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NOT MEASUREMENT SENSITIVE

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31 July 1995
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DEPARTMENT OF DEFENSE

HANDBOOK FOR

MAINTAINABILITY OF AVIONIC AND ELECTRONIC SYSTEMS AND EQUIPMENT

AMSC N/A
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AREA MNTY

DEPARTMENT OF THE NAVY
NAVAL AIR SYSTEMS COMMAND
Washington, D.C. 20361

General Requirements for Maintainability of Avionic and Electronic Systems and Equipment.

MIL-STD-2084(AS)

1. This Military Standard is approved for use by the Naval Air Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commanding Officer, Engineering Specifications and Standards Department (Code 93), Naval Air Engineering Center, Lakehurst, NJ 08733, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

Maintainability is an attribute of design and is a measure of the ease, rapidity, and accuracy with which systems or equipment can be restored to operational status following failure or repair. A high degree of readiness and availability of avionic and electronic systems and equipment can be assured only when their design allows for positive and accurate identification of operational status, and when items are found defective, rapid and efficient fault isolation, removal, replacement, and subsequent repair.

The special features designed and built into systems which make them easy to maintain and efficient to support result when maintainability is clearly defined as a system requirement and the maintainability program is established as a functional area of design. The purpose of this standard is not to subrogate the maintainability program requirements of MIL-STD-470, but merely to amplify the design criteria requirements of the maintainability program and to emphasize maintainability by design.

Under the concept of maintainability by design, emphasis is placed on those design areas which tend to have the greatest influence on ease of maintenance. This includes requirements for modularization, replacement at higher levels, and increased depth of localization. These physical and technical considerations of maintainability design are necessary if complex avionic and electronic systems and equipment are to be supported efficiently at all levels of maintenance.

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TABLES

1. SCOPE

1.1 Scope. This standard covers the common maintainability design requirements to be used in military specifications for avionic and electronic systems and equipment.

1.2 Application. This standard is applicable to Naval Air Systems Command procurements for the design and development of avionic and electronic systems and equipment. The requirements contained herein are intended to provide uniform requirements and shall be incorporated by reference in detailed equipment specifications. Other documents may reference requirements when applicable.

1.3 Method of reference When specifying requirements of this standard, both the standard and the specific requirement number(s) are to be cited. Applicable "Details to be specified" shall be included in the Statement of Work. Details annotated by an "(R)" shall be provided to the contractor for proper implementation of the requirement.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on the date of invitation for bid or request for proposal, are referenced in this standard for information and guidance.

STANDARDS

Military

MIL-STD-280	Definitions of Item Levels, Item Exchangeability, Models, and Related Terms
MIL-STD-411	Aircrew Station Signals
MIL-STD-415	Test Provisions for Electrical Systems and Associated Equipment, Design Criteria for
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-470	Maintainability Program Requirements for Systems and Equipment, Development and Production
MIL-STD-471	Maintainability Verification/Demonstration/Evaluation
MIL-STD-721	Definitions of Terms for Reliability and Maintainability

STANDARDS (Continued)

Military (Continued)

MIL-STD-882	System Safety Program Requirements
MIL-STD-1390(AS)	Level of Repair
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL-STD-1629	Procedures for Performing a Failure Mode, Effects, and Criticality Analysis
MIL-STD-2068	Reliability Development Test
MIL-STD-2076	Unit Under Test Compatibility with Automatic Test Equipment; General Requirements for

HANDBOOKS

Military

MIL-HDBK-472	Maintainability Prediction

OTHER PUBLICATIONS

NAVMAT-P-9405	Built-In-Test Design Guide

(Copies of specifications, standards, drawings, 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

3.1 Terms. See each individual requirement for applicable definitions with the exception of the following which are applicable to all requirements:

3.1.1 Shop replaceable assembly (SRA). A generic term which includes all the packages within a WRA including the chassis and wiring as a unit.

3.1.1.1 Quick replaceable assembly (QRA). A preferred form of SRA which is easily removable from the WRA without complex operations or special tools and is typified by a plug-in design.

3.1.1.2 Bench replaceable assembly (BRA). A less desirable form of SRA which is not easily removable; e.g., item bolted to chassis or heat sink or soldered in place.

3.1.1.3 Sub-shop replaceable assembly (sub-SRA). A modular item packaged in an SRA.

3.1.2 Weapons replaceable assembly (WRA). A generic term which includes all replaceable packages of a system installed in the weapon system with the exception of cables, mounting provisions, and fuse boxes or circuit breakers. The WRA is generally modular in form and designed to facilitate an organizational level removal and replace maintenance concept. The preferred form of WRA is the light replaceable assembly (LRA) which is easily removed and replaced in the weapon system by one man in not more than 15 minutes.

4. GENERAL REQUIREMENTS

4.1 Application of requirements. Requirements described in this standard are to be selectively applied and are intended to be tailored as required and as appropriate to particular systems and equipment programs. The purpose is to provide criteria for features which will minimize maintenance downtime, costs, complexity, and personnel requirements.

5. DETAIL REQUIREMENTS

5.1 Individual requirements. Individual requirements for avionic and electronic systems and equipment (electronic system) follow.

Preparing Activity
NAVY - AS
(Project No. MNTY-N001)

*REQUIREMENT 101
MAINTAINABILITY PROGRAM

1. Purpose. This requirement establishes criteria for tasks and requirements of a maintainability program.

2. Referenced documents. The following documents are applicable to Requirement 101.

STANDARDS

Military

MIL-STD-470	Maintainability Program Requirements for Systems and Equipment, Development and Production
MIL-STD-471	Maintainability Verification/Demonstration/ Evaluation
MIL-STD-721	Definitions of Terms for Reliability and Maintainability

HANDBOOKS

Military

MIL-HDBK-472	Maintainability Prediction

3. Definitions. Definitions applicable to Requirement 101 are in accordance with MIL-STD-470, MIL-STD-471, MIL-HDBK-472, MIL-STD-721, and Section 3 of this standard.

4. Maintainability program. The tasks and requirements for a maintainability program in accordance with MIL-STD-470 shall be specified in the contract statement of work.

4.1 Quantitative maintainability requirements. Quantitative maintainability requirements for organizational (O) level and intermediate (I) level shall be specified in the contract Statement of Work or equipment specification. Unless otherwise specified, the maximum time to repair (Mmaxct) within which 95% of all organizational corrective maintenance actions will be completed shall not exceed thirty (30) minutes. Maximum time to repair includes all elements (e.g., verification, location, repair, etc.) as defined in MIL-STD-471 and MIL-HDBK-472.

4.2 Maintainability analysis. A maintainability analysis shall be performed in accordance with MIL-STD-470 to develop the detailed quantitative and qualitative maintainability requirements for the electronic system. Analysis results shall be used to allocate the maintainability requirements to lower indenture levels of the electronic system and to update the design criteria and the maintenance plan.

4.3 Maintainability prediction. A maintainability prediction shall be performed to estimate the quantitative maintainability parameter values of the planned design configuration of the electronic system. For prediction of organizational level maintainability values, Procedure 1 of MIL-HDBK-472 shall be adapted for the particular design and shall include only direct maintenance times. The effects of a malfunction of built-in-test (BIT) and fault isolation functions and all preventive maintenance times, including calibration and adjustment times, shall be included. Descriptions of the installation and removal procedures for the electronic system shall be prepared and shall include the following:

a. The equipment mounts, including fasteners.

b. Function and test connectors at weapon replaceable assembly (WRA) and lower levels of assembly.

c. All other aspects of equipment installation such as cooling lines or ducts which will influence maintenance time.

5. Design criteria and guidelines. The contractor shall develop detail design criteria and guidelines in accordance with MIL-STD-470 to provide guidance for the integration of maintainability enhancement features into the electronic system design. Specific design guidance shall be provided for the areas of fault detection and isolation, location and grouping of test points, interchangeability, and physical accessibility for repair and replacement. The design criteria and guidelines shall be documented and made available to the procuring activity or its designated representative on request.

6. Details to be supplied. Details to be supplied in the Statement of Work include the following, as applicable.

a. Identification of each maintainability program task in accordance with MIL-STD-470.

(R) b. Quantitative maintainability requirements for organizational level and intermediate level.

c. Delivery identification of any data item required.

REQUIREMENT 102
FAILURE MODE AND EFFECTS ANALYSIS

1. Purpose. This requirement establishes the criteria for the failure mode and effects analysis of electronic systems to identify the necessary design characteristics that must be ascribed to maintainability.

2. Referenced documents. The following document is applicable to Requirement 102.

STANDARDS

Military

MIL-STD-1629	Procedures for Performing a Failure Mode, Effects, and Criticality Analysis

3. Definitions. Definitions applicable to Requirement 102 are in accordance with MIL-STD-1629.

4. Failure mode and effects analysis (FMEA). An FMEA in accordance with MIL-STD-1629, Task 101, shall be utilized to document probable failures in the electronic system and to determine the effects of the failures on electronic system operation. FMEA(s) shall be performed to the level(s) specified to identify failure modes, failure causes, and failure effects. This analysis shall be scheduled and completed concurrently with the design effort so that the design will reflect analysis conclusions and recommendations.

5. Failure mode, effects, and criticality analysis (FMECA)-maintainability information. An FMECA-maintainability information analysis shall be performed in accordance with MIL-STD-1629, Task 103. This analysis is utilized to provide early criteria for maintenance planning analysis (MPA), logistics support analysis (LSA), and to identify maintainability design features requiring corrective action. FMECA-maintainability information analysis shall be performed to the level(s) specified to identify incipient failure indicators, failure detection means, failure isolation means, and basic maintenance actions.

6. FMECA results. The result and current status of the FMEA and the FMECA-maintainability information analysis shall be presented at all design reviews and shall be used as inputs to design trade-offs, MPA's, LSA's, test equipment design, test planning, and inspection and checkout planning. These results shall be used during the built-in-test (BIT) and test point design to determine:

a. The type of fault detection and isolation means.

b. At what points fault detection and isolation, to single items or group of items, can be implemented.

c. Proportion of faults in each single item or group of items detectable by the proposed design approach.

d. Proportion of detectable faults which can be isolated to a single item or group of items by the proposed design approach.

7. Details to be specified. Details to be specified in the Statement of Work shall include the following as applicable:

(R) a. Identification of the level to which FMEA shall be conducted.

(R) b. Identification of maintenance levels for which FMEA is to be performed.

c. Logistic support coordinated reporting requirements for logistic support analysis.

d. Identification of maintenance plan(s) and support requirements.

e. Identification of reviews required.

f. Delivery identification of any data item required.

REQUIREMENT 103
PHYSICAL DESIGN

1. Purpose. This requirement establishes criteria for the design of the physical characteristics which influence the maintainability features and maintenance requirements of the electronic system.

2. Referenced documents. The following documents are applicable to Requirement 103.

STANDARDS

Military

MIL-STD-280	Definitions of Item Levels, Item Exchangeability, Models, and Related Terms
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-1390 (NAVY)	Level of Repair

3. Definitions. Definitions applicable to Requirement 103 are in accordance with MIL-STD-280, MIL-STD-454, MIL-STD-1390, and Section 3 of this standard.

4. Design. The electronic system shall be designed to provide functional and physical partitioning at all levels of assembly to enable modular packaging of assemblies and subassemblies into weapons replaceable assemblies (WRA) and shop replaceable assemblies (SRA). Consideration shall be given to designing circuits into discrete functional packages of such cost and reliability that discard at failure rather than module repair is the most cost-effective logistic support action. A level of repair (LOR) analysis shall be utilized to establish the most cost-effective method of logistically supporting the electronic system.

4.1 Weapons replaceable assembly (WRA). Each WRA shall be designed and constructed as the least complex assembly of the weapon system which can be removed and replaced as a modular package at the organizational level of maintenance. Physical measures shall be provided (e.g., alignment pins, keying, etc.) to preclude interchange of WRAs of similar form which are not functionally interchangeable and to preclude improper mounting at installation. As a design objective, the design weight of each WRA shall be less than 40 pounds. The design weight of a WRA shall never exceed 80 pounds.

4.2 Shop replaceable assembly (SRA). Each SRA shall be designed and constructed for removal and replacement in a WRA as a modular package. To the maximum extent practicable, each SRA shall be designed into discrete functional packages for discard at failure rather than repair. The maintenance criteria for discard at failure or repair shall be established through LOR analysis. Physical measures shall be provided (e.g., alignment pins, keying, etc.) to preclude interchange of SRA's of similar form which are not functionally interchangeable and to preclude improper mounting at installation.

4.2.1 Quick replaceable assembly (QRA). Each QRA using a plug-in interface and connection with a WRA shall be designed to be removed and replaced with ease of physical effort and without inducing maintenance related failures. Specifically, the QRA shall be designed to be removed without disassembly and without disturbing elements of adjacent installations. The plug-in design shall preclude the possibility that force to effect removal and replacement can be applied with hand or designated tool in direct contact with a part, component, or circuit of the QRA, adjacent SRAs, or WRA. Maintenance procedure provisions or caution notes shall not be sufficient to satisfy this requirement. Special tools shall not be required to remove or replace QRAs.

4.2.2 Bench replaceable assembly (BRA). Each BRA shall be designed and constructed to conform to the internal wiring practices criteria of MIL-STD-454, Requirement 69.

4.2.3 Sub-shop replaceable assembly (sub-SRA). Each sub-SRA shall be designed, to the maximum extent practicable, into discrete functional packages for discard at failure rather than repair. The maintenance criteria for discard at failure or repair shall be established through LOR analysis.

4.3 Interchangeability. All items in the electronic system shall be designed, selected, and applied in accordance with the criteria for interchangeability of MIL-STD-454, Requirement 7.

4.4 Conformal coating. Materials used for conformal coating shall be in accordance with the applicable design requirements specified in the equipment specification. No conformal coating material shall be applied to test points.

4.5 Encapsulation and embedment. No encapsulation or embedment material shall be applied to reparable modules, assemblies, or subassemblies.

5. Accessibility. Accessibility requirements for all reparable items in the electronic system shall be in accordance with the criteria of Requirement 36 of MIL-STD-454. Accessibility considerations shall include:

a. A minimum number and diversity of fasteners commensurate with specific design requirements. Hand-operated fasteners are preferred and fasteners requiring use of common tools are acceptable. Fasteners requiring special tools shall not be used.

b. Access openings shall be sufficiently large for visual inspections and manipulative actions for adjusting, removal, and handling.

c. A sufficient number of accessible test points shall be provided so it is not necessary to remove assemblies or subassemblies to accomplish testing.

6. Elapsed time indicators. Elapsed time indicators (ETI) shall be easily read with the WRA in its normally installed position in the weapon system. Electrochemical ETIs shall not be used.

7. Protective devices. Circuit breakers shall be used in lieu of fuses and shall be accessible from the exterior of each WRA with the WRA in its normally installed position in the weapon system. Circuit breakers will be of the fault indicating type and shall be plainly marked as to rating and size.

8. Details to be specified. Details to be specified in the Statement of Work shall include the following, as applicable.

(R) a. Specification of policies or guidance to be considered for use in guiding the design process.

(R) b. Specification of particular Government or Industry Handbooks to be utilized.

c. Logistic support coordinated reporting requirements for logistic support analysis.

(R) d. Information available from procuring activity (PA) relative to constraints on system or equipment due to personnel, physical location, use environment, or maintenance concept.

(R) e. Lists of standard tools and equipment.

f. Delivery identification of any data items required.

REQUIREMENT 104
BUILT-IN-TEST

1. Purpose. This requirement establishes criteria for design and application of built-in-test (BIT) which will adequately support the defined maintenance concept.

