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MILITARY SPECIFICATION

OFFENSIVE AVIONICS SYSTEM

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W A R N I N G

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AMSC: N/A FSC 5895

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1. SCOPE

1.1 **Scope.** This specification establishes the performance and verification requirements for the offensive avionics system to be used in the ____________ weapon system.

1.2 **Use.** This specification cannot be used for contractual purposes without supplemental information relating to the performance requirements of the offensive avionics system. (This paragraph should be deleted in an applied specification.)

1.3 **Instructional handbook.** The instructional handbook, which is attached as an appendix, provides the rationale for requirements, gives guidance on document usage, acts as a lessons-learned repository, and provides the supplemental information relating to performance requirements. (This paragraph should be deleted in a tailored specification.)

1.4 **Deviation.** Any projected design for a given application which will result in improvement of system performance, reduced life cycle cost, or reduced development cost through deviation from this specification or where the requirements of this specification result in compromise in operational capability shall be brought to the attention of the contracting activity for consideration of change.

2. APPLICABLE DOCUMENTS

2.1 Government documents

2.1.1 **Specifications, standards, and handbooks.** Unless otherwise specified, the following specifications, standards, and handbooks, of the issue in effect on the date of request for proposal, listed in the current Department of Defense Index of Specifications and Standards (DODISS) and its supplement thereto form a part of this specification to the extent specified herein. Subsidiary documents, referenced in the documents listed below, will be used as guides in the performance or verification of the requirements of this document.

SPECIFICATIONS

Military

MIL-B-5087	Bonding, Electrical, and Lightning Protection for Aerospace Systems
MIL-E-6051	Electromagnetic Compatibility Requirements, Systems

STANDARDS

Military

DOD-STD-1795 Lightning Protection for Aerospace Vehicles and Hardware

2.1.2 **Other government documents, drawings, and publications.** The following other government documents, drawings, and publications form a part of this specification to the extent specified herein.

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

2.2 **Other publications.** The following document(s) form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DOD adopted shall be the issue in the current DODISS and the supplement thereto, if applicable.

(Application for copies should be addressed to (name and address of the source).)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

2.3 **Order of precedence.** In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

3. REQUIREMENTS

3.1 **System description.** Offensive avionics are equipment and software which contribute by signal output to accomplish the offensive tasks of the __________ aircraft. The offensive avionics system shall perform the allocated air vehicle offensive avionics mission functions and be compatible with overall air vehicle requirements. The primary mission of the air vehicle is ____________ and the secondary mission is ____________.

a. Communication. The offensive avionics system shall provide bidirectional communication between aircraft and ground, between aircraft and aircraft (may include space vehicles, guided missiles, or guided munitions), and among crew members and to ground crew. This will include command, control, and tactical communications for both voice and data.

b. Navigation. The offensive avionics system shall provide both self-contained and radio navigation capability to navigate to and from the target or destination, to provide escort or other mission objectives. It will interface with the automatic flight control system and terrain-following, terrain-avoidance, and threat-avoidance functions as required.

c. Air-to-air combat. The offensive avionics system shall provide for the location and identification of airborne targets with sufficient accuracy and confidence to successfully engage and destroy airborne targets. The offensive avionics shall provide for the delivery of the weapons listed in table I.

d. Air-to-ground combat. The offensive avionics system shall provide for the location and tracking of fixed and moving ground targets, and collecting and processing of target data required for displaying targets and computing weapon delivery. The offensive avionics shall provide for the delivery of those weapons listed in table I.

e. Controls and displays. The offensive avionics system shall provide the necessary controls and displays to enable the air crew to select and control the offensive avionics system and its subsystems in fulfillment of the required missions.

f. Weapon management. The offensive avionics system shall contain the hardware, software, controls, and displays nessary to initiate signals for the control of weapon inventory, weapon release, weapon release sequencing, weapon conditioning, and jettisoning of selected weapons singly or in groups as listed in table I.

g. Computation and data handling. The offensive avionics system shall contain the equipment necessary to transfer and compute information for the integrated operation of the offensive avionics system within the air vehicle. This equipment shall provide the flexibility to adapt to changing mission and subsystem requirements without adversely affecting the system.

h. Air data. The offensive avionics system shall provide air data information to the navigation and fire control functions.

TABLE I. Weapons.

Air-to-Air	Air-to-Ground

3.1.1 Item diagram. A functional diagram of the offensive avionics is depicted in figure 1.

FIGURE 1. Offensive avionics functional diagram.

3.1.2 **Major components.** The offensive avionics system shall consist of the following major functional components ____________.

3.1.3 **Government furnished property.** The following government furnished property shall be utilized:

a.
b.
c.

3.2 **Performance requirements**

3.2.1 **System characteristics.** The offensive avionics system shall be an integrated system that meets all requirements of this specification while installed in the aircraft and while operating at all points within the operating and environmental envelope of the aircraft, as defined in ____________.

3.2.1.1 **Physical characteristics.** Restrictions to the physical characteristics of the offensive avionics systems are ____________.

3.2.1.2 **Operational characteristics**

3.2.1.2.1 **Operational conditions.** The offensive avionics system shall perform under the following operational conditions:

a.
b.
c.
d.

3.2.1.2.2 **Nonoperational conditions.** To accomplish the ____________ mission, the offensive avionics shall consider nonoperational conditions in worldwide terrain and climatic extremes. The cold-start reaction times shall be ______________. The following nonoperational conditions shall apply:

a.
b.
c.
d.

3.2.1.2.3 **Air-to-air combat.** The system shall be mechanized so that the probability of launching a missile out of bounds shall be no greater than ____________ and the probability of missing a valid launch opportunity shall be no greater than ____________. Air-to-air gunnery shall provide a circular error probable (CEP) of no more than ____________ mils.

