NOTE: This draft, dated August 1987, prepared by Naval Air Development Center has not been approved and is subject to modification.

DO NOT USE FOR ACQUISITION PURPOSES.

MIL-E-6051E
Draft Revision
August 1987
Superceding
MIL-E-6051D
7 September 1967

MILITARY SPECIFICATION

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3) CONTROL REQUIREMENTS, SYSTEM

1. SCOPE

1.1 This specification defines the overall system electromagnetic environmental effects (E^3) control design and testing requirements. E^3 includes the following:

a. Electromagnetic Compatibility (EMC)

b. Electromagnetic Interference (EMI)

c. Electromagnetic Vulnerability (EMV)

d. Electromagnetic Pulse (EMP)

e. Electromagnetic Radiation Hazards (RADHAZ)

f. Emission Control (EMCON)

g. Lightning Protection

h. Precipitation Static (P-Static)

i. Bonding

j. Grounding

1.2 This document is applicable to complete aircraft systems (new and modified), including all associated systems and equipments (see 6.1).

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids or request for proposals, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-C-5	Capacitors, Fixed, Mica-Dielectric, General Specification for
MIL-B-5087	Bonding, Electrical and Lightning Protection for Aerospace Systems

MIL-W-5088	Wiring, Aerospace Vehicle
MIL-D-9129	Discharger, Electrostatic; General Specification for
MIL-C-11693	Capacitors, Feed Through, Radio Interference, Reduction, AC and DC (Hermetically Sealed in Metallic Cases), General Specification for
MIL-C-12889	Capacitors, By-Pass, Radio Interference, Reduction, Paper Dielectric, AC and DC (Hermetically Sealed in Metallic Cases), General Specification for
MIL-F-15733	Military Specification, Filters, Radio Interference; General Specification for
MIL-F-28861	Filters and Capacitors, Radio Frequency/Electromagnetic Interference Suppression; General Specification for
MIL-I-8700	Installation and Test of Electronic Equipment in Aircraft; General Specification for
MIL-C-83413	Connector, Electric Ground
MIL-C-85485	Cable, Electric, Filter Line, Radio Frequency Absorptive

STANDARDS

Military

MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-461	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-1377	Effectiveness of Cable, Connector, and Weapon Enclosure Shielding and Filters in Precluding Hazards of Electromagnetic Radiation to Ordnance; Measurement of
MIL-STD-1385	Preclusion of Ordnance Hazards in Electromagnetic Fields; General Requirements for
MIL-STD-1512	Electro-explosive Subsystems, Electrically Initiated, Test Methods and Design Requirements
DOD-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

MIL-STD-1757	Lightning Qualification Test Techniques for Aerospace Vehicles and Hardware
MIL-STD-2072	Survivability, Aircraft; Establishment and Conduct of Programs for
MS3493	Connector, Plug and Cap, Electric, Grounding
MS25384	Plug, Fuel Nozzle, Grounding
MS33645	Receptacle, Grounding, Installation of
MS90298	Connector, Receptacle, Electric, Grounding

HANDBOOKS

Military

MIL-HDBK-235	Electromagnetic (Radiated) Environment Considerations for Design and Procurement of Electrical and Electronic Equipment, Subsystems and Systems
MIL-HDBK-237	Electromagnetic Compatibility Management Guide for Platforms, Systems and Equipment
MIL-HDBK-253	Guidance for the Design and Test of Systems Protected Against the Effects of Electromagnetic Energy
DOD-HDBK-263	Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
MIL-HDBK-274	Electrical Grounding for Aircraft Safety
MIL-HDBK-419	Grounding, Bonding, and Shielding for Electronic Equipments and Facilities

MANUALS

Air Force

AFSC-DH1-4	Electromagnetic Compatibility
AFSC-DH2-X	Handbook of Instructions for Aerospace Vehicle Equipment Design
TO-31Z-10-4	Technical Order for Radiation Hazards
TO-00-25-172	Ground Servicing of Aircraft and Static Grounding/ Bonding

Defense Nuclear Agency

DNA-2048H	Handbook for Analysis of Nuclear Weapon Effects on Aircraft
DNA-2114H-3	DNA EMP (Electromagnetic Pulse) Handbook, Environment and Applications

Navy

OP 3565	Electromagnetic Radiation Hazards (Hazards to Personnel, Fuel and Other Flammable Material)
OD 10773	Safety Principles for Operations Involving Electro-Explosive Devices
OD 30393	Design Principles and Practices for Controlling Hazards of Electromagnetic Radiation to Ordnance
AD 1115	Electromagnetic Compatibility Design Guide for Avionics and Related Ground Support Equipment

2.2 Other publications. The following document forms a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

USAS C1 1965	National Electrical Code

(Application for copies should be addressed to The American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.)

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI C95.1 1982	Safety Level of Electromagnetic Radiation with Respect to Personnel

(Application for copies should be addressed to The American National Standards Institute, 1430 Broadway, New York, New York, USA 10018.)

3. REQUIREMENTS

3.1 System E^3 Control Program. An integration system E^3 control program shall be established and implemented for the system throughout the system life cycle. The program shall include the necessary approach, planning, technical criteria and management controls using MIL-HDBK-237 as a guide.

3.2 Electromagnetic Compatibility Advisory Board (EMCAB). An EMCAB shall be established to govern the E^3 control program, provide means of expediting solution of problems and establishing high level channels of coordination. The details of the EMCAB operation, responsibilities and members are contained in Appendix A.

3.3 System E^3 Control Design and Engineering Requirements. Interference and susceptibility within the system shall be controlled by design provisions to eliminate undesired responses and emissions from all electronic and electrical subsystems/equipments either in or associated with the system, regardless of an electrical, aural, video or mechanical output. This requirement applies to the entire spectrum (including generated harmonics, spurious emissions and susceptibilities) utilized by the installed subsystems and associated ground support equipment (GSE). This requirement includes the operation of subsystems/ equipment with their installed antennas or sensing elements when performing their intended functions. There shall be neither unacceptable response or malfunction of any subsystem/equipment due to EMI produced by any or all of the subsystems/equipments associated with the system. Equipment design and installation shall utilize good electromagnetic protection design practices delineated in the applicable documents.

3.3.1 Analysis and Prediction. Analysis and prediction techniques will be used to identify and prevent EMI problems, and in specifying degradation criteria and safety margins. Available computer programs or mathematical models shall be used to identify potential problem areas in the design, development and production of systems. E^3 analysis shall include the following:

a. Intended operational electromagnetic environment (EME).

b. System design concepts.

c. Mission requirements.

d. EM characteristics of equipment and subsystems.

e. Signal characteristics, power distribution, equipment wiring and cabling installation.

3.3.2 Subsystem/Equipment Criticality Categories. All subsystem/equipment shall be assigned E^3 criticality categories. These assignments shall be based on the impact of safety, or EMI, or susceptibility malfunction, or degradation of performance for all assigned mission. These assignments will be provided in the E^3 control plan.

a. Category I - EMC problems that could result in loss of life, loss of vehicle, mission abort, costly delays, or unacceptable reduction in system effectiveness.

b. Category II - EMC problems that could result in injury, damage to vehicle, or reduction in system effectiveness that would endanger the success of mission.

c. Category III - EMC problems that result only in annoyance, minor discomfort, or loss of performance that do not reduce desired system effectiveness.

3.3.3 Degradation Criteria. Degradation criteria shall be established for each system/subsystem. These criteria shall be used to define and evaluate malfunctions and unacceptable and undesirable responses. When available, the results of subsystem/equipment laboratory interference tests shall be used in establishing or defining criteria. When error budgets are established, the portion allocated to EMC shall be included as part of the degradation criteria.

3.3.4 Safety Margins. Safety margins shall be established for systems/equipments assigned to criticality categories I and II which would result in a catastrophic failure if susceptible to EMI. Flight critical avionics and flight controls shall have a safety margin of 6 dB. The safety margin for Electro-Explosive Devices (EEDs) is defined by MIL-STD-1385.

3.3.5 Intrasystem E^3 Control. Unless otherwise specified, subsystems/equipments shall be designed to meet the requirements of MIL-STD-461 and MIL-STD-462. Each equipment/subsystem will not cause EMI to nor be susceptible to EMI from other equipments/subsystems contained within the system in accordance with the degradation criteria established for each equipment/subsystem.

3.3.6 Intersystem E^3 Control. The system design shall be compatible with the external EME as specified in MIL-HDBK-237A unless specified otherwise in the system specification. Consideration shall be given to the intended mission profiles, and the degree to which the external environment can reduce the desired effectiveness of the system. The system and its subsystems shall meet all design requirements including Operational Readiness Test (ORT) and Built-In Test (BIT) checks when in a friendly or hostile external EME. Mission and safety requirements shall be met during operations when electromagnetic energy is coupled to the aircraft through equipment, subsystems, GSE and external electrical power. Guidance for the design and testing for EME protection is provided in MIL-HDBK-253.

3.3.7 Bonding and Grounding. Bonding and grounding of all electrical/electronic equipments shall be in accordance with MIL-B-5087B to provide a low path resistance (equal to or less than 2.5 milliohms) from equipment enclosure to the structure as required for class R bonding.

3.3.7.1 Composite Structures. Components and/or equipments located behind composite structures shall be shielded from E^3. Each structure made from fibrous composites shall be properly bonded (electrically) to the main structure and shall comply with the lightning requirements of MIL-B-5087B and MIL-STD-1795.

3.3.7.2 Doors and Hatches. All doors, hatches, panels and covers shall be properly bonded to the structure in accordance with MIL-B-5087B. When conductive gasketing is used to meet EMP requirements, materials shall be selected to maintain the conducting contact needed for successful shielding during the life of the system.

3.3.7.3 External Grounds for Aircraft. Grounding jacks shall be installed on the system in sufficient quantity to permit connection of grounding cables for fueling, weapons handling, and other servicing operations, MS90298 jacks shall be used or an approved equivalent flush-mounted jack. As a minimum, the following grounding jacks are required:

a. Fuel nozzle ground. A ground jack is required at each fuel inlet and shall be installed to comply with MS33645.

b. Servicing grounds. Multiple ground jacks shall be installed at locations convenient for servicing and maintenance. A minimum of two grounding jacks are required for utility and helicopter aircraft, and four for other types of aircraft, in addition to those required for fueling or weapons.

c. Weapon grounds. Multiple grounding jacks shall be installed at locations convenient for use in handling of weapons or other explosive devices. Typically, a grounding jack is necessary near each pylon or other attachment or loading point, in addition to those required for fueling or servicing.

3.3.7.4 Grounding Jack Installation. The grounding jacks shall be attached to structure so that the resistance between the mating plug and structure shall not be greater than 2.5 milliohms. When possible, the jacks should be mounted so that the grounding cable can disconnect, if inadvertently not removed before flight.

3.3.7.5 External Grounds for Servicing Equipment. Each item of servicing equipment or aerospace ground equipment shall have a grounding wire suitable for connection to an earth ground rod. In addition, all servicing equipment that handles flammables, explosives, oxygen, or other potentially hazardous materials shall have a permanent bonding cable attached for connection to the aircraft. The bonding and grounding cables shall use plug MS25384 for the connection to the aircraft and an approved fitting for connection to the ground rod.

3.3.7.6 External Grounds for Missiles and Spacecraft. External grounding points for missiles and spacecraft shall be specified in the system specification or E^3 plan.

3.3.7.7 Grounding at Bases and Fixed Sites. Grounding provisions at fixed sites such as air base ramps, fueling and defueling, weapons handling, and other hazardous servicing areas, missile sites, and ground based subsystems shall, as a minimum, meet the requirements of the National Electrical Code USAS C1 1965 and MIL-B-5087.

3.3.8 Transients. For aircraft systems, spikes (transients) less than 50 microseconds duration shall not exceed +50 percent nor -150 percent of the nominal d-c line voltage, nor ±50 percent for a-c power lines. Spikes of duration longer than 50 microseconds shall comply with the overvoltage curve in the applicable power quality specification. Requirements for other types of systems shall be included in the systems specification or EMC plan. In addition, the operation of individual equipment/subsystem (from on to off, off to on or from operational mode to operational mode) shall not cause EMI in the other equipments/subsystems.

3.3.9 Emission Control. The equipments/subsystems in standby or receive modes shall not emit electromagnetic energy in excess of -110 dBns/m^2 at one nautical mile from 10 kHz to 40 GHz.

3.3.10 Personnel Hazards. The system design shall include provisions for protection of personnel from R-F hazards, electromagnetic, electrostatic and shock hazards in accordance with requirement 1, MIL-STD-454. Where possible, protection provisions shall be designed into associated subsystems/equipments. When protection by design is not technically feasible, adequate safety precautions shall be included in operating and maintenance manuals. The shock hazard, requirement 5, MIL-STD-454, shall apply for all suppression devices used.

3.3.11 Radiation Hazards. The system shall be designed to protect personnel, ordnance and fuel from any form of electromagnetic or electrostatic energy.

3.3.11.1 Hazards of Electromagnetic Radiation to Personnel (HERP). Personnel shall be protected against HERP to the requirements of MIL-HDBK-238 and ANSI C95.1-1982.

3.3.11.2 Hazards of Electromagnetic Radiation to Ordnance (HERO). The HERO requirements for the aircraft shall be in accordance with MIL-STD-1385A. All modes of operation during the mission including loading, unloading, check-out, prelaunch, etc., shall be those defined in MIL-STD-1385A.

3.3.11.3 Hazards of Electromagnetic Radiation to Fuel (HERF). The aircraft shall be protected from hazards to fuel from the electromagnetic environment and the lightning threat.

3.3.12 Static Electricity (P-Static). The system shall be designed to prevent static electricity (precipitation static/p-static) from degrading system effectiveness.

3.3.12.1 P-Static Control. Anti-precipitation static systems, utilizing approved components, shall be provided and include insulated wire antennas and wick dischargers, where appropriate. The exterior of the aircraft and the location of all antennas shall be such as to minimize the generation and coupling of corona-type interference. Plastic canopies which house antennas, radomes, windshields, and similar insulating surfaces which protrude into the airstream (except antenna masts and insulators) shall be semiconducting surfaces to prevent the accumulation and impulsive redistribution of charges. In general, the surface resistivity shall be within the limits of 1 to 10,000 ohms per square, but radio compass-loop antenna housings may have a surface resistivity as low as 9,000 ohms per square. The lower limit of resistivity in a particular case may be relaxed to any practical value, provided that nonexistence of serious attenuation or other affect on the antenna performance has been demonstrated.

3.3.12.2 Static Dischargers. An active, passive, or combination discharge system capable of discharging 1 milliampere of static electricity shall be provided.

3.3.12.3 Conductive Coatings. Conductive coatings shall be applied to all nonmetallic materials on the external surface of airborne vehicles that are exposed to airflow. After application, coating resistance shall measure not less than 10 megohms and not greater than 50 megohms per unit area at any given point.

3.3.12.4 Electrostatic Discharge (ESD) Device Protection. Solid-state devices will be protected from ESD by implementation of DOD-HDBK-263 and DOD-STD-1686. Ultra sensitive (0 to 1000 volts) Class 1 devices shall not be used.

3.3.13 Lightning Protection. Flight-critical equipment shall be designed (MIL-STD-1795) to operate during, and remain flightworthy after, the effects of a lightning strike to the airframe as defined by MIL-STD-1757. Mission-essential equipment shall remain mission-capable following such a strike. All other subsystems and equipments shall be hardened against lightning effects to the extent that burn-out and permanent upset are prevented. Systems other than flight-critical shall be protected to prevent burn-out. A lightning protection analysis shall be prepared by the developing activity and submitted for approval.

3.3.14 EMP. The equipment and the integrated system shall be designed so that repeated exposures to EMP shall not upset or degrade performance or lessen the probability of mission completion. System responses to EMP which cause momentary outages shall not be deemed to degrade mission completion probabilities when the operating mode or condition is maintained.

3.3.15 Wiring and Cabling. A general specification shall be prepared and utilized defining requirements for wire and wire bundle routing, shielding, grounding, line separation, line shielding and shield termination. All interconnecting cables shall be classified on the system and subsystem levels into groupings representing categories of similar signals. The contractor shall provide each cable type with shielding and grounding criteria. Maximum spacings between dissimilar cable harnesses shall be maintained and harnesses shall be routed as closely to the ground plane as permitted. All new interfaces shall use MIL-C-38999, Series III or IV connectors. All connectors shall be cadmium plated. Any electroless nickel-plated receptacles shall be mated with cadmium plugs. Shielded wires shall be terminated at each end to backshells or connectors that are conductive and provide bonding of shields 360° around the connector. Wiring and cabling shall be designed in accordance with MIL-W-5088. RF absorptive filter line electrical cabling in accordance with Specification MIL-C-85485 shall be the preferred EM suppression technique, where applicable, over filter connectors.

3.3.16 Electrical Connectors. Electrical connectors shall conform to the requirements of MIL-E-5400 except that external connectors used to interface units with aircraft wiring shall be in accordance with MIL-C-38999, Series 3 or 4. Insert configurations shall be selected from MIL-STD-1353. All connectors shall be cadmium-plated. Any electroless nickel-plated receptacles shall be mated with cadmium plugs. Connectors used to carry shielded wires shall not use a nonconductive finish and shall use a backshell or a connector that provides for bonding of shields 360° around the connector.

3.3.17 Electrical Power. The contractor shall provide E^3 design criteria to ensure that subsystem/equipments for aircraft installation shall not malfunction or have unacceptable responses when supplied with electrical power conforming to MIL-STD-704D. This includes surges, ripples and other electrical conditions which can cause EMI.

3.3.18 Suppression Components. Suppression components shall be of the minimum practicable volume and weight. Capacitors should be used when filters are not required. If excessively larger, heavy components are found to be necessary, the procuring activity shall be notified. Suppression components shall be in accordance with MIL-C-15733 for filters, and MIL-C-5, MIL-C-11693, or MIL-C-12889 for capacitors. The components may be qualified during subsystem/equipment qualification tests when installed in the initial design, and with permission of the procuring activity.

3.3.19 Frequency Management. The developing activity shall design the equipment for required performance using the specified or allocated frequencies with channelling and signal characteristics compatible with other systems across the frequency spectrum. On newly-developed equipment, the electromagnetic signal characteristics shall be measured for both transmitter and receiver, in accordance with MIL-STD-449 and MIL-STD-469 for the system. Frequency Allocation and Equipment Spectrum Signature Data reports shall be provided. Submission of frequency data to the procuring activity does not relieve the developing activity of any responsibility for obtaining Federal Communication Commission (FCC) authorization to operate the equipment while in his possession.

3.3.20 Commercial Subsystems/Equipments. When commercial off-the-shelf subsystems/equipments, either airborne or ground, are considered for use in a system, the following rules shall be used in selecting and utilizing the equipment in the system:

a. The equipment may be considered adequate if the system requirements are not significantly more stringent than those to which the equipment was designed, and interference test reports are available to adequately demonstrate compliance; however, compliance with the requirements relating to subsystems/equipments shall not relieve the contractor of the responsibility of providing system compatibility.

b. Where compliance with interference requirements cannot be substantiated due to unavailability of test reports, laboratory interference tests may be performed for qualification of the subsystem as negotiated with the procuring activity.

c. After evaluation of the data, if it is determined that more stringent requirements are necessary, it shall be the responsibility of the developing activity to implement these requirements, or select another equipment with adequate characteristics.

3.3.21 Government Furnished Subsystems/Equipments. Government furnished equipment (GFE) that is required for use in the system shall be acceptable from an EMI viewpoint, provided the interference and susceptibility requirements as outlined below are met:

a. New subsystem/equipment designs must have met, as a minimum, the requirements of MIL-STD-461 and be supported by approved qualification test reports.

b. When compliance with applicable military specifications cannot be substantiated, the developing activity may perform laboratory test for qualification of subsystem to the applicable requirements as negotiated with the procuring activity.

c. GFE, which cannot meet the requirements, and for which external suppression measures are ineffective, may be modified in accordance with the terms of the contract if approved by the procuring activity. If such procedures are not specified in the contract, the developing activity shall advise the procuring activity, by letter, of subsystems/equipments that cannot meet the requirement and pertinent details concerning the modifications required.

3.3.22 Subsystem/Equipment Installation. The developing activity is responsible for the proper installation engineering of all subsystems/equipments to achieve a compatible installation. Where it is demonstrated that interference caused by GFE cannot be eliminated either by proper installation, control of the system electromagnetic environment, or by reasonable modification to the subsystem/equipment, as permitted by the contract, the procuring activity may consider waiving the requirement applicable to the particular equipment upon request from the developing activity in accordance with the terms of the contract.

3.3.23 Redesign of Systems. When this document is applied to a system redesign (modification) program, the developing activity's control plan shall propose requirements suitable for the system for review and approval by the procuring activity.

3.4 E^3 Control Plan. The details of the system E^3 control program shall be included in the system E^3 control plan that is submitted for review and approval by the procuring activity. The control plan shall be prepared and submitted in accordance with the requirements of the contract, and compliance with it, after approval, is a contractual requirement. The control plan shall include, but not be limited to, the elements of the overall program as specified in Appendix B and shall be updated during the contract as necessary. The E^3 control plan shall be kept updated by use of supplements or revised pages. Information required by Appendix B, but not available at the time of original submission, shall be included in the supplements.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsible for Inspection. Unless otherwise specified, the developing activity is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the developing activity may utilize his own facilities or any commercial laboratory that has been accreditated by the National Bureau of Standards. The procuring activity reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 E^3 Test Program. The E^3 test program shall be developed and prepared by the developing activity and submitted in a test plan which shall provide for a system E^3 test, an E^3 general acceptance test, missile and space systems tests and shall include, but not be limited to, the items contained in Appendix C.

4.3 Tests

4.3.1 System E^3 Test. The developing activity shall perform a complete E^3 test on the system designated and approved by the procuring activity. The system tested shall be typical of the production configuration and shall preferably be the first article. The E^3 tests shall be performed as delineated in Appendix D.

4.3.1.1 Any production changes or modifications required as a result of the compatibility test shall be incorporated into the system in accordance with the terms of the contract. The developing activity shall then perform the minimum retesting deemed necessary to demonstrate that the production modifications enable the system to comply with this specification. The retest shall be performed on a system acceptable to the procuring activity.

4.3.2 General Acceptance Test. Each production system shall be given a limited test as outlined in the developing activity's approved test plan to ensure production compliance with the EMC requirements. Each unmanned system shall be subjected to a simulated prelaunch countdown and mission with the minimum instrumentation necessary to ensure production compliance.

4.3.3 Additional Tests for Missile and Space Systems. The following tests shall be performed, when required, by an approved control plan.

a. Tests to demonstrate that GSE is compatible.

b. Tests to demonstrate that each stage and its GSE is compatible at the interface.

c. Tests to demonstrate that subsystems/equipments on each stage are compatible.

d. Tests to demonstrate compatibility at the interface of the facility and the system.

e. Tests to demonstrate compatibility at the interface between stages.

4.3.4 Lightning Tests. Every effort shall be made to minimize lightning tests on actual sites or vehicles, although those tests required to demonstrate safety shall be run. Analyses and tests on scale models of the vehicle or sites will often be adequate. Safety of external stores, fuel tanks, radomes, canopies, navigation lights, fuel dump, wiring, explosives, weapons, gantries, and cable runs shall be demonstrated. The contractor shall investigate the availability of Government facilities for these tests.

4.3.5 Static Electricity. Tests to verify adequacy of electrification design of the system shall be performed as specified in the contract or approved test plan.

4.4 Test Conditions. All outstanding approved engineering orders, engineering change proposals, modifications, and configuration changes shall be incorporated and installed. All exceptions to these shall be approved, and all such requests shall identify that portion of the system that is not of flight or production configuration.

4.4.1 All subsystems/equipments shall have complied with MIL-STD-461 and MIL-STD-462, or have approved deviation requests.

4.4.2 The test plan and procedures for the system shall have been approved and all required changes incorporated. Tests shall not be permitted without an approved test plan.

4.4.3 External electrical power supplied to the system under test shall meet the power quality requirements of the applicable specification.

4.4.4 Test locations shall be approved by the procuring activity. Tests shall not be conducted in any area or at any time when the EME at the test site would affect the validity of the tests.

4.4.5 During tests, all electronic subsystems/equipments under control of crew personnel shall be adjusted, within the limits of the subsystem specification, for maximum indication of interference or susceptibility consistent with normal subsystem operation.

4.4.6 Tests shall be performed to indicate compatible operation, undesirable responses, unacceptable responses, or malfunctioning while all subsystems/equipments are operated. It shall be the responsibility of the developing activity to determine conclusively and correctly the causes of all such indications of noncompatibility.

4.4.7 Each subsystem/equipment shall be monitored by appropriate means to adequately evaluate the effects of system operation and demonstrate applicable safety margins. Instrumentation to be used shall be specified in the test plan.

4.4.8 The overall system shall be operated in all normal modes of operation. Where necessary, programmed missions, flight, and launch sequences shall be used.

4.4.9 When subsystems/equipments require special inputs such as doppler, simulated stars, temperature, et cetera, the means of simulating these inputs shall be described in the test plan.

4.4.10 The EMC tests shall demonstrate the required compatibility when subsystems/equipments, including AGE, trainers, and simulators, are individually or collectively operated in all modes of operation as specified in Appendix D. Transmitters and receivers shall be operated at those critical frequencies identified during system analysis and subsystem/equipment laboratory tests. Transmitter frequencies shall be chosen so that harmonics fall receiver tuned frequencies, intermediate frequencies, et cetera. Multichannel transmitters and receivers shall be tested at a representative number of frequencies usually not less than 20. If the system uses special frequencies for command channel distress messages, or other purposes, they shall be given special attention.