2. Referenced documents. The following documents are applicable to Requirement 104.

STANDARDS

Military

MIL-STD-411	Aircrew Station Signals
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-470	Maintainability Program Requirements for Systems and Equipment, Development and Production
MIL-STD-882	System Safety Program Requirements
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL-STD-1629	Procedures for Performing a Failure Mode, Effects, and Criticality Analysis
MIL-STD-2068	Reliability Development Test

OTHER PUBLICATIONS

NAVMAT-P-9405	Built-In-Test Design Guide

3. Definitions. Definitions applicable to Requirement 104 are in accordance with MIL-STD-411, MIL-STD-454, MIL-STD-470, MIL-STD-882, MIL-STD-1472, MIL-STD-1629, MIL-STD-2068, and Section 3 of this standard with the exception and addition of the following:

3.1 Built-in-test (BIT). The self test hardware and software which is internal to a unit to test the unit.

3.2 Built-in-test-equipment (BITE). A unit which is a part of a system and is used for the express purpose of testing the system. BITE is an identifiable unit of a system.

3.3 Mission critical failure. A failure which includes the MIL-STD-882 hazard severity categories of catastrophic and critical.

3.4 Operational readiness test. That set of functional tests and observations necessary for the flight crew to determine the operational usability of a system.

3.5 Sensor. A device designed into a system which converts a particular parameter into a form suitable for measurement by test equipment.

3.5.1 Sensor, active. A sensor requiring a source of power other than the signal being measured.

3.5.2 Sensor, passive. A sensor requiring no source of power other than the signal being measured.

3.6 Stimulus. Any physical or electrical input applied to a device intended to produce a measurable response.

3.7 Testability. A characteristic of an item's design which allows the status (operable, inoperable, or degraded) of that item to be confidently determined in a timely manner.

4. Built-in-test (BIT). BIT as considered herein is an integral part of each unit of the electronic system which may be removable but which does not operate out of the system environment. Built-in-test equipment (BITE) which is defined as an identifiable unit of a system is not considered herein except as related to BIT.

4.1 Purpose of BIT. BIT shall be utilized to provide an indication of electronic system performance and to permit fault detection and isolation to the replaceable module or functional entity. BIT shall be compatible with the electronic system circuitry to minimize possible loss of performance occasioned by its use.

4.2 BIT test points. BIT test points shall be selected on their ability to detect and isolate faults with a maximum degree of confidence to the lowest practicable hardware level. Performance monitoring and fault detection and isolation at a point shall be available from a single sensor. In the event that sensing circuitry neccessary to monitor the key parameter(s) of the signal would degrade the performance of the circuit, would be difficult to install, or would seriously degrade

reliability, consideration shall be given to obtaining the information through evaluation of a group of interrelated test points. Priority shall be given to the testing of functions that are most important to the operational mission, that are basic to fault diagnosis, and are least reliable or least accessible.

5. BIT design. BIT shall be designed as an integral part of the electronic system design. BIT functions shall be performed on-line by exercising components and circuitry within the electronic systems by use of software and hardware stimuli or monitoring circuits. BIT shall require no external stimuli or measurement equipment to perform its function. The required performance of an item shall not be degraded by the design or the use of BIT. Guidance in the application of BIT to the electronic system may be found in NAVMAT-P-9405.

5.1 Operational readiness tests. BIT circuitry and devices shall be designed to test the electronic system operating modes and furnish an indication of the operational readiness of the system. The operational readiness test shall be designed to be functional in both the mission and maintenance environments. The BIT features utilized for operational readiness testing shall be designed to evaluate the electronic system without need for external stimuli or test equipment. Performance below acceptable levels and, to the extent practicable, marginal or degraded functions shall result in an advisory or caution indicator being energized at the aircrew station.

5.1.1 Automatic initiation. The operational readiness test shall be designed for automatic initiation when the electronic system is energized (power ON) and at periodic intervals during operation unless it can be shown by analysis that on-demand, manual initiation is more practical. Unless otherwise specified, continuous monitoring or operational testing shall be provided during the electronic system operation for those items which contain mission critical failure modes. The continuous monitoring or operational testing of other items within the electronic systems shall be on a selective basis justified by an analysis which considers both the BIT false alarm rate and the consequences of BIT failure.

5.1.2 Manual initiation. When manual initiation is to be utilized, a switch shall be incorporated in the electronic system control panel for initiating the operational readiness test.

5.1.3 Remote initiation. Provisions shall be included in the operational readiness test circuitry for the use of a remote signal to initiate testing. To the extent practicable, a provision shall also be included for inhibiting the operational readiness test by means of a remote signal.

5.2 Fault detection and isolation. The BIT design shall provide a capability for fault detection and isolation of the fault to a defective WRA or SRA. No external stimuli or test equipment shall be required to perform the BIT fault detection and isolation function.

5.2.1 BIT fault detection level. The BIT design shall provide a fault detection function as a GO/NO GO visual indication. Unless otherwise specified, BIT shall detect failure and out-of-tolerance modes which represent at least 98 percent of all electronic system faults. Analytical estimates of design compliance with BIT detectability requirements shall be a consideration at all design reviews.

5.2.2 BIT fault isolation level. The BIT design shall provide a failure and out-of-tolerance mode isolation and identification functions by means of the BIT circuitry, devices, and indicators. At least 99 percent of all electronic system failure and out-of-tolerance modes detected at organizational level maintenance shall be isolated and identified without ambiguity to the faulty WRA by BIT. The acceptable requirements for the percentage of all WRA faults which shall be isolated and identified by BIT to the faulty SRA, or small group of SRAs, shall be as listed in the Table 104-I. Analytical estimates of design compliance with BIT fault isolation requirements shall be a consideration at all design reviews.

Table 104-I. Nonambiguous SRA isolation groups

PERCENT OF WRA FAULTS ISOLATED	SRA AMBIGUITY GROUP SIZE
100%	$\leq$ 10% of TOTAL SRAs
95%	$\leq$ 5 SRAs
90%	$\leq$ 4 SRAs
85%	$\leq$ 3 SRAs
80%	$\leq$ 2 SRAs
75%	= 1 SRA

5.3 Design growth limit. The growth of the electronic system design due to the incorporation of BIT circuitry and devices shall not exceed 10 percent of the electronic system circuitry, parts, and devices.

6. BIT reliability. Reliability of BIT circuitry and devices shall be an allocated portion of the electronic system, WRA, or SRA reliability. In no case shall the apportioned failure rate of the BIT circuitry and devices exceed 10 percent of the failure rate of the item or function being monitored.

7. False alarm rate. The probability of false indications of electronic system failures, considering both the electronic system and BIT, shall not exceed one percent of all BIT indicated failures.

8. BIT self-test. Self-test provisions shall be incorporated into the electronic system as a means of testing the operational status of BIT and BIT circuitry as well as a means of ensuring unambiguous BIT readouts. The maximum time for accomplishing the self-test shall be specified in the electronic system specification.

9. BIT calibration. BIT circuits which contain reference circuits or measurement devices shall be provided with test points which allow isolation from the electronic system circuitry and permit injection of test signals. Adjustments to these reference circuits or measurement devices shall be readily accessible and fault indication devices shall be visually accessible while adjustments are being performed.

10. Fail-safe provisions. The circuits and devices which provide BIT and fault isolation functions shall be designed so that failure of these circuits or devices will not cause a failure of the electronic system. The following criteria shall apply:

a. Switches shall not be placed in series paths for purposes of introducing stimuli, introducing normal signals, or measuring system performance.

b. Isolation shall be provided at signal functions with BIT circuitry and devices and other fault isolation circuitry such that normal BIT or other test operations will not affect system performance, nor will failure of BIT interfere with system operation.

c. BIT stimuli shall be selected such that system performance degradation is minimized in the presence of the stimuli.

11. Indicators. Indicators shall be utilized to provide clear indications of electronic system operational readiness and fault locations. Indicators selected shall comply with the requirements of MIL-STD-1472. For integrated or multi-mode systems, indicators for the various subsystems and equipment may be grouped together in an electronic system readiness advisory panel.

11.1 Aircrew station indicators. Electronic system status and caution or warning indicators shall be designed and applied in accordance with the requirements of MIL-STD-411. The system status indicators shall provide GO/NO GO indications of system readiness or functional status.

11.2 Fault indicators. Fault indicators shall continuously sense fault signals and provide indications at the aircrew station and, as required, at the WRA or SRA level. BIT fault location features shall energize a GO/NO GO device located at the WRA and, to the extent practicable, at the SRA. Fault location indicators at the WRA level shall be capable of holding the last test result if power is interrupted or removed. All fault location indicators shall be visible to maintenance personnel with the item in its normally installed position.

11.3 Maintenance panel. One of the WRAs provided for an integrated or multi-mode electronic system may be a maintenance panel. When provided, a maintenance panel shall be placed in a weapon system so it may be readily viewed and operated by maintenance personnel with all WRAs in their normally installed position. A maintenance panel shall, as a minimum, consist of a group of several visual fault indicators which will indicate to maintenance personnel which WRA has malfunctioned. To reduce the number of indicators required, the maintenance panel may contain a switch(es) and a failure summary indicator(s) which is independent of switch position.

12. Sensors. Passive sensors shall be used in preference to active sensors wherever possible. Where active sensors are used to provide the necessary information not obtainable from passive sensors, there shall be minimal effect on the reliability of the circuit-sensor combination.

12.1 Calibration. The use of sensors requiring calibration, initial or otherwise, shall be avoided.

12.2 Shielding. All sensors shall be designed so that interference caused by electromagnetic radiation is minimized through the use of good design principles and by filtering or shielding as required. Electromagnetic interference requirements of the electronic system specification shall apply.

13. BIT fault detection and isolation level verification. When reliability development tests in accordance with MIL-STD-2068(AS) are required by contract, the contractor shall maintain a record of all failures and develop data to verify the WRA and SRA fault detection and isolation requirements. On the occurrence of an electronic system failure, the BIT function shall be exercised and a record made in the test log and in the failure report of BIT capability to fault detect and fault isolate in accordance with this requirement. During repair and

troubleshooting, BIT capability to fault isolate to the faulty SRA shall be recorded. BIT failures or the inability of BIT to detect or isolate failures shall be reported and investigated in accordance with the failure reporting, analysis, and corrective action requirements of MIL-STD-2068(AS). The failure summary report required by contract shall include the listings of all reported BIT failures and malfunctions. Data from all primary system failures occurring during the reliability development test shall be used to evaluate WRA and SRA fault detection and isolation requirements. These data shall be summarized and reported in the reliability test results reports.

14. Details to be specified. Details to be specified in the Statement of Work shall include the following, as applicable.

(R) a. Identification of maintenance and support concepts.

(R) b. Projected facility, training program, skills, and equipment availability.

c. Specification of particular continuous monitoring or operational testing requirements.

d. Specification failure and out-of-tolerance mode detection requirements.

(R) e. Specification of maximum BIT self-test time.

f. Specification of a reliability development test in accordance with MIL-STD-2068(AS).

(R) g. Identification of test attribute data to be reported (proportion of detection, percent isolation, false alarm rate, ambiguity, etc.).

h. Delivery identification of any data items required.

Requirement 10
6 April 1982

REQUIREMENT 105
TEST POINTS

1. Purpose. This requirement establishes the criteria for the design and application of test points which will adequately support the defined maintenance concept.

2. Referenced documents. The following documents are applicable to Requirement 105.

STANDARDS

Military

MIL-STD-415	Test Provisions for Electrical Systems and Associated Equipment, Design Criteria for
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-2076	Unit Under Test Compatibility with Automatic Test Equipment; General Requirements for

3. Definitions. Definitions applicable to Requirement 105 are in accordance with MIL-STD-415, MIL-STD-454, MIL-STD-2076, and Section 3 of this standard.

4. Test points. Both external and internal test points shall be provided which will permit the functional and static parameters of an electronic system to be monitored, evaluated, and isolated. The number of test points shall be kept to a minimum but sufficient to provide the scope of maintenance required by the defined maintenance concept.

5. Design. Test points shall be designed as an integral part of the electronic system design in accordance with this requirement and MIL-STD-415. Test points provided shall permit quantitative testing, performance monitoring, fault isolation, and calibration or alignment. Test point compatibility with the designated or planned Automatic Test Equipment (ATE) shall be in accordance with MIL-STD-2076.

5.1 External test points. External test points shall be grouped, to the extent practicable, in a single multi-pin connector which is readily accessible on the surface of each WRA to permit testing while the WRA is in its normally installed position in the weapon system and without need for disconnecting operational connectors. Unless otherwise specified, external test points shall be provided for the functional checkout and monitoring of the electronic system and for WRA and SRA fault isolation. To the extent practicable, the functional and fault isolation test points shall be combined in a single connector. All external test point connectors shall be provided with captive caps.

5.2 Organizational level test points. The external test points shall permit application of external functional stimuli for conducting end-to-end quantitative checkouts and measurements of the electronic system functional performance. The fault isolation test points shall permit unambiguous fault isolation, calibration or alignment of WRAs, and checkout or calibration of BIT while the WRAs are installed in their normal position in the weapon system.

5.3 Shop repair test points. External test points shall be provided on each WRA for use when the WRA is removed from the weapon system. The external test points, in conjunction with the operational connectors, shall permit end-to-end quantitative checks, calibration or alignment, and other functional testing of the WRA. External test points shall also permit, in the event of a failure, the fault isolation of the faulty SRA or circuit within the WRA. The acceptable percentage of all WRA faults which shall be isolated to the faulty SRA, or small group of SRAs, by ATE utilizing external test points shall be as listed in Table 105-I.

Table 105-I. Nonambiguous SRA isolation groups.

PERCENT OF WRA FAULTS ISOLATED	SRA AMBIGUITY GROUP SIZE
100%	$\leq$ 3 SRAs
95%	$\leq$ 2 SRAs
90%	= 1 SRA

5.4 Internal test points. Internal test points shall be provided on each SRA to permit the application of external stimuli and to permit external measurement of performance when the SRA is removed from the WRA. Internal test points shall be conditioned to provide undistorted signals to the test equipment and shall provide the means for measuring input and output parameters to enable calibration or alignment of SRAs. The internal test points shall also permit, in the event of failure, the isolation of the faulty subassembly, sub-SRA, or part within the SRA. The acceptable percentage of all SRA faults which shall be isolated to the faulty subassembly, sub-SRA, or part, or small group of subassemblies, sub-SRAs, or parts, shall be as listed in Table 105-II.

6. Manual fault isolation level. Provisions and procedures shall be developed which enable the ambiguous SRA groups resulting from BIT or ATE isolation to be further isolated to the faulty SRA. No special support equipment shall be required and isolation procedures shall not include the use of spare SRAs from the supply system.

Table 105-II. Fault isolation groups within SRA.

PERCENT OF SRA FAULTS ISOLATED	SUBASSEMBLY OR PART GROUP SIZE IN SRA	
	GROUP SIZE ≤ 10	GROUP SIZE > 10
100%	≤ 4	≤ 7
95%	≤ 3	≤ 5
80%	≤ 2	≤ 3

7. Automatic test equipment (ATE) compatibility. The electronic system and each WRA and SRA shall be designed to be compatible with the ATE designated or planned for fleet use. Compatibility requirements shall be in accordance with MIL-STD-2076(AS).

8. Details to be specified. Details to be specified in the Statement of Work shall include the following, as applicable:

(R) a. Operational and support concepts and requirements, including environmental conditions.

(R) b. Lists of standard tools, equipment, and designated or planned Automatic Test Equipment.

(R) c. Projected facility, training program, skills, and equipment availability.

d. Establishment of PA approval requirements for manual fault isolation provisions and procedures.

(R) e. Identification of test attribute data to be reported (proportion of detection, percent isolation, ambiguity rates, etc.).

f. Delivery identification of any data items required.

REQUIREMENT 106
MAINTAINABILITY INDEX

1. Purpose. This requirement establishes criteria for determining maintainability indices of the electronic system.

2. Referenced documents. The following referenced document is applicable to Requirement 106.

STANDARDS

Military

MIL-STD-1390 Level of Repair

3. Definitions. Definitions applicable to Requirement 106 are in accordance with MIL-STD-1390 and Section 3 of this standard.

4. Fixed interface (FI) ratios. Fixed interface (FI) ratios are a measure of the capability to replace a single WRA or SRA without need for adjustment or trimming at installation.

4.1 WRA FI ratio. The ratio of WRAs replaced at O-level maintenance which do not require adjustment or trimming at installation in the weapon system to the total number of WRAs in the electronic system shall always be less than 1.0. Analytical estimates of the WRA FI ratio shall be a consideration at all design reviews. The WRA FI ratio is calculated as follows:

$$\text{WRA FI ratio} = \frac{\text{Number of WRAs not requiring adjustment}}{\text{Total number of WRAs in electronic system}}$$

4.2 SRA FI ratio. The ratio of the number of SRAs replaced at I-level maintenance which do not require adjustment or trimming at installation in the WRA to the total number of SRAs in the WRA shall always be less than 1.0. Analytical estimates of the SRA FI ratio for each WRA shall be a consideration at each design review. The SRA FI ratio is calculated as follows:

$$\text{SRA FI ratio} = \frac{\text{Number of SRAs not requiring adjustment}}{\text{Total Number of SRAs in the WRA}}$$

5. Light replaceable assembly (LRA) ratio. Unless otherwise specified, the ratio of LRAs to the total number of WRAs in the electronic system shall not be less than 1.0. Analytical estimates of the LRA ratio shall be a consideration at all design reviews. The LRA ratio is calculated as follows:

$$\text{LRA ratio} = \frac{\text{Number of LRAs in electronic system}}{\text{Total number of WRAs in electronic system}}$$

6. Quick replaceable assembly (QRA) ratio. The ratio of QRAs to the total number of SRAs in a WRA shall not be less than 0.90. Analytical estimates of the QRA ratio for each WRA shall be a consideration at all design reviews. The QRA ratio is calculated as follows:

$$\text{QRA ratio} = \frac{\text{Number of QRAs in WRA}}{\text{Total number of SRAs in WRA}}$$

7. FI ratio verification. When WRAs and SRAs are replaced or substituted during engineering and reliability development tests, a record shall be maintained for all calibration or alignment required to establish specified performance levels. These data shall be summarized to determine compliance or noncompliance with the FI ratio requirements and reported in the reliability test results reports.

8. Details to be specified. Details to be specified in the Statement of Work shall include the following, as applicable:

a. Specification of alternative LRA ratio.

b. Identification of reviews required.

c. Delivery identification of any data items required.

APPENDIX A

APPLICATION GUIDE

10. GENERAL

10.1 Scope. This appendix provides notes for the guidance of the procuring activity in generating the contractual requirements for the maintainability features designed and built into avionic and electronic systems and equipment.

10.2 Tailoring requirements. Each provision of this standard should be reviewed to determine the extent of applicability. Tailoring of requirements may take the form of deletion, addition, or alteration to the statements in sections 3, 4, and the individual requirements in section 5 to adapt the requirements to specific system characteristics, procuring activity options, contractual structure, or acquisition phase. The tailored requirements are specified in the contractual provisions to include input to the statement of work, contract data requirement list (CDRL), and other contractual means. The depth and detail of the maintainability design effort will be defined in appropriate contractual and other program documentation.

10.3 User. The user of this appendix may include the procuring activity, Government in-house activity, prime contractor, or subcontractor who wishes to impose requirements for maintainability of avionic and electronic systems and equipment upon his supplier(s).

20. REFERENCED DOCUMENTS (not applicable)

30. DEFINITIONS (not applicable)

40. GENERAL REQUIREMENTS

40.1 Requirements selection. The considerations presented herein are intended to provide guidance and rationale for selection of requirements. Once appropriate requirements have been selected, the requirements themselves can be tailored. The timing and depth of each requirement, as well as action to be taken based on requirement outcome, are largely dependent on individual experience and program requirements. For these reasons, hard and fast rules are not stated.

40.2 Application matrix for program phases. Table A-I herein provides general guidance, in summary form, of which requirements to include in an RFP in order to emphasize maintainability by design. This table can be used to initially identify requirements then the user can refer to the particular requirement and determine if it is appropriate for his program. The use of the matrix is to be considered as optional guidance only and is not to be construed as covering all procurement situations. The provisions of applicable regulations must also be followed.

TABLE A-I. Application matrix.

Requirement Title	Concept	Valid	FSED	Prod
101 Maintainability program	S	G(1)	G(1)	G(1)
102 Failure mode and effects analysis	S	G(1)(2)	G(1)	C
103 Physical design	S	G(2)	G	C
104 Built-in-test	S	G	G	C
105 Test points	S	G	G	C
106 Maintainability index	S	G(2)	G	C

Code Definitions

S - Selectively applicable
G - Generally applicable
C - Generally applicable to design changes only
(1) - MIL-STD-2084 is not primary implementing document
(2) - Depends on physical complexity of system being procured, its packaging, and maintenance policy.

40.3 Requirement prioritization. The problem of prioritizing requirements cannot be solved unless variables like system complexity, availability of funds, schedule, maintenance concept, logistic support requirements, et cetera are known. The maintainability program (Requirement 101) should always be considered for selection; however, individual maintainability program tasks from MIL-STD-470 may be cited in the contract without requiring Requirement 101.

50. DETAIL REQUIREMENTS

50.1 Requirement 101 - Maintainability Program. The elements of the maintainability program identified in Requirement 101 are considered to be the minimum for effectively implementing a maintainability by design approach. The tasks which are included establish the framework for maintainability by design and such tasks should be levied at the equipment level or at the system level whichever is most appropriate. Other elements of a maintainability program must be selected from MIL-STD-470 to meet the overall maintainability needs. Identifying and quantifying program needs must be accomplished prior to release of an RFP for the appropriate acquisition phase so that maintainability program tasks commensurate with the needs may be included in the RFP.

50.2 Requirement 102 - Failure Mode and Effects Analysis (FMEA). An FMEA is a powerful tool in the development of fault detection and isolation designs at all hardware levels. The effectiveness and efficiency of fault detection and isolation are critical drivers of maintainability at organizational, shop, and depot levels of maintenance. Through the use of an FMEA, potential design weaknesses which can impact safety and reliability may also be identified.

Depth and scope of the FMEA is dependent on the maintainability requirements levied in the RFP and the complexity and nature of the item undergoing procurement. Care must be taken when specifying maintainability requirements to indicate whether they relate to organizational maintenance, shop level maintenance or depot level maintenance or to some combination of these as such requirements impact interpretations of what is required for the FMEA requirement.

50.3 Requirement 103 - Physical Design. The physical design of electronic systems is directed to incorporating features which will minimize maintenance downtime, cost, complexity, and personnel requirements. Design criteria must be developed to assist the maintainability analyst in the selection of maintainability quantitative design features which enable cost effective maintenance support throughout the deployed life of the system.

The physical design must consider each maintenance task and provide for logical and sequential functions with minimum numbers of personnel and maintenance specialities. The design should permit physical and functional access to any active item upon opening or removal of access entries without need for prior removal or movement of other items. All repair part items having the same part number shall be physically and functionally interchangeable without modification or adjustment of the item or the system in which they are used. The performance of all maintenance tasks at organizational and intermediate level maintenance should be accomplished without need for special tools and with a minimum of maintenance tools, accessories and equipment.

50.4 Requirement 104 - Built-In-Test (BIT). The maintainability requirements of electronic systems are, in most cases, highly dependent on the adequacy and efficiency of test system design. Test systems cannot be considered as an afterthought, but must be considered as an integral part of the design if ease of maintenance is to be increased and maintenance downtime decreased.

A BIT capability incorporated into the system design serves two basic functions. First, to provide a fault detection function, and second, to provide isolation to the defective item or function. The level of BIT that will be required to isolate defective items or functions is

directly related to the mean-time-to-repair (MTTR) requirement for the system. Rapid and easy fault localization and repair dictate that the fault be diagnosed by function and that the function be implemented by a small set of replaceable modules. Modularization permits faster fault isolation, correction, and verification.

Designing for testability is important to assure effective BIT design. The BIT design should be kept simple and "state-of-the-art" designs that are unproven should be avoided. BIT must be reliable and a failure in the BIT circuitry or devices should not affect system performance. The type of circuitry used in BIT should be, where feasible, of the same types used in the electronic system design to minimize the number of different part types used.

Valuable and necessary inputs to BIT design are obtained from among the following:

- Reliability predictions
- Failure mode and effects analysis
- Maintainability analysis
- Human factors studies which recommend skill levels and numbers of personnel required.

50.5 Requirement 105 - Test Points. Test points are a consideration in both electronic system design and BIT design since Automatic Test Equipment (ATE) accessibility must be provided to both initiate BIT operation and to test the system. BIT and ATE test points must be compatible and harmonizing. BIT and ATE require evaluating the relative advantages of each method. Allocation of respective test functions will be the result of trade-off considerations since neither test method can fully replace the other. From the total life cycle cost point of view, BIT permits considerable cost savings through the reduction of maintenance manhours when properly applied and designed to interface with ATE.

Enough test points and connectors should be provided to permit monitoring or injection of input signals into shop replaceable assemblies (SRA), the monitoring or injection of output signals to SRA's, and the monitoring or injection of control signals. Primary consideration in determining number and location of test points is the degree of required fault isolation. All functions of each next lower assembly should be checked out. All available pins on a test connector should be utilized instead of relying on manual probing of internal test terminals.

In the design of electronic systems, it is often not possible to locate all faults to a single item with BIT or at the available test points with ATE. Thus, fault isolation may also require a manual approach. A procedure utilizing a tabular approach to fault finding can be used to localize faults within a small set of replaceable items. This procedure

is based upon a tabular presentation of system behavior under different input conditions or modes of operation. Each replaceable item can be identified in the columns of a matrix and each test performed identified in the rows. The entries in each position of the matrix will then define the items involved in a given test. An "X" in the box means that the item could be the cause of failure in a particular test. Test for this manual procedure would not be confined to the usual BIT or ATE, but may encompass all modes of operation including normal, BIT, calibration, ATE, and self-test. There could be several tests associated with a given set of input conditions where each test represents a row in the matrix. Each test should be considered independent with respect to the order in which they are performed and the outcome of each test would be a pass or fail. If one test fails, then all items "X"ed in that row would be fault candidates and further testing would be necessary. Manual procedures are simple. If a test fails, vertical lines are drawn through all columns that do not have any "X" entries. The "X"s in these columns are eliminated from further consideration in any subsequent test. If a test passes, a horizontal line is drawn through the test row. Wherever an "X" appears in that row, that column is then eliminated by drawing a vertical line through that column. Thus, fault ambiguities can be resolved manually through the process of elimination.

50.6 Requirement 106 - Maintainability Index. A measure of how well a particular electronic system design meets specific maintainability requirements can be assessed through the various maintainability indices. The design can be assessed through the LRA, QRA, and FI ratios for WRAs and SRAs to provide indication of the ease of remove and replace and the influence on numbers of personnel and maintenance manhours. The lower these ratios are, the more difficult the maintenance tasks will become and, in general, more personnel and more maintenance manhours will be required.

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