3.2.1.2.3.1 **Target location and attack.** The offensive avionics shall provide the locations of multiple airborne vehicles which have signatures of ____________ at ranges of __________ NM, flying at velocities of ________ ft/sec to _________ ft/sec over a terrain reflective coefficient of ____________ dB and in atmospheric conditions of ____________. The locating sensor(s) shall provide all the data required for attack of ____________ targets under the following conditions: ____________.

3.2.1.2.3.2 **Target identification.** The identification function shall provide for discrimination between friendly and hostile targets. At maximum weapon launch range a hostile target shall be identified as hostile at least ______% of the time. A hostile target shall not be identified as friendly more than ______% of the time. Friendly targets shall be identified as friendly ______% of the time. Friendly targets shall not be identified as hostile more than ______% of the time. The identification function shall provide identification of neutrals and noncombatants. The identification function shall discriminate types of hostile targets to the following extent: __________.

3.2.1.2.3.3 **Electronic combat (EC) performance.** The offensive avionics system shall operate at ______% of mode specification performance in an electronic combat environment of the electronic combat level defined by __________ for the modes listed in 3.2.2.10.

3.2.1.2.4 **Air-to-ground combat.** Target location and tracking shall provide the weapon delivery accuracy in the air-to-ground modes specified in table II. The circular errors probable (CEP) stated in table II shall result from all sources of error.

TABLE II. Air-to-ground combat.

Delivery Mode	Delivery Conditions (Alt, Angle, Vel)	Weapon	CEP

3.2.1.3 **Electrical characteristics.** The offensive avionics equipment shall operate within its performance requirements with the electrical power supplied by the ____________ aircraft and its associated ground power.

3.2.1.4 **Environmental conditions.** The offensive avionics system shall operate as specified herein while exposed to the environments of operational use. The equipment shall not fail or suffer functional degradation during lifetime exposures to the environments of operation, deployment, storage, transportation, maintenance, and manufacture. Combined natural and induced environments of worldwide deployment and operation for the offensive avionics equipment are as follows: ____________.

3.2.1.4.1 **Thermal design.** The offensive avionics equipment shall employ internal thermal design techniques which minimize high temperature operation. Specific design requirements are as follows: ____________.

3.2.1.4.2 **Mechanical design.** The offensive avionics equipment shall be designed to withstand and function in the vibration, shock, acceleration and acoustic noise environments. Specific design requirements are as follows: ____________.

3.2.1.5 **Transportability.** Transportability requirements for the equipment shall be as follows: ____________.

3.2.1.6 **Electromagnetic compatibility (EMC).** The offensive avionics system, when installed on the aircraft, shall comply with the system electromagnetic compatibility requirements of MIL-E-6051. These requirements shall apply to the intrasystem, intersystem, and mission electromagnetic environments.

3.2.1.6.1 **Electromagnetic interference.** The electromagnetic interference requirements of the offensive avionics shall be as follows:

a.
b.
c.
d.

3.2.1.6.2 **Lightning protection.** The offensive avionics system shall meet the lightning protection requirements of DOD-STD-1795.

3.2.1.6.3 **Electrical grounds.** The grounding scheme of the offensive avionics system shall be designed to minimize ground loops and common current returns for signal and power circuits, provide effective shielding, and protect personnel from electrical hazards to include the following:

a.
b.
c.
d.

3.2.1.6.4 **Electrical bonding.** All metallic components of the offensive avionics system shall be electrically bonded to each other in accordance with the class R requirements of MIL-B-5087. A defined electrical bonding path from each chassis to aircraft structure shall be provided in accordance with the class R requirements of MIL-B-5087.

3.2.2 **Functional subsystem characteristics**

3.2.2.1 **Voice communication.** The offensive avionics system shall provide voice communications between aircraft and aircraft, aircraft and ground crew, aircraft and ground, and among crew members. The specific frequency band and range coverage are as listed in table III.

TABLE III.

Frequency (MHz)	Omnidirectional Range (Nautical miles)	Secure Voice (Yes or No)
a.		
b.		
c.		
d.		

3.2.2.2 **Data communication.** The offensive avionics shall provide the following data communications:

a.
b.
c.
d.

3.2.2.3 **Radio navigation.** The offensive avionics shall provide the following radio navigation functions:

a.
b.
c.
d.

3.2.2.4 **Self-contained navigation.** The offensive avionics system shall provide a self-contained navigation capability. The performance parameters shall be ____________.

3.2.2.5 **Offensive avionics integration.** The offensive avionics system shall integrate the constituent subsystems to provide functional redundancy, mission reliability, optimal sensor information and aircrew situational awareness. Performance of constituent avionics subsystems shall be ____________.

3.2.2.6 **Computers and multiplexing.** The offensive avionics system shall use ____________ computers and ____________ data bus architecture. The input/output, throughput, and memory capability shall be adequate to accomplish the avionics tasks with adequate spare capacity. Identical computers and microprocessors shall be used to the maximum extent possible. The following detail multiplex characteristics shall apply:

a.
b.
c.
d.

3.2.2.7 **Software.** The offensive avionics operational software shall consist of all computer programs and data necessary to implement and integrate the offensive avionics. The support software shall include the compilers, assemblers, linkage editors, loaders, and simulators required to support the offensive avionics software development, integration, flight test, and operational maintenance efforts.

3.2.2.8 **Information processing requirements.** The software shall efficiently operate within the throughput, precision, accuracy, and stability constraints imposed by the real-time information processing and man-in-the-loop requirements of the offensive avionics system. At ____________ the software shall use no more than _____% of the throughput and _____% of the memory for each general purpose computer and no more than _____% throughput and _____% of the memory for each embedded microprocessor. All software shall be written in __________, an Air Force approved higher order language (HOL).

3.2.2.9 **Fault management.** The offensive avionics system shall incorporate a comprehensive and effective fault detection, isolation, and reporting capability in support of a ____________-level maintenance concept. During the mission, continuous noninterruptive self-testing shall be utilized to alert the aircrew and the offensive avionics system to malfunctions. Before or after the mission, maintenance personnel shall be able to utilize operator-initiated built-in tests and interrogate recorded faults. The offensive avionics system shall perform a self-test (ST) while other operational requirements are being performed. As a minimum the self-test shall provide __________% detection of true faults with no more than _____% false alarms. A built-in test (BIT) capability is required for each subsystem. The BIT shall provide _____% detection, and _____% isolation to the _________ level of all avionics failures with no more than _____% false failure reports.

3.2.2.10 **Avionics modes.** The offensive avionics system shall provide all the modes required to perform the intended missions. These modes shall include, but shall not be limited to, the following:

a.
b.
c.
d.

3.2.2.11 **Growth.** The following __________ (modes, characteristics, performances, etc.) shall permit growth in the design of the equipment. The extent to which the design will include provisions for growth shall be as follows: __________.

3.3 **Avionics integrity.** The offensive avionics system shall be developed to the requirements of __________ to meet the design durability and system life requirements. The life values to be met are service life, expected operating life, and failure-free operating period within the total environment of the air vehicle.

a. Service life. The avionics shall be designed to last for ________ years with economical maintenance before retirement from inventory or salvaging.

b. Expected operating life (EOL). The avionics shall operate for ________ hours within the service life.

c. Failure-free operating period (FFOP). The avionics shall operate for a minimum of ________ hours before failing for the first time and for follow-on failure-free operating periods after replacement of life-limited parts and materials.

3.4 **Maintainability.** The offensive avionics system maintainability shall be as follows:

a.
b.
c.
d.

3.5 **System safety.** The offensive avionics system safety requirements shall be as follows: __________.

3.6 **Human engineering.** The offensive avionics system shall consider human engineering requirements as follows:

a.
b.
c.
d.

3.7 **Interface.** The offensive avionics system interfaces shall meet the following requirements:

a.
b.
c.
d.

4. VERIFICATIONS

4.1 **Verification, general.** The verifications (inspections, analyses, tests, and demonstrations) specified herein shall verify the ability of the offensive avionics system to meet the requirements of section 3 herein. The government reserves the right to witness or conduct any verification.

4.1.1 **Item diagram.** Not applicable.

4.1.2 **Major components.** Not applicable.

4.1.3 **Government-furnished property.** Not applicable.

4.2 **Performance requirements**

4.2.1 **System characteristics.** The system characteristics specified herein shall be tested and verified by the following methods: __________.

4.2.1.1 **Physical characteristics.** Physical characteristics of the offensive system shall be verified by __________.

4.2.1.2 **Operational characteristics**

4.2.1.2.1 **Operational conditions.** Offensive avionics integrity in stated operational conditions shall be verified by analysis and tests as follows: __________.

4.2.1.2.2 **Nonoperational conditions.** Offensive avionics integrity in stated nonoperational conditions shall be verified by analysis and tests as follows: __________.

4.2.1.2.3 **Air-to-air combat.** Air-to-air combat performance stated in 3.2.1.2.3 shall be verified by analysis and test under the following conditions: __________.

4.2.1.2.3.1 **Target location and attack.** Target location and attack capabilities shall be verified by the following test methods: __________.

4.2.1.2.3.2 **Target identification.** Target identification capabilities stated in 3.2.1.2.3.2 shall be verified by the following test methods: __________.

4.2.1.2.3.3 **Electronic combat performance.** The capability of the offensive avionics shall be verified for performance in an ECM environment to assure that the requirement of 3.2.1.2.3.3 has been complied with. Verification methods shall be employed to show the contribution of each ECCM technique and combinations of techniques to counter the threat and accomplish the missions as follows: __________.

4.2.1.2.4 **Air-to-ground combat.** Air-to-ground combat performance stated in 3.2.1.2 shall be verified by analysis and test under the following conditions: __________.

4.2.1.3 **Electrical characteristics.** The offensive avionics equipment shall be demonstrated to be compatible with air vehicle and ground power systems as follows: ____________.

4.2.1.4 **Environmental conditions.** Compatibility of the offensive avionics with the intended environmental conditions shall be verified by analysis and test utilizing the following methods:

a.
b.
c.
d.

4.2.1.4.1 **Thermal design.** The thermal design requirements of 3.2.1.4.1 shall be verified as follows: ____________.

4.2.1.4.2 **Mechanical design.** Design analysis and engineering tests shall be conducted to verify that the requirements of 3.2.1.4.2 are achieved. Analysis and tests shall be as follows: ____________.

4.2.1.5 **Transportability.** Transportability requirements stated in paragraph 3.2.1.5 shall be verified as follows: ____________.

4.2.1.6 **Electromagnetic compatibility (EMC).** The offensive avionics system, when installed in the aircraft, shall conform to the requirements of 3.2.1.6 when tested in accordance with the quality assurance provisions of MIL-E-6051.

4.2.1.6.1 **Electromagnetic interference (EMI).** The offensive avionics system shall conform to the requirements of 3.2.1.6.1 when tested in accordance with the following:

a.
b.
c.
d.

4.2.1.6.2 **Lightning protection.** The offensive avionics system shall conform to the lightning protection requirements of 3.2.1.6.2 when verified in accordance with DOD-STD-1795.

4.2.1.6.3 **Electrical grounds.** Proper grounding topology shall be verified by inspection of the design drawings and examination of the actual hardware.

4.2.1.6.4 **Electrical bonding.** The electrical bonding requirement of 3.2.1.6.4 shall be verified by measurements. An approved milliohm meter shall be used to measure the DC resistance of all bonds.

4.2.2 **Functional subsystem characterization**

4.2.2.1 **Voice communication.** Verification of the voice communication function shall be by ____________.

4.2.2.2 **Data communications.** Verification of the data communication function shall be by ____________.

4.2.2.3 Radio navigation. Verification of the radio navigation function shall be by ___________.

4.2.2.4 Self-contained navigation. Self-contained navigation capability shall be verified by analysis and test as follows: ___________.

4.2.2.5 Offensive avionics integration. Verification of the offensive avionics integration compatibilities shall be by inspection, analysis, demonstration, and test as follows: ___________.

4.2.2.6 Computers and multiplexing. Verification of the requirements of 3.2.2.6 shall be as follows: ___________.

4.2.2.7 Software. The software functional capabilities shall be verified as follows: ___________.

4.2.2.8 Information processing requirements. Information processing requirements shall be verified as follows: ___________.

4.2.2.9 Fault management. The adequacy of the fault management design shall be verified as follows: ___________.

4.2.2.10 Avionics modes. The ability of the offensive avionics system to support all the avionic modes shall be verified by ___________.

4.2.2.11 Growth. The required growth capability shall be verified by inspection and analysis.

4.3 Avionics integrity. Verification of the offensive avionics integrity requirements of 3.3 shall be in accordance with the avionics integrity specification.

4.4 Maintainability. The requirements of 3.4 for maintainability shall be verified by analysis, demonstration, and test as follows: ___________.

4.5 System safety. The verification of the safety requirements of 3.5 shall be accomplished as follows: ___________.

4.6 Human engineering. The compliance with requirements of 3.6 for human engineering shall be verified by ___________.

4.7 Interface. The interface requirements specified in 3.7 shall be verified by inspection, analysis and tests as follows:

a.
b.
c.
d.

5. PACKAGING

5.1 **Deliverable items.** All deliverable items shall be prepared for shipment as directed by the procuring activity.

6. NOTES

6.1 **Intended use.** The offensive avionics system is intended for use in aircraft.

6.2 **Definitions**

6.3 **Responsible engineering office.** The responsible engineering office (REO) for the technical maintenance of this document is Mr. Joseph Gebele, ASD/ENASA, Wright-Patterson AFB OH 45433-6503, AUTOVON 785-6749, Commercial (513) 255-6749.

6.4 **Subject term (key word) listing.** The following list is provided to facilitate identification of this document during retrieval searches.

Avionics

Avionics, offensive

Navigation

System integration

Target location and attack

Weapon delivery

Custodian:
Air Force - 11

Preparing activity:
Air Force - 11

Project No. 5895-F321

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APPENDIX

OFFENSIVE AVIONICS SYSTEM

HANDBOOK FOR

10.0 SCOPE

10.1 Scope. This appendix provides rationale, background criteria, guidance, lessons learned, and instructions necessary to tailor sections 3 and 4 of the basic specification (MIL-O-87243) for a specific application.

10.2 Use. This appendix is designed to assist the Government project engineer in tailoring MIL-O-87243. The blanks of the basic specification must be filled in to meet operational needs of the system being developed.

10.3 Format. Section 30 provides each requirement (section 3) and associated verification (section 4) as stated in the basic specification. This section has been so arranged that the requirement and associated verification is a complete package to permit addition to, or deletion from the criteria as a single requirement. In some cases options are provided that can be added to the basic requirement or verification. A requirement is not specified without an associated verification.

10.4 Responsible engineering office. The responsible engineering office (REO) for this appendix is ASD/ENASA, Wright-Patterson AFB OH 45433-6503, AUTOVON 785-6749, Commercial (513) 255-6749.

20.0 APPLICABLE DOCUMENTS

20.1 References. The documents referenced in this appendix are not intended to be applied contractually. Their primary purpose is to provide background information for the Government engineers responsible for developing the most appropriate performance values (filling in the blanks) for the requirements contained in the specification proper.

20.2 Avoidance of tiering. Should it be determined that the references contained in this appendix are necessary in writing an RFP or building a contract, excessive tiering shall be avoided by calling out only those portions of the reference which have direct applicability. It is a goal of the Department of Defense that the practice of referencing documents in their entirety be eliminated in order to reduce the tiering effect.

20.3 **Government documents.** The documents identified herein are referenced to provide supplemental technical data.

20.3.1 **Specifications, standards, and handbooks**

MIL-C-675	Coatings of Glass Optical Elements (Antireflection)
MIL-W-5088	Wiring, Aerospace Vehicle
MIL-E-5400	Electronic Equipment, Aerospace, General Specification for
MIL-H-5606	Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance
MIL-T-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-L-7808	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Number O-148
MIL-A-8243	Anti-icing and Deicing-Defrosting Fluids
MIL-P-9024	Packaging, Handling, and Transportability in System/Equipment Acquisition
MIL-Q-9858	Quality Program Requirements
MIL-M-38510	Microcircuits, General Specification for
MIL-H-46855	Human Engineering Requirements for Military Systems, Equipment, and Facilities
MIL-T-83133	Turbine Fuel, Aviation, Kerosene Type, Grade JP-8
MIL-H-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft NATO Code Number H-537

STANDARDS

Military

MIL-STD-188	Military Communications System Technical Standards
MIL-STD-210	Climatic Extremes for Military Equipment
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-470	Maintainability Program for Systems and Equipment
MIL-STD-471	Maintainability Verification/Demonstration/Evaluation
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-781	Reliability Design Qualification and Production Acceptance Tests: Exponential Distribution
MIL-STD-810	Environmental Test Methods and Engineering Guidelines
MIL-STD-877	Antenna Subsystems, Airborne, Criteria for Design and Location of
MIL-STD-882	System Safety Program Requirements
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities.
MIL-STD-1553	Aircraft Internal Time Division Command/Response Multiplex Data Bus
MIL-STD-1589	JOVIAL (J73)
MIL-STD-1750	Sixteen-Bit Computer Instruction Set Architecture
MIL-STD-1760	Aircraft/Store Electrical Interconnection System
DOD-STD-1788	Avionics Interface Design Standard
MIL-STD-1796	Avionics Integrity Program (AVIP)
MIL-STD-1815	ADA Programming Language
MIL-STD-1862	NEBULA Instruction Set Architecture
MIL-STD-2165	Testability Program for Electronic Systems and Equipments
DOD-STD-2167	Defense System Software Development
MS 25271	Relay, 10 Amp, 4 PDT, Type I, Hermetically Sealed, Solder Hook

HANDBOOKS

Military

MIL-HDBK-217	Reliability Prediction of Electronic Equipment
MIL-HDBK-287	Defense System Software Development Handbook
MIL-HDBK-1553	Multiplex Application Handbook

Air Force Systems Command Design Handbooks

AFSC DH 1-3	Human Factors Engineering
AFSC DH 1-4	Electromagnetic Compatibility
AFSC DH 1-6	System Safety

20.1.3 Other government documents, drawings and publications

AFR 205-16	Automatic Data Processing (ADP) Security Policy, Procedures, and Responsibilities
AFR 700-13	Electromagnetic Interference, Electromagnetic Radiation Hazards and Meaconing, Intrusion, Jamming, and Interference (MIJI) Reporting
AFR 700-14	Radio Frequency Spectrum Management
AFSCR/AFLCR 800-23	Policy for Modular Automatic Test Equipment (MATE)
ARINC-429	Mark 33 Digital Information Transfer System (DITS)
ARINC-575	Mark 3 Sub-Sonic Air Data System (Digital) DADS
ASD/ENA-TR-80-3	MIL-STD-462 Application Note, Identification of Broadband and Narrowband Emissions
ASD-TR-78-6	Airborne Systems Software Acquisition Engineering Guidebooks for Regulations, Specifications, and Standards
ASTM B117	Salt Spray (Fog) Testing, Method of
NACSIM 5100	Compromising Emanations Laboratory Test Requirements, Electromagnetics
NACSIM 5203	Guidelines for Facility Design and RED/BLACK Installation
RADC-TR-82-189	RADC Testability Notebook

20.2 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

GUIDANCE

The above list of specifications, standards, and other documents is given as representative of the types used in offensive avionics systems. It is not intended as a complete list, nor shall any specification be used without careful consideration of the cost-effectiveness of its impact on the program.

Additionally, good engineering practice dictates that only the applicable sections of a generalized specification be used. Only on rare occasions is a specification or standard used in its entirety, as doing so can be costly and can lead to conflicts among requirements.

LESSONS LEARNED

One of the most common problems with listing military specifications and standards as applicable documents is the use of an outdated version. The words "of the issue in effect on the date of invitation for bids" can also create a problem. In some cases the documents have been revised between the time the specification was written and the release of the request for proposal (RFP).

When Government furnished property (GFP) is specified the GFP may have been built to earlier documents and it would be inappropriate to redesign the equipment to later revisions. In this case several versions of the same basic document may need to be called out and referenced to particular items.

Another problem can be referencing of a document by title without checking the contents. This is occasionally done because other similar programs had referenced this document.

20.3 Abbreviations

AC	alternating current
AF	Air Force
AFMRL	Air Force Medical Research Laboratory
AFSC	Air Force Systems Command
AI	air interdiction
AIL	Avionics Integration Laboratory
AILA	airborne instrument low approach
ALT	altitude
AM	amplitude modulation
ASD	Aeronautical Systems Division
AVIP	Avionics Integrity Program
AWG	American wire gauge
BB	broadband
BAI	battlefield air interdiction
BIT	built-in test
C	Celsius
CAS	close air support
CCIP	continuously computed impact point
CEP	circular error probable
CERT	combined environment reliability test
cm	centimeter
dB	decibel
dBμA	decibel micro-amps
DC	direct current
DOD	Department of Defense
DTE	development test and evaluation
EC	electronic combat
ECCM	electronic counter-countermeasures

ECM	electronic countermeasures
ECP	engineering change proposal
ECS	environmental control system
EM	electromagnetic
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EMOL	expected maximum operating life
EMRG	emergency
EO	electro-optical
ERT	estimated repair time
F	Fahrenheit
FDTS	functional development test fixture
FLOT	forward line of own troops
FFOP	failure-free operating period
FLIR	forward looking infrared
FOV	field of view
fps	feet per second
FTD	Foreign Technology Division
ft	feet
g	acceleration
GFP	Government-furnished property
GPS	global positioning system
HDBK	handbook
HOL	higher order language
HUD	heads-up display
Hz	hertz
HF	high frequency
HFE	human factors engineering
IAW	in accordance with
ICD	interface control document
IFF	identification friend or foe
ILS	instrument landing system
INS	initial navigation system
IRST	infrared search and track
JTIDS	joint tactical information distribution system
KHz	kilohertz
LISN	line impedance stabilization network
LOS	line of sight
LRU	line replaceable unit
m	meter
MATE	modular automatic test equipment
MFD	multifunction display
MHz	megahertz
MIL	military
MLS	microwave landing system
mr	milliradian
ms	millisecond
NAV	navigation
NEMP	nuclear electromagnetic pulse
NB	narrowband
NM	nautical mile
NSA	National Security Agency
OAS	offensive avionics system
OFP	operational flight program

OTE	operational test and evaluation
PIDS	prime item development specification
PMAT	production manufacturing acceptance test
PMD	program management directive
PRF	pulse repetition frequency
PXL	pixel
RADC	Rome Air Development Center
RF	radio frequency
RFP	request for proposal
RSS	root sum square
RT	remote terminal
SATCOM	satellite communications
SEAFAC	Systems Engineering Avionics Facility
sec	second
SEL	select
SIL	systems integration lab
SON	statement of need
SPO	system program office
SQ	square
SRU	shop replaceable unit
ST	self test
STD	standard
TA	terrain avoidance
TACAN	tactical air navigation
TDMA	time division multiple access
TF	terrain following
TFR	terrain-following radar
T/R	transmit/receive
UHF	ultra high frequency
UUT	unit under test
UV	ultraviolet
VEL	velocity
VHF	very high frequency
VLF	very low frequency
VOR	VHF omni range
W	watt
WB	wideband

30. REQUIREMENTS AND VERIFICATIONS

3.1 **System description.** Offensive avionics are equipment and software which contribute by signal output to accomplish the offensive tasks of the ___________ aircraft. The offensive avionics system shall perform the allocated air vehicle offensive avionics mission functions and be compatible with overall air vehicle requirements. The primary mission of the air vehicle is ___________ and the secondary mission is ___________.

a. Communication. The offensive avionics system shall provide bidirectional communication between aircraft and ground, between aircraft and aircraft (may include space vehicles, guided missiles, or guided munitions), and among crew members and to ground crew. This will include command, control, and tactical communications for both voice and data.

b. Navigation. The offensive avionics system shall provide both self-contained and radio navigation capability to navigate to and from the target or destination, to provide escort or other mission objectives. It shall also interface with the automatic flight control system and terrain-following, terrain-avoidance, and threat-avoidance functions as required.

c. Air-to-air combat. The offensive avionics system shall provide for the location and identification of airborne targets with sufficient accuracy and confidence to successfully engage and destroy the airborne targets. The offensive avionics shall provide for the delivery of the weapons listed in table I.

d. Air-to-ground combat. The offensive avionics system shall provide for the location and tracking of fixed and moving ground targets, and collecting and processing of target data required for displaying targets and computing weapon delivery. The offensive avionics shall provide for the delivery of those weapons listed in table I.

e. Controls and displays. The offensive avionics system shall provide the necessary controls and displays to enable the air crew to select and control the offensive avionics system and its subsystems in fulfillment of the required missions.

f. Weapon management. The offensive avionics system shall contain the hardware, software, controls, and displays necessary to initiate signals for the control of weapon inventory, weapon release, weapon release sequencing, weapon conditioning, and jettisoning of selected weapons singly or in groups as listed in table I.

g. Computation and data handling. The offensive avionics system shall contain the equipment necessary to transfer and compute information for the integrated operation of the offensive avionics system within the air vehicle. This equipment shall provide the flexibility to adapt to changing mission and subsystem requirements without adversely affecting the system.

h. Air data. The offensive avionics system shall provide air data information to the navigation and fire control functions.

TABLE I. Weapons.

Air-to-Air	Air-to-Ground
____________	____________
____________	____________
____________	____________

REQUIREMENT RATIONALE (3.1)

The major functions of the offensive avionics system must be specified to establish the performance and characteristics the offensive avionics system will exhibit. Major functions will vary depending on mission type.

REQUIREMENT GUIDANCE

A major system procurement, such as a new aircraft, will generally have a system requirements document in the initial request for proposal (RFP) and the contractor will be required to submit an Air Vehicle Prime Item Development Specification and a System Segment Specification on each major system segment (offensive avionics system, defensive avionics system, etc.), either as part of his proposal or as a data item.

Some aircraft modification programs consist only of completely integrating an offensive avionics system. In this case the project engineer may prepare a System Segment Specification which specifies the offensive avionics system's operational and functional requirements. This specification will include requirement for functions and subsystems such as communication, navigation, controls and displays, air data, computation and data handling, stores management, air-to-air combat, air-to-ground combat, and others. The specification should generally include all key performance characteristics of each of these functions and subsystems. These key characteristics should be selected from appropriate parts of 3.2 herein and made to be subparagraphs of the offensive avionics system paragraphs.

The first blank in 3.1 should be filled in with the aircraft designation; the second and third blanks, with the types of missions the aircraft offensive avionics system is to fulfill.

The avionics system characteristics usually fall into mission objectives such as close air support (CAS), battlefield air interdiction, air interdiction, counter air, air defense, strategic bombing, long-range combat, etc. Sometimes these are combined to provide a multirole or multimission system. This creates a more complex system which may require additional detail specification.

Close air support objectives are to support surface operations by attacking hostile targets in close proximity to friendly surface forces. CAS can support offensive, counteroffensive, and defensive surface force operations with preplanned or immediate attacks. All preplanned and immediate CAS missions require detailed coordination and integration with the fire and maneuver of friendly surface forces. CAS missions require timely intelligence information and accurate weapons delivery.

Air interdiction (AI) objectives are to delay, disrupt, divert, or destroy an enemy's military potential before it can be brought to bear effectively against friendly forces. AI attacks against land force targets which have a near-term effect on friendly land forces are referred to as battlefield air interdiction (BAI). The primary difference between BAI and AI is the near-term effect and influence produced against the enemy in support of the land component commander's scheme of maneuver. BAI may require coordination during execution, but operations are performed at such distances from friendly surface forces that detailed integration of specific actions with the fire and movement of friendly forces is not required. AI presents the usually additional requirement for longer range penetration capability. In either case coordination with friendly forces will probably be required for safe ingress and egress.

A defensive counter air mission supports and provides air defense for the close air support missions. It is an air superiority mission up to and over the forward line of troops (FLOT). Offensive counter air provides sweep and escort missions behind the FLOT. Its objective is to clear out the opponents' air defense and temporarily obtain air superiority. This mission frequently provides air cover to the air interdictors. Autonomous by nature, this mission role requires as much information about the present situation as possible.

The air defense mission objective is to achieve and maintain air superiority on the friendly side of the FLOT. This includes attacking strike forces and neutralizing escort aircraft. This role is performed autonomously or as directed by ground or airborne command and control systems.

REQUIREMENT LESSONS LEARNED

The mission of the aircraft, in general, will determine which aircraft functions and characteristics are required. At the outset of a weapon system development, very general guidance will be available in the form of statement of need (SON) and program management direction (PMD) documents. Studies analyses and meetings with the using and supporting commands must all be used with good engineering judgment to arrive at a suitable set of offensive avionics requirements.

4.1 **Verification, general**. The verifications (inspections, analyses, tests, and demonstrations) specified herein shall verify the ability of the offensive avionics system to meet the requirements of section 3 herein. The government reserves the right to witness or conduct any verification.

VERIFICATION RATIONALE (4.1)

Compliance with the overall requirements of 3.1 will generally become obvious during other tests and inspections. 4.1 provides all of the introductory and general verification provisions. These are included here in order to allow all of the remaining paragraphs of section 4 to exactly parallel the section 3 paragraphs with similar numbers. Responsibility for verification, standard test conditions, test equipment, and allocated accuracies must be specified to insure that the contractor performs the required verifications and uses conditions and accuracies to obtain accurate and consistent results.

VERIFICATION GUIDANCE

Methods of verification:

a. Inspection. Inspection is defined as investigation, without the use of special laboratory appliances, procedures, supplies, or services, to determine conformance to specified requirements. Inspection is generally nondestructive and includes, but is not limited to, visual and other investigations; simple physical manipulation, gaging and measurement.

b. Analysis. Analysis is defined as verification that a specification requirement has been met by technical evaluation of equations, charts, simulation, reduced data, and/or representative data.

c. Demonstration. Demonstration is defined as a test that relies primarily upon qualitative assessment. Included in this category are tests that require simple quantitative measurements such as dimensions, time to perform tasks, etc.

d. Tests. Test is defined as verification that a specification requirement is met by a thorough exercising of the applicable element under appropriate conditions in accordance with approved test procedures.

Verification can also be done by qualification by similarity. When this method is chosen ground rules will need to be established. Qualification should be accomplished by using test data from previously developed and qualified items when possible. When qualification by similarity is proposed, the test data from the earlier qualification should be submitted with design data to substantiate that: (1) the equipment is to perform a similar function in the new application as it did in its earlier qualification, (2) the environmental and operating limits shall be no more demanding or degrading than in the earlier operation, (3) the new item does not incorporate differences that would invalidate the criteria of (1) or (2), and (4) the equipment operated satisfactorily in its earlier application as indicated by its Mean Time Between Failure (MTBF) field failure data.

Unless otherwise specified, the contractor is responsible for the performance of all tests and inspections. The contractor may use his own facilities, specialized commercial facilities, and in some instances, with government approval, special government facilities. Regardless of where testing is conducted, records of the examinations and tests should be kept. These records should include a complete description of each test method, identification of instrumentation used and test assumptions made, and actual test data and results.

While compliance with aircraft offensive avionics system requirements will generally become obvious during other tests and inspections, specific demonstrations, tests, analyses, and inspections should be added for any specific requirements called out in 3.2. For environmental tests, the conditions, tolerances, and accuracies of MIL-STD-810 are often adequate and reasonable and are in general use. Exceptions should be added to account for any program-peculiar requirements. Care must be taken to insure that various levels of test plans and procedures are compatible and not self-contradictory.

VERIFICATION LESSONS LEARNED

Very little trouble is encountered in this area as long as normal and reasonable conditions are specified.

3.1.1 **Item diagram.** A functional diagram of the offensive avionics is depicted in figure 1.

REQUIREMENT RATIONALE (3.1.1)

Item block diagrams can sometimes be helpful in defining the major parts of the system development, particularly if the specification is to become part of a request for proposal (RFP). The diagram should be explanatory in nature, rather than an attempt to show how the missions should be accomplished. WHAT is to be done should be defined, not how or why.

REQUIREMENT GUIDANCE

The diagram should not include considerations of quality or quantity of performance. It may show generic source and destination information to clarify intent and to portray subsystem interaction.

REQUIREMENT LESSONS LEARNED

The government often places too much emphasis on HOW a job is to be accomplished rather than specifying a job to be done (the WHAT). The contractor needs more latitude for new solutions to design problems.

4.1.1 **Item diagram.** Not applicable.

FIGURE 1. Offensive avionics functional diagram.

3.1.2 **Major components.** The offensive avionics system shall consist of the following major functional components ___________.

REQUIREMENT RATIONALE (3.1.2)

Major components or functional components may require the more detailed breakdown into detailed requirements identified in prime item development specifications (PIDS) than that specified herein. Major components should be consistent with the intended configuration management approach.

REQUIREMENT GUIDANCE

This paragraph can be completed with a generalized description of the components or functional components of the system, including the software. Functional block diagrams can be included if necessary.

REQUIREMENT LESSONS LEARNED

Overspecification at the system level leads to predefined component design solutions, resulting in bottom-up design and top-down testing.

4.1.2 **Major components.** Not applicable.

3.1.3 **Government furnished property.** The following government furnished property shall be utilized.

a.
b.
c.

REQUIREMENT RATIONALE (3.1.3)

On many programs, existing hardware, software, services, or data are directed for use. This is done to insure commonality of equipment with other aircraft, reduced logistics impacts, or reduced development costs.

REQUIREMENT GUIDANCE

When providing Government furhished property (GFP), insure that the availability of this item is compatible with the overall development schedule.

REQUIREMENT LESSONS LEARNED

In some cases, an enumerated accounting of the equipment in the specification will help the contractor assess the impact of the program requirement on his resources. This is particularly true for test equipment which may be common for the Air Force, but unfamiliar to the commercial research and development community. GFP has been specified on program in which the GFP has not been made available in time; the result has been overall program schedule slips and accompanying cost increase. Provisions should always be made to insure good communications between the GFP supplier and the system integrator. This is normally handled with an associate contractor relationship clause, when the GFP is supplied by the vendor.

When software is provided as GFP, particularly when requested by a contractor, it should be provided "as is." Standard clauses exist to help keep Government liabilities to a minimum.

The contractor may require proof that the equipment meets its specification. The results of test data should prove satisfactory. If no test data is available, the contractor may require that the equipment rerun qualification testing before he will assume any performance liability relating to the equipment.

4.1.3 **Government furnished property**. Not applicable.

3.2 **Performance requirements**

3.2.1 **System characteristics**. The offensive avionics system shall be an integrated system that meets all requirements of this specification while installed in the aircraft and while operating at all points within the operating and environmental envelope of the aircraft, as defined in ____________.

REQUIREMENT RATIONALE (3.2.1)

This paragraph is intended to establish the top-level system characteristics that the offensive avionics system is to be compatible with and operate in. Performance requirements are generally met over the full range of environments specified, except degraded performance may be specified during gunfire vibration. Other exceptions may also be specified, such as allowing deviations from full accuracy during the first 5-15 minutes after turning on at the cold temperature extreme.

REQUIREMENT GUIDANCE

Combat conditions continually require an offensive avionics system which will provide greater combat effectiveness. The tasks of monitoring information sources, performing maneuvers, locating targets, making combat decisions, and employing weapons will become increasingly complex. The ability of the aircrew to manage all the offensive avionics system functions during stressful engagement conditions is critical and will require a great deal of effective automation that supports real-time aircrew interaction and decision-making.

In many ways the military utility of the offensive avionics system is limited to the extent that the aircrew can utilize displayed information to develop the required situational awareness and the ease with which systems can be operated to accomplish required tasks. Systems that are not predictable or controls and displays that are not compatible with each other require an accomplishment. Systems that are compatible, easily operated, and properly automated will accomplish many mission tasks while allowing the aircrew to concentrate on the total aspect of the mission.

The mission requirements are usually derived from the Statement of Need (SON) and provide the basis for the air vehicle operational characteristics. The offensive avionics system must also be compatible with the air vehicle system specification. The avionics operating conditions are derived from these air vehicle characteristics. A mission route or scenario is very useful in further scoping the characteristics and in establishing a baseline for verification of the requirements. A very general mission scenario might consist of takeoff, climb-cruise, orbit, ingress, penetrate, target attack, egress, refueling, return, and landing. Mission duration requirements impact system reliability as well as various accuracy requirements during different segments of the mission.

REQUIREMENT LESSONS LEARNED

When this specification is applied to existing systems, care should be taken to resolve conflicts between military requirements, that is, requirements in published specifications and standards, which are less severe than those found on the aircraft. For example, a recent update to the F-111 found a power system with more severe power transient characteristics than those specified in current versions of MIL-STD-704. Similarly the A-10 has more severe vibration and shock from gun firing than most aircraft.

4.2.1 **System characteristics.** The system characteristics specified herein shall be tested and verified by the following methods: ____________.

VERIFICATION RATIONALE (4.2.1)

Test and evaluation efforts must be conducted to establish that the requirements have been met.

VERIFICATION GUIDANCE

Verification of system requirements will be accomplished by varying degrees of analysis, inspections, simulations, demonstrations, ground mock-up tests, and flight tests. Unique or specialized requirements will probably require specialized testing criteria and possibly specialized test equipment or test ranges. In some cases test results, simulation results, and analysis will provide conflicting results. In this case special emphasis will be placed on evaluating the applicability of each result and possibly modifying procedures.

VERIFICATION LESSONS LEARNED

Predicted and actual results should be compared to assess system performance. System simulations should also be verified to insure reasonable simulation results.

3.2.1.1 Physical characteristics. Restrictions to the physical characteristics of the offensive avionics systems are ___________.

REQUIREMENTS RATIONALE (3.2.1.1)

Total sizing, weight, power consumption, available cooling, apertures, etc., may have to be restricted due to the air vehicle involved. Specific operational vulnerability factors such as nuclear, chemical, or biological requirements should also be specified.

REQUIREMENT GUIDANCE

a. Weight and volume. The weight and volume of the equipment comprising the avionic system, including racks, shall not exceed _________ pounds and _________ cubic feet.

Weight and volume are frequently allocated from the air vehicle specification. Actual avionic equipment weight and volume will then be specified in the item specification.

Guidance as to available space, payload weight, power, etc., should be available from a survey of the air vehicle involved, particularly when an existing airframe is used. In addition the statement of need (SON) and good engineering practice may dictate growth margins. User inputs of longterm planