (LSI), and Hybrid Devices FMEA. For the purposes of this standard, MSI, LSI, and hybrid devices shall be considered to be components. Component FMEA (40.2.6.4) and product design/manufacturing FMEA (40.2.6.5) shall be performed on these devices. Early emphasis shall be placed on hybrids, on devices newly designed or modified for the system, and on devices with no history of successful use in similar applications.

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40.3 Integration with Other Activities

40.3.1 Related Activities. The FMEA shall include not only the failure modes identified as a result of the analytical activity designed specifically to study and analyze failure modes, their effects and correction, but shall also include failure modes detected by related analyses, investigations, tests, reviews and other studies. All failure modes, whether discovered as a result of a specific search or other analysis, shall be incorporated into the FMEA with emphasis on timely and effective feedback into the design process, manufacturing work instructions, and system effectiveness activities. Although the major emphasis of the FMEA activity shall be the identification, for purposes of elimination or control, of single point failures, critical items, and safety critical failures, the FMEA activity shall also support other activities as specified in 40.1 and shall continue in effect throughout the life of the program. FMEA data shall be presented as required by 50.9, and the contractor shall show how the FMEA has been utilized in support of the above activities.

40.3.2 Integrated Information. The following activities shall be integrated with the FMEA as specified below:

a. The reliability prediction developed in accordance with 5.4 shall be the source of failure rates and math models used in assessing probability of occurrence of FMEA failure modes.

b. Circuit and item stress analysis conducted in accordance with 4.6 shall serve as an input to the FMEA. All potential failure modes identified by the circuit and item stress analysis shall be analyzed in accordance with this appendix.

c. Dynamic analyses and analyses of structures and mechanisms that are conducted in the performance of the contract shall serve as a source of identification of failure modes for FMEA input.

d. Test failures, inspection discrepancies, GIDEP alerts, information on operation of similar equipment, etc., shall be reviewed for identification of failure modes. All such identified potential failure modes shall be input to the FMEA for analysis and correction in accordance with the requirements of this standard.

e. System safety analyses that are conducted in the performance of the contract shall be a source for identifying hazardous effects and failure modes.

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40.3.3 Input Data Base. In addition to other data specified elsewhere in this standard, input data to specific FMEA's shall include, but not be limited to, system specification requirements and failure mode information from development test data, qualification test data, acceptance test data, parts screening data, GIDEP alerts and similar reliability data. Results of other FMEA's shall also be included. For example, the component FMEA shall be an input to the subsystem or system FMEA. Graphical materials produced as part of other system activities shall be inputs to the FMEA's. See Appendix D for examples. The contractor shall make maximum usage of such existing design documentation.

a. Previous FMEAs on existing designs shall be reviewed for program applicability and adequacy by PDR and shall be updated commensurate with design and manufacturing schedules.

40.4 Traceability. The contractor shall select methods of identifying entries and items in the FMEA such that it shall be possible to trace directly and unambiguously to identification (such as part number) of items and equipments in the system. In addition, traceability shall be maintained between all elements of the FMEA, e.g., from component to subsystem, to system level FMEA's, and between the FMEA and related analyses of 40.3.

40.4.1 Configuration Identification. The FMEA shall identify or permit traceability to the specific item configuration (such as specific drawing number revision or ECP) covered by the analysis.

40.5 Mission Timeline. The contractor shall ensure that the FMEA is performed for all mission phases and system modes as specified in 40.2.1 and 40.2.2, even though the contractor's hardware may function during only a limited portion of the mission. The effect upon interfacing hardware during these phases and the effect upon subsequent operation of the contractor's hardware shall be determined.

40.6 Timeliness. The FMEA shall be performed in a timely manner and maintained current with the design and other program activities. In a timely manner means at such time in the flow from concept to end system use that the FMEA may effectively fulfill the purposes stated in 40.1.

a. The analysis shall be scheduled and completed concurrently with the design effort so that the design will reflect analysis conclusions and recommendations.

b. FMEA's shall be available at and presented in

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conjunction with design reviews and milestones, such as the system level reviews listed in MIL-STD-1521, and with audits and review meetings for the system and subsystems.

40.7 Audit and Review

40.7.1 Review Techniques. The contractor shall develop techniques for determining the adequacy of his FMEA, subject to the approval of the procuring contracting officer. These techniques shall include direct audit and review jointly by the Government (or designated representative) and the contractor and shall include an overall review, selective detailed review of critical design characteristics and associated critical manfacturing process, and sampling review of other areas. If the review process discloses undetected SPFM, then the FMEA shall be reworked as directed by the procuring contracting officer. Rework may include use of modified methods or different analysts as required to insure adequacy of the FMEA.

40.7.2 Review Criteria. Criteria for judging the adequacy of the FMEA shall include:

a. Comprehensiveness (40.2 and 50.1 through 50.5)

b. Use of well defined, substantiated and approved methodology

c. Timeliness (40.6)

d. Traceability (40.4)

e. Utility (i.e., the FMEA data (50.9) should comprise working tools in a form useful to managers, designers, and customers).

f. Repeatability (e.g., independent analysis by the contractor or customer should produce equivalent results).

g. Application of FMEA results to enhancement of system effectivness (50.7 and 50.8).

h. Completeness, accuracy, and validity of data. (40.3.3.)

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50. DETAILED REQUIREMENTS

50.1 Failure Modes Analyzed. The following failure modes shall be addressed:

a. Failure to meet functional specifications
b. Premature operation
c. Failure to operate at a prescribed time
d. Failure to cease operating at a prescribed time
e. Failure during operation
f. Intermittent operation
g. Degraded operation
h. Change in thermal, dynamic, physical, or chemical interfaces
i. Unintended (sneak) paths or sequences caused by design or analytical error and not necessarily by item failure.

50.2 Redundancy Effects. The effect upon the system resulting from redundancy management shall be included. Typical factors include the following:

a. Malfunction signaling, sensing, logic and switching
b. Effect of subsystem selections
c. Ability to check out redundant items
d. Failure detectability in operation
e. Effect of correlated or sympathetic failures
f. Effect of inadvertent switching
g. Effect of early or late time-out or time-in events.

50.3 Mission Hardware. The FMEA shall include electrical, electronic, mechanical, thermal, electromechanical, hydraulic, pneumatic, optical, structural, propulsion, and ordnance mission hardware.

50.4 Other Failure Sources. In addition to hardware failure modes analyses, the FMEA shall include an analysis of potential failures due to test equipment and procedures, human error, operational procedures, and loss or change in characteristics of inputs.

50.5 Design Related Potential Failures. The contractor shall address potential failures introduced as part of the design process. See Appendix E for typical examples.

50.6 Failure Detection. The contractor shall verify that the means have been defined by which a failure can be detected through use of telemetry data. For vehicles where command and control is possible, time limits from detection of a problem to implementation of corrective actions shall be defined.

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particular emphasis shall be placed on those conditions which, if left alone, would progress to an uncorrectable state and cause mission failure. When the same telemetry indicator is used to represent more than one potential problem condition, the contractor shall define the effect of misinterpreting the indicator and correcting for the wrong condition.

50.6.1 Flight Detection. The FMEA shall verify that instrumentation, including telemetry, is provided for purposes of in-flight failure detection. In addition to detection of failures where timely action is required, the FMEA shall verify that the instrumentation is adequate to support redundancy management and provides for isolation of failures to significant functional elements.

50.6.2 Ground Test and Checkout. The FMEA shall verify that, in addition to the flight instrumentation specified above, system functions are testable to assure satisfactory status prior to committment to flight.

50.6.3 Safety Related Failures. The FMEA shall verify that instrumentation is adequate to detect safety related failure conditions.

50.7 Critical Items and SPFM

50.7.1 Critical Items List. A list of all critical items as defined in this standard (3.4 and 4.4) shall be prepared and maintained by the contractor when required by 5.7.1.

50.7.2 List Content. The critical items list shall contain the following FMEA information:

a. The identification of the item under analysis, the same information described in 50.9.2a, and a statement as to whether or not it is a single point failure mode.

b. Citation of the pages or entry identifications of the FMEA that describe the failure modes.

c. Statements identifying compensating features included in the design (e.g., extra safety margins), control methods (e.g., overstress testing, special checkout procedures), or other practices incorporated to minimize the occurrence of failures associated with critical items. Examples of compensating features are included in Appendix C.

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50.7.3 Single Point Failure Modes (SPFM). The contractor shall identify all SPFM's, classify each by criticality of mission function and present the results at all design reviews, technical audits, and mission readiness reviews. The contractor shall also determine the effects of failure of these items and present proposed actions, such as eliminate from the design or use special operational procedures. Mission critical SPFM's shall be eliminated from the design or their mission effects reduced to the lowest practical level.

a. The contractor shall develop and maintain a current listing of all SPFM's and a record of each SPFM together with the design, manufacturing, or other corrective actions implemented to eliminate or reduce the mission effects of each SPFM. This record shall be available for inspection by the Government on request.

b. Each SPFM not corrected as in the preceding subparagraph (a.) shall be characterized as to mission impact, probability of occurrence, and practicality of correction. The contractor shall recommend appropriate options for elimination or mitigation of the failure modes for consideration by the procuring contracting officer.

c. The FMEA shall identify each SPFM by subsystem and parent critical item. When compensating features are used to minimize effects, they shall be treated in specific terms. Each SPFM shall be traceable to the levels of assembly and times in checkout and test or inspection sequences at which the function or critical characteristic is verified.

50.8 FMEA Follow-up and Update

50.8.1 FMEA Finding Implementation. All corrective actions, procedural changes, tests, quality control measures, or other compensating features described in the FMEA shall be incorporated into the methods which the contractor establishes for critical item control as required by this standard.

50.8.2 FMEA Update and Review. Changes to the design, fabrication, packaging, procedural, or other activities shall require an update of the affected portion of the FMEA and Critical Items List. This update shall be accomplished within 30 days of the change.

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a. The FMEA shall be updated whenever testing reveals a failure mode that was not included in the FMEA analysis.

b. After CDR, the FMEA shall be reviewed for each spacecraft and launch vehicle manufactured on this contract. These FMEA reviews shall be conducted in conjunction with each applicable hardware technical audit and mission readiness review. As a result of each FMEA review, the FMEA shall be updated as necessary to include an analysis of all changes to the design, test results to date, and the as-built configuration of each spacecraft/launch vehicle. All new single point failures shall be listed and reviewed to assure each is eliminated or the mission effects reduced in accordance with paragraph 50.7.3 of this standard. The effectiveness of each single point failure correction shall also be reviewed and the residual risk reported.

50.8.3 Continuing FMEA. The FMEA activity shall continue throughout the fabrication, testing, and operational activity with the intent of discovering and eliminating potential failures.

50.8.4 FMEA Iteration. The contractor shall provide for the following:

a. Timely initiation and iteration of FMEA activities

b. A review and approval procedure

c. A positive iteration process

d. Input of failure mode data from all sources of project activities throughout the life of the contract.

50.9 FMEA Data

50.9.1 Format. The contractor shall use formats of his choice to document analysis data provided all the requirements of 50.9.2 and 50.9.3 are included. Selected format shall be approved by the procuring contracting officer. Standardized formats are included in the documents listed in 60.3, and are included for guidance. In addition, the contractor is encouraged to use special formats and procedures to mechanize the analytical methods identified in 40. One format shall be employed for all like analyses.

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50.9.2 Analysis Data. The FMEA shall result in and incorporate the following information for items analyzed and possible failure modes:.

a. The identification of the item or function under analysis, and cross-reference information such that it is possible to trace directly from the FMEA to drawings, schematics, and hardware.

b. A concise statement of the function performed.

c. The specific failure mode.

d. Redundancy management conditions as noted in 50.2.

e. The operational or mission phase in which the failure may occur.

f. A brief narrative description of the effect of the failure mode on the item or function and next higher assemblies, including known primary and secondary effects.

g. A description of the effect of the failure mode on the system or operational objectives of the system. Symptoms and warnings prior to failure occurence shall be included.

h. Critical item information as noted in 50.7 including control methods, compensating features and SPFM identification. The Critical Items List of 50.7.1 and 50.7.2 shall also be maintained as a separate document.

i. Identification of failure modes impacting safety.

j. An itemization of the causes of each failure mode.

k. An estimate of the probability of occurrence of each failure mode. For other than uncorrected SPFM's (50.7.3.b) and critical items, probability estimates may be by range groupings indicating relative probabilities if the actual estimates are available.

l. Identification of failure modes for which ground checkout or flight instrumentation is inadequate for timely detection.

m. Identification, in the ground checkout information, of failure modes not detectable in final launch preparation checkout.

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50.9.3 Supporting Data. In addition to the analysis results of 50.9.2, the FMEA shall include the following supporting information:

a. A system, system segments, subsystem, or component description as appropriate, which shall include a functional block diagram and any other required graphical material such as that described in Appendix D. The description shall include a comprehensible narrative description of the operation of each item for each system operating mode with any unusual functions fully described.

b. A description of the methodology used to generate the FMEA including groundrules.

c. A cross-reference to data base information used in support of the FMEA, with significant data extracted as needed for completeness and clarity.

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60. NOTES

60.1 Tailored Application. The cost of imposing each requirement of this appendix should be evaluated against the benefits that will be realized. Provisions (sections, paragraphs or sentences) not required for the specific application should be excluded. The surviving provisions should be tailored to impose only the minimum requirements necessary to support the system.

60.2 Data Requirements. The data normally required for delivery under this Appendix are listed in Appendix G.

60.2.1 Schedule of Delivery of CDRL Items

60.2.1.1 Initial Submittals. In order to facilitate timely and effective use of the FMEA and to foster early agreement on FMEA planned approach and content, it is recommended that the initial submittal of CDRL deliverables be required in accordance with the following typical schedule:

a. With proposal: System function FMEA, time-independent analysis (40.2.6.1.1), Analysis techniques (40.2), Definition of system (40.2.3), Ground rules (40.2.4), Review techniques (40.7.1), Format (50.9.1), Preliminary critical items list (50.7).

b. Prior to System PDR: System functional FMEA, time-dependent analysis (40.2.6.1.2), system interface FMEA (40.2.6.2).

c. Prior to subsystem PDR if a subsystem PDR is conducted (otherwise at a comparable time in the subsystem design schedule): Subsystem interface FMEA (40.2.6.3).

d. Prior to component PDR if a component PDR is conducted (otherwise at a comparable time in the component design schedule): Component FMEA (40.2.6.4).

e. Prior to the first release of product design drawings or equivalent information: Product design/manufacturing FMEA (40.2.6.5).

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60.2.1.2 Update. In addition to the initial submittals above, updates should be submitted prior to each subsequent major activity (e.g., CDR, PCA). In some cases it may also be desirable to require additional submittals, either on a periodic basis, or in conjuction with other milestones.

60.3 Information Documents. The following documents are listed as possible references on past approaches and formats of FMEA-related analyses. No implication is intended that their use will automatically yield compliance with the requirements of this appendix.

NASA-MSFC 85M08246, Procedures for Performing Failure Mode Effects Analysis and Criticality Analysis on the High Engergy Astronomy Observatory Program, 28 July 1971.

GIDEP Report 347-40-00-000N5-04, Fault Tree Analysis, U.S. Army Picatinny Arsenal, January 1974, GIDEP Access Nr. E3778 (67 pages).

SAE, Aerospace Recommended Practice ARP 926, Design Analysis Procedure for Failure Mode, Effects and Criticality Analysis (FMECA), 15 September 1967.

60.4 Supersession Data. This appendix incorporates the provisions of SAMSO-STD 77-2 and the FMEA provisions of MIL-STD-1543 (USAF) and supersedes SAMSO-STD 77-2, Failure Modes and Effects Analysis for Satellite, Launch Vehicle, and Reentry Systems. Appendix F correlates the previous FMEA provisions to those incorporated in this standard.

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APPENDIX C

COMPENSATING FEATURES

Examples of compensating features referenced by Appendix B include but are not limited to the following:

a. Mandatory inspection of key product characteristics
b. Detail design review of failure mode features
c. Control of soldering, welding, brazing, plating, and flatness
d. Nitrogen purge, proof test, leak test, x-ray, of brazed or welded joints
e. Special handling provision requirements: gloves, special care, special workers
f. Torque measurement
g. Electrical functional test and verification of performance
h. Structural design margin and derating of loads
i. Special lubricant control
j. Moisture or temperature control
k. Clean room environment or contamination controls
l. Connector x-ray after mating
m. Connector pin/socket retention tests
n. Mate-demate logs
o. Special tracking of Failure Reports, Material Review Board actions and related discrepancy data
p. Purchase order review for mandatory Government Source Inspection (GSI)
q. X-ray or other nondestructive testing
r. Extended actuation or life tests
s. Special environmental tests
t. Pre-launch checkout tests
u. Process baseline control

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APPENDIX D

EXAMPLES OF GRAPHICAL MATERIAL

Examples of graphical material referenced by Appendix B include but are not limited to the following:

a. Functional block diagrams which graphically show all items comprising a system, system segment, subsystem, or component, the series and redundant relationships among the items, the interconnections between the items, the interface circuitry, the monitoring points, the switching capability, each of the items' inputs and outputs, and inputs to the system as a whole. A separate functional block diagram may be required for each operational phase since both item use and criticality may vary with the phase or the mode of operation.

b. Functional flow diagrams

c. Cross section drawings

d. Cutaway views

e. Worst case analysis data

f. Fault trees

g. Connector and wiring lists

h. Schematic diagrams

i. Design layouts

j. Printed circuit board layouts

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APPENDIX E

DESIGN RELATED POTENTIAL FAILURE CAUSES

Typical examples referenced by Appendix B of potential failures introduced as part of the design process include but are not limited to the following:

a. Deficient design (e.g., lack of dynamic stability).
b. Deficient parts
   (1) Failures of a generic/chronic character
   (2) Limited capability substitute parts
   (3) Over stressed parts
c. A single multi-pole relay carrying redundant functions.
d. Unintended thermal coupling between high dissipation or heat sensitive elements.
e. Harness, connectors, and tie points shared in common by otherwise redundant paths.
f. Sympathetically induced failures such as common heat sink and electrical path for transistor, rectifiers and blocking diodes.
g. Redundancy paths integrated into a common multi-layer printed circuit board.
h. Redundancy negated due to sneak paths embodied in sensors or signal processing circuits.
i. Command logic and execution hardware forming single point failure site for pyrotechnic or ordnance devices.
j. Sharing of fuses
k. Sharing of redundant items
   (1) Common power supplies or converters
   (2) Common power lines and returns
   (3) Jumpered signal points
   (4) Common printed wire traces
   (5) Common connectors and pins
l. Multi-function parts (dual transistors, dual/quad/hex integrated circuits) shared in redundant paths or alternate modes of operation.
m. Failure to derate printed circuit board traces and wires.
n. Common line decoupling capacitors
o. Single line decoupling capacitors or blocking diodes.
p. Structural or mechanical failure of housings (and support structure) containing redundant items.

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APPENDIX F

MIL-STD-1543 and SAMSO-STD 77-2 Provision Cross References

This appendix is not a mandatory part of this standard. It is intended as an aid in correlating the FMEA provisions of MIL-STD-1543 (USAF) and SAMSO-STD 77-2 to those combined into this standard in paragraph 5.2 and Appendices B through E. Paragraphs and sentences (S) listed in the left two columns were combined and reflected in this standard as listed in the right column with additions as noted. The other STD 77-2 provisions were converted to STD-1543A provisions with editorial changes, primarily paragraph number changes (e.g., 5.9.2 is now 50.9.2). Appendices A through C of SAMSO-STD 77-2 are Appendices C through E of this standard.

MIL-STD-1543 (USAF)	SAMSO-STD 77-2	(Appendix B) MIL-STD-1543A (USAF)
5.2 (S1)	---	5.2 (M) (R)
(S2)	---	40.6.a
---	4.6	40.6, 40.6.b
(S3)	4.6	40.6.b (I)
(S3)	4.1.k, 4.1.m	40.1.k (M), 40.1.m (I)
(S4)	---	40.3.3.a
---	4.1.n	40.1.n (Note 1)
(S5)	4.1.o	40.1.o (C)
(S6)	4.1.h, i	40.1.h, i (C)
(S7)	5.8.2	50.8.2 (I)
5.2.1 (S1-S4)	---	40.2.6.1 (M)
5.2.2 (S1)	---	40.2.6.4 (S1)
(S2)	---	40.2.6.5 (S2)
(S3)	---	40.2.6.4.a (M)
---	4.2.6.4 (Last S)	40.2.6.4.b (M)
5.2.3 (S1-S3)	---	50.7.3
(S4)	5.7.3.a	50.7.3.a (M)
5.2.4	---	50.6
5.2.5 (S1)	---	40.3.3 (Last S)
5.2.5.a	5.9.2.b	50.9.2.b (I)
.b	5.9.2.c	50.9.2 and .c (I)
.c	5.9.2.f	50.9.2.f (I)
.d	5.9.2.j	50.9.2.j (I)
.e	5.9.2.k	50.9.2.k (I) (Note 2)
.f	5.9.2.h	50.9.2.h (C)
.g	5.9.2.f	50.9.2.f (C)
---	---	50.9.2.m (Note 3)
5.2.6 (S1)	5.8.2	50.8.2 and .a (C)
(S2-S6)	---	50.8.2.b
---	4.2.6.6	40.2.6.6 (Note 4)

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LEGEND:

(C) = Combined STD-1543 and STD 77-2 provisions.
(I) = STD-1543 provision was included in STD 77-2 and is retained in STD-1543A.
(M) = Some content or wording modification made.
(R) = 5.2 (S1) intent is retained in STD-1543A to invoke Appendix B.
(S) = Sentence (e.g., S2 = second sentence).

NOTES:

1. In 40.1.n, added clarification for use in orbital operations documents.

2. In 50.9.2.k, added that relative probabilities may be used for non-critical item failure modes.

3. In 50.9.2.m, added clarification to identify failure modes not detectable in final launch preparation checkout. As separate item to facilitate tailoring where not needed.

4. In 40.2.6.6, added clarification for MSI, LSI, and hybrid FMEA for early emphasis on hybrids and on newly designed or unproven devices.

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APPENDIX G

APPLICABLE DATA REQUIREMENTS

This appendix is not a mandatory part of this standard. Data requirements of this standard are not deliverable to the procuring activity unless specified by the Contract Data Requirements List (DD Form 1423). The data normally required for delivery under this standard includes:

a. DI-R-3548 - Suspect Material Deficiency Notice (ALERT) and Response. (5.5.5)

b. DI-R-7033 - Plan, Reliability Test. (4.2, 4.5)

c. DI-R-7034 - Reports, Reliability Test and Demonstration. (4.2, 4.5)

d. DI-R-7041 - Report, Failure Summary and Analysis. (5.5)

e. DI-R-7079 - Reliability Program Plan. (4) (See Note 1)

f. DI-R-7080 - Reliability Status Report. (4)

g. DI-R-30507 - Failure Modes and Effects Analysis (FMEA) Report. (5.2 and Appendix B, 40.2.6, 40.4, 40.7, 50.9) (See Note 2.)

h. DI-R-30508 - Critical Items List. (3.4, 4.4, 5.7.1, and Appendix B, 40.4, 50.7.1, 50.7.2) (See Note 2.)

i. DI-R-30509 - Reliability Allocations, Assessments, and Analysis Report. (4.1, 4.2, 4.3.1, 4.5, 4.6, 5.3, 5.4.1, 5.4.2, 5.7, 5.8)

j. DI-R-30511 - Critical Item Control Plan. (4.4)

Notes:

1. DI-R-7079 should be tailored to invoke this standard.

2. DI-R-30507 and DI-R-30508 should be tailored to correct specific paragraph and appendix references of SAMSO-STD-77-2 to those of this standard. (See Appendix F.)

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