4.5 Acceptance Criteria

4.5.1 Compliance with the specification shall have been achieved when compatible operation, including any approved safety margins, is demonstrated without unacceptable responses or malfunctions. If the procuring activity agrees that it is impractical, or not within the contractor's ability to make corrections, minor undesirable responses shall not prevent the system from complying.

4.5.2 At no time shall the spike (transient) voltage at the electrical power input terminals of category I or II subsystems/equipments exceed the levels specified. Special equipments and spike detectors shall be used to monitor power input circuits.

4.6 Safety Margins. When safety margins have been established and approved for subsystems/equipments, the inputs, outputs or other test points shall be monitored on a continuous basis.

4.7 Instrumentation. Where possible, approved support equipment intended for use with the system shall be used to monitor subsystems/equipments and provide data records. If the procuring activity agrees, special instrumentation may be used. All records shall be provided with time or event correlation.

4.8 Test Site Ambient EME. The ambient EME at the test site shall be monitored, measured, analyzed, or controlled to the extent necessary to ensure that this ambient environment does not degrade test results or mask interference from the system. When possible, all support or site equipment that generates interference that is unacceptable shall be suppressed, removed, or not operated. The frequency range to be considered shall be from 10 kHz to 20 GHz. If the procuring activity agrees, measurements at the test site may be limited to the frequency ranges of receivers associated with the system. All ambient signals that may degrade test results shall be recorded on permanent records and identified.

4.9 Test Report. A complete test report, describing the E^3 TP, conforming to MIL-STD-831 shall be provided in accordance with the contract. The report shall contain complete information on all applicable tests and other information required by this document.

5. PREPARATION FOR DELIVERY

5.1 This section is not applicable to this specification.

6. NOTES

6.1 Intended Use. This specification is intended for use by the Army for procurements of airborne systems and vehicles; by the Navy for associated subsystems and aircraft; and by the Air Force for both aerospace and ground systems.

6.2 Definitions. Definitions are those contained in MIL-STD-463.

APPENDIX A

CHARTER FOR

AIRCRAFT WEAPON SYSTEM

ELECTROMAGNETIC COMPATIBILITY ADVISORY BOARD

(EMCAB)

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 PURPOSE

1.1.1 This document describes the objectives, organization, responsibilities and actions of the Electromagnetic Compatibility Advisory Board (EMCAB).

1.1.2 The EMCAB is an advisory body established to assist the Program Manager and the Assistant Program Manager in assuring that the aircraft weapon system is electromagnetically compatible within its operational electromagnetic environment.

1.2 SCOPE. This charter delineates the general requirements applicable to the formation and operation of the EMCAB. The EMCAB is cognizant over the following Electromagnetic Environment Effects (E^3):

a. Intrasystem Electromagnetic Compatibility (EMC)

b. Intersystem Electromagnetic Vulnerability (EMV)

c. Electromagnetic Interference (EMI)

d. Electromagnetic Pulse (EMP)

e. Hazards of Electromagnetic Radiation to Ordnance (HERO)

f. Hazards of Electromagnetic Radiation to Personnel (HERP)

g. Hazards of Electromagnetic Radiation to Fuels (HERF)

h. Emission Control (EMCON)

i. Precipitation Static (P-Static)

j. Lightning

k. High Power Microwave (HPM)

1.3 RESPONSIBILITIES. It is the responsibility of the EMCAB to perform technical analysis and evaluations, make recommendations and assist in achieving EMC of the system in its operational electromagnetic environment (EME). The EMCAB shall be composed of members qualified to make appropriate technical recommendations on system, subsystem and equipment E^3 problem solutions. EMCAB recommendations do not change any contractual obligations, but contractual changes may result from EMCAB recommendations if the recommendations are outside the scope of existing contractual obligations. Any contractual changes will be processed through established management channels.

1.4 OBJECTIVES

1.4.1 The objectives of the EMCAB shall be to assist in the achievement of EMC throughout the life cycle of the system. This assistance shall be provided by advising the contractors of appropriate methods of assuring good EMC design. EMCAB activities shall include but not be limited to the following:

a. Review of E^3 requirements and specifications.

b. Recommendation of E^3 requirement changes as appropriate.

c. Review of E^3 program status.

d. Review of E^3 documentation.

e. Coordination of Government Furnished Equipment (GFE) E^3 requirements with the V-22 E^3 requirements.

f. Coordination of E^3 tasks through appropriate management channels for action.

g. Review of contractor system and equipment E^3 planning, design, test and data.

h. Identification of E^3 problems.

i. Recommendation of solutions to E^3 problems.

j. Review and evaluation of E^3 Engineering Change Proposals (ECPs), deviations and waivers.

1.4.2 The EMCAB chairman shall ensure that each participating activity establishes an individual effort in consonance with the overall program EMC objectives; that effective methods of monitoring EMC efforts and progress are established and followed; that periodic EMC program design reviews are scheduled and conducted; and that deficiencies noted are promptly reported.

2.0 ORGANIZATION. The EMCAB shall consist of representatives of the procuring activity, government activities, prime contractor and subcontractors, as required.

2.1 MEMBERSHIP

2.1.1 The EMCAB shall be chaired jointly by the government and the prime contractor. The vice chairman shall be a government representative and contractor representative. The secretary shall be the prime contractor. Individual member responsibilities shall include the following:

a. Chairman - Government - Co-chair all EMCABs with the contractor Chairman and chair the government only meetings. Approve agenda, meeting dates, EMCAB documents and EMCAB meeting minutes. Distribute agenda, meeting notices, EMCAB documents and EMCAB meeting minutes. Provide tri-service E^3 point-of-contact.

b. Chairman - Contractor - Co-chair all EMCABs with the government chairman. Plan, organize and implement V-22 contractor participation at all EMCABs.

c. Vice-Chairman - Government Representative - Serve as government chairman in the absence of the government chairman. Assist the government chairman as required.

d. Vice-Chairman - Contractor Representative - Serve as the contractor chairman in the absence of the designated contractor chairman.

e. Secretary - Contractor - Provide secretarial services. Prepare agendas, summary reports and minutes of the meetings.

f. Members - Permanent - Represent their organization and provide an interface between the EMCAB and their organization. Participate in EMCAB activities specified in paragraph 1.4.1 above. Present E^3 problems to the board. Provide agenda items. Participate in E^3 problem-solving. Report E^3 problem/solutions to their organization.

g. Members - Consulting - Represent their organization and provide an interface between the EMCAB and their organization. Participate in EMCAB activities specified in paragraph 1.4.1 above as required by NAVAIRSYSCOM (AIR-5161). Provide information on specialized E^3 designs.

2.1.2 Permanent Members. Organizations to have permanent members are as follows:

a. Government procuring activity

b. Government support activities

c. Prime Contractor

2.1.3 Consulting Members. Consulting members are considered the technical support group of the EMCAB and such, shall be available for attendance at EMCAB meetings when requested by the procuring activity. The consulting member organizations are as follows, but not limited to:

a. Government support activities

b. Subcontractors

3.0 MEETING DOCUMENTATION

3.1 Agenda. The agenda shall be prepared by, or under the supervision of, the government chairman in advance of each regular or special meeting. The government chairman shall be responsible for the content, preparation, and distribution of the agenda. The final agenda shall be approved and distributed at least fifteen days prior to the meeting and fully coordinated with the contractor chairman and government procuring activity.

3.1.1 Permanent Agenda Items. The following shall be addressed at each EMCAB:

a. Approval of previous meeting minutes.

b. Review of outstanding Action Items.

c. Review of E^3 Program Schedule/Milestones.

d. Discussion of E^3 designs and/or problem areas.

e. New E^3 activity.

f. Review of newly assigned Action Items.

g. Tentative date and place of next EMCAB meeting.

3.1.2 Specialized Items. Technical items requiring an in-depth presentation or discussion will be scheduled on an "as required" basis and included as new E^3 activity. Such specialized items include:

a. Support material for technical action items.

b. Progress reports from specialized subcommittee chairmen.

c. Discussion of E^3 test plans, procedures, results.

d. Discussion of E^3 documentation.

e. Identification of E^3 problem areas.

f. Recommended approaches for E^3 problem solution.

3.2 Action Items. Action item assignments shall be noted in the meeting minutes. The status of each open item will be reviewed at each meeting and recorded in the minutes. Reports, letters, data, etc., necessary to close the action item shall be provided from the person or persons responsible for performing the action for publication in the minutes.

3.3 Minutes. Minutes of each EMCAB meeting shall be recorded by the secretary. A copy of the minutes shall be forwarded to all members within 30 days after each meeting. The published minutes shall include:

a. Date and place of meeting.

b. List of all attendees.

c. Name of person(s) chairing the meeting.

d. Summary of topics discussed.

e. Complete descriptions of action items and decisions.

f. EMCAB recommendations.

g. Tentative date and place of next EMCAB meeting.

h. Action Item Summary.

i. Copy of unclassified presentations.

4.0 MEETING SCHEDULE. Meetings shall be scheduled no more than six months apart. Tentative planning for the subsequent meeting shall be accomplished at each meeting. Such planning will include date, time, location, and preliminary agenda items.

APPENDIX B

REQUIREMENTS FOR

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3)

CONTROL PLAN

The electromagnetic environmental effects (E^3) control plan shall include, but not be limited to, the following elements of the overall program:

a. Responsibility, and authority of the individual who will direct and implement the contractor's electromagnetic compatibility program.

b. Number and experience of full-time and part-time electromagnetic compatibility (EMC) personnel available for the program.

c. Methods and requirements for ensuring that contractor developed subsystems/equipments will not be adversely affected by interference from sources within the system nor be sources of interference that might adversely affect the operation of other subsystems (Implementation of MIL-STD-461 and 462).

d. Predicted problem areas and proposed methods of approach for solution for problems not resolved by compliance with MIL-STD-461 and 462.

e. Radiation characteristics from system antennas, including fundamental and spurious energy, and antenna-to-antenna coupling.

f. General approach to cable design including wire categorization criteria for identifying, labelling and installing interference generating or susceptible wires; shielding techniques; and wire-routing.

g. Impact of corrosion control requirements on EMC and recommendations for resolution of problem areas.

h. Design criteria and required tests for lightning protection and design impact on individual subsystems.

i. Design criteria and required tests for electrification, including precipitation static (P-Static) and propulsion subsystem charging.

j. Methods of implementation of design changes required for EMC.

k. Special requirements, test methods, and limits necessary for the system and associated subsystem/equipment.

l. Facilities that will be required and made available for the EMCP.

m. Methods of accomplishing design review and coordination with subcontractors and vendors.

n. Spike protection requirements for subsystems/equipments connected to the power bus.

o. Bonding criteria.

p. Grounding criteria.

q. EMC requirements for contractor furnished off-the-shelf equipment.

r. Application of interference control specifications and standards through the phases of definition, design, and production.

s. Proposed charter and details of operation of the electromagnetic compatibility board.

t. Criticality category and degradation criteria for each subsystem/equipment including safety margins, where necessary.

u. Spectrum utilization design provision measures including control of emitters and frequencies, harmonics thereof bandwidth control of oscillator frequencies, rise time, et cetera.

v. Scheduling and milestones.

APPENDIX C

REQUIREMENTS FOR

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3)

TEST PLAN

The electromagnetic environmental effects (E^3) test plan shall include, but not be limited, to the following information:

a. Methods to be used to select critical circuits to be monitored for compliance to the degradation criteria and safety margin.

b. Procedures used for developing failure criteria and limits.

c. Test conditions and procedures for all electronic and electrical equipment installed in or associated with the system and the sequence for operations during tests, including switching.

d. Implementation and application of test procedures which shall include modes of operation and monitoring points for each subsystem and equipment.

e. Use of approved results from laboratory interference tests on subsystems and equipment.

f. Flight test program (manned systems only).

g. Methods and procedures for data readout and analysis.

h. Means of testing design adequacy of vehicle electrification (static electricity) and lightning protection.

i. Means of simulating and testing electroexplosive subsystems and devices.

j. Demonstration of the approval safety margin for electroexplosive devices, and for systems whose degradation affects safety-of-flight or mission success.

k. Electrical power voltage limits, and methods for monitoring a-c and d-c power buses to assure that voltages are within the proper limits.

l. Test locations and descriptions of arrangements for simulating operational performance in cases where actual operation is impractical.

m. Adjustments and settings of variable controls such as audio gain, video gain, sensitivity, squelch settings, et cetera.

n. Details concerning frequency ranges, channels, and combinations to be specifically tested such as image frequencies, intermediate frequencies, local oscillator, and transmitter fundamental and harmonically related frequencies. Subsystem susceptibility frequencies identified during laboratory testing shall be included.

o. Personnel required, Government, contractor, and vendor.

p. Calibration schedules and description of unique EMC instrumentation for measuring electrical, video, and mechanical outputs of equipments and subsystems to be monitored during the testing including applicable safety margins.

q. Means of simulating signal inputs such as doppler, radar altimeter, et cetera.

r. Evaluation and degradation criteria for each subsystem and equipment.

s. All E^3 tests as required by Appendix D.

APPENDIX D

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3)

TEST AND EVALUATION REQUIREMENTS

1.0 E^3 TEST AND EVALUATION

1.1 Scope

1.1.1 The E^3 evaluation will include, but not be limited to the following:

a. Pre-evaluation inspection

b. Intrasystem

(1) Bonding

(2) Equipment functional compatibility (Intrasystem)

c. Intersystem

(1) Radiated emissions

(2) EMCON

(3) Radiated susceptibility

d. Flight evaluation

1.2 Pre-Evaluation E^3 Inspection

1.2.1 This inspection shall be performed on the subject aircraft to document the equipment available on board versus the avionic suite, and verify full mission capability, expedite any action required to obtain missing equipment or repair or replace malfunctioning equipment.

1.3 Intrasystem Evaluation

1.3.1 The intrasystem E^3 evaluation will be performed to determine the electromagnetic compatibility (EMC) of the electrical and electronic equipments and subsystems with each other. The intrasystem E^3 test and evaluation shall include the following:

a. Bonding

b. Equipment EMC

1.3.2 Bonding. Measurements will be performed as required by MIL-B-5087B. The results will be recorded on data sheets and out-of-specification conditions will be noted. The following areas will be measured:

a. Avionics bay shelves to airframe

(1) shelf to rack

(2) rack to equipment

b. Racks/consoles to airframe

(1) console to control box/instrument, etc.

c. Instrument panel to airframe

d. Antenna mount to airframe

1.3.3 Equipment Electromagnetic Compatibility

1.3.3.1 An evaluation of the operational EMC of the system shall be performed. Proper interaction of subsystems will be established to preclude identification of multi-subsystem failures (i.e., when only one subsystem is susceptible and other subsystems are responding properly to the invalid command of the susceptible subsystem). All susceptible equipment will be operated as victim equipment in predetermined modes, while the source equipments are operated. Outputs and displays of the victims will be monitored for possible malfunction or indications of degradation while being subjected to all EMI sources. All data will be logged by identification of the source and victim, measured levels of undesirable response, indications or malfunctions and the EMI frequency where applicable. Data will be recorded on data sheets. The following combinations will determine the EMI effects for the E^3 evaluation:

a. Receiver to receiver

b. Transmitter to receiver

(1) fundamental, harmonic and spurious frequencies

(2) receiver spurious response

(3) intermodulation

(4) cross modulation

c. Transmitter to active device

d. Transmitter to passive device

e. Receiver to active device

f. Receiver to passive device

g. Active device to passive device

h. Active device to receiver

i. Electrical power system transients

j. Electrical/electronic subsystems transients

k. Simulated mission.

1.3.3.2 Signal-to-Override Test. The signal-to-override test measures the degradation of equipment performance produced by an EMI source.

1.3.3.3 Crosstalk (Circuit Isolation). Crosstalk is the electromagnetic disturbance introduced by the cross-coupling of energy between circuits. The evaluation will be performed to measure the degree of isolation between interphone and receiver circuits.

1.3.3.4 Background Noise Level Measurement. The level of background noise will be measured in two phases. The first is performed during the application of each individual load while any increase over the background is recorded on data sheets. The second phase is performed while all loads are applied to simulate operational loading conditions.

1.3.3.5 Receiver-to-Receiver. These evaluations will be performed to determine if onboard receivers will be a source or a victim of interference due to other receiver emissions. The evaluation frequencies to be used will be chosen to specifically evaluate spurious outputs and responses of the receivers. Receivers as a source of EMI will be examined for spurious output of the first local oscillator.

1.3.3.6 Transmitter versus Receiver. This evaluation will be performed to determine whether there is interaction between each transmitter and receiver. The frequencies to be used will be chosen in the same manner as the receiver-to-receiver evaluation (paragraph 4.4.3.5). The transmitter outputs investigation includes:

a. First order spurious

   (1) Mixer input frequency

   (2) Local oscillator frequency

   (3) Image (spurious mixer product)

b. Higher order mixing products

   (1) Inband mixing products

   (2) Out-of-band mixing products

      (a) HF if a harmonic filter is not installed

      (b) LF if a high pass filter is not installed

c. Harmonics through the seventh

1.3.3.6.1 Intermodulation. The intermodulation measurements provide the resultant quieting or signal modulation of an undesired signal produced in a receiver or transmitter as a result of the mixing of two or more off-channel signals in a non-linear device. Transmitter frequencies and receiver response frequencies will be identified in terms of response characteristics of each receiver.

1.3.3.6.2 Cross-Modulation. Cross-modulation is the transfer of amplitude modulation from an interfering signal to the desired signal. Cross-modulation occurs when both the desired signal within the receiver passband and the undesired signal are simultaneously present in a nonlinear device. Adjacent channels, upper and lower, and image-frequency interfering signals will be investigated.

1.3.3.7 Transmitter versus Active Devices. This evaluation will be performed to determine whether the onboard transmitter(s) will interfere with active devices. Active devices will consist of HF/VHF/UHF security, secure data line, transponder and IFF interrogator computers, mission computers and stores management systems, etc. The transmitters will be tuned and transmit on frequencies which coincide with digital clock frequencies, etc.

1.3.3.8 Transmitter versus Passive Devices. The evaluation will be performed to determine whether the onboard transmitters will cause EMI in the passive devices. Passive devices include: INS, HSI, radar scan converter set, AFC, true airspeed system, lighting, etc.

1.3.3.9 Receivers versus Active Devices. This evaluation will be performed to determine if onboard receivers will be a source of EMI to any active device. The frequencies to be used will be chosen specifically to test spurious outputs of the local oscillator.

1.3.3.10 Receiver versus Passive Devices. This evaluation will be performed to determine if onboard receivers will be a source of EMI to any passive device. The frequencies to be used will be chosen specifically to test spurious outputs of the local oscillator.

1.3.3.11 Active Devices versus Passive Devices. This evaluation will be performed to determine if the active devices will be a source of EMI to any passive device.

1.3.3.12 Active Devices versus Receivers. This evaluation will be performed to determine if any active device will be a source of EMI to any receiver.

1.3.3.13 Electrical Power System Transients. This evaluation will be performed to determine if power transfer transients will be a source of EMI to the ac and dc power systems and the avionics equipments.

1.3.3.14 Electrical/Electronic Subsystems Transients. This evaluation will be performed to determine if electrical/electronic subsystems switching and duty cycle transients will be a source of EMI to the ac and dc power systems and the avionics equipment.

1.3.3.15 Simulated Mission. This evaluation will be performed by turning all equipments and subsystems on for each mission configuration of the aircraft to determine if equipments/subsystems are either a source or victim of EMI.

1.4 Intersystem Evaluation

1.4.1 The Intersystem E^3 evaluation will be performed to determine the EMC or incompatibility of the electrical and electronic equipments and subsystems with the EME.

1.4.2 Radiated Emissions

1.4.2.1 The Radiated Emission evaluation will measure the frequency and field strengths of the signals and spurious radiation from the electrical and electronic subsystems and equipments. The measurements will be made using various measuring positions. This portion of the intersystem evaluation will consist of the following:

a. Unintentional emissions

b. Simulated mission emissions

1.4.2.2 Measurements of unintentional emissions shall be made so as to comply with the EMCON requirements. The evaluation will be performed with all transmitting equipment placed in standby and receivers functioning normally or by introducing EMCON switch(es). Location of unintentional radiators will be determined by de-energizing equipment or by probing the aircraft with directional probes.

1.4.2.3 The simulated mission emission test will be performed by operating the aircraft in a simulated mission condition. The simulated mission will exercise the various equipment and subsystems in both frequency and operational modes to demonstrate actual emissions. This evaluation will be conducted for all aircraft operating with all engines running.

1.4.3 Radiated Susceptibility

1.4.3.1 This evaluation is to determine the susceptibility of all aircraft equipments and GSE, the malfunction of which could effect safety-of-flight or cause mission abort. The aircraft will be exposed to the environments encountered during all typical mission scenarios, as outlined in MIL-HDBK-235 for guidance. Aircraft equipments will be exercised solely and jointly as would occur during typical mission conditions. Specific evaluation phases will include the following:

a. Pre-flight checks on external power

b. Pre-flight checks with engine turning

c. Simulated launch, approach and touch-and-go operations with engines turning

d. Simulated aircraft mission scenario.

1.4.3.2 The data will show the susceptibility threshold, frequency and field strength calculated and measured at the victim equipment.

1.5 Flight Evaluation

1.5.1 Flight evaluation of selected E^3 problems found during the laboratory/ground evaluations will be conducted to ensure/validate the E^3 problems under actual flight conditions.

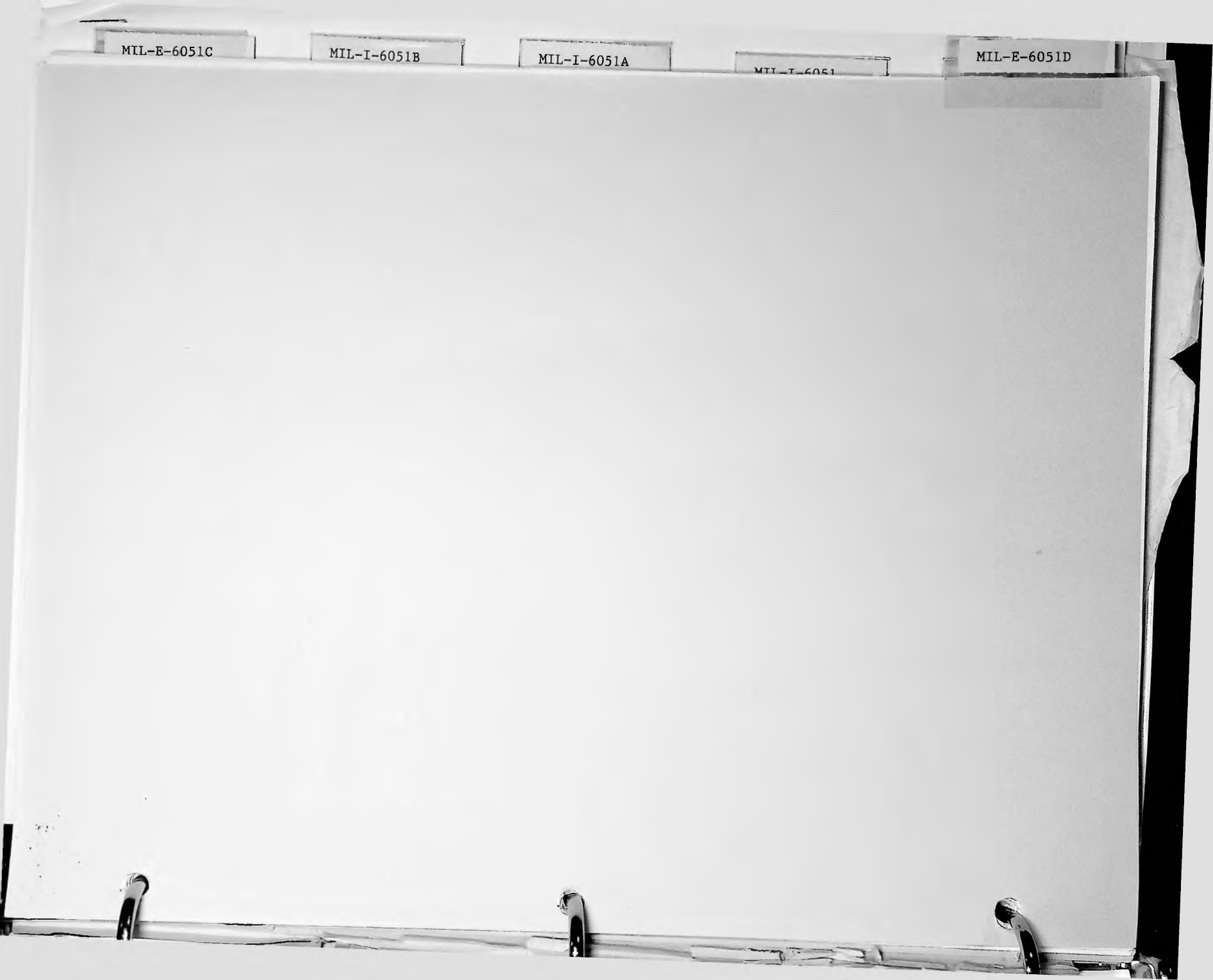
APPENDIX E

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3)

TEST AND EVALUATION REPORT

REQUIREMENTS

(To be determined)


MIL-E-6051C
MIL-I-6051B
MIL-I-6051A
MIL-E-6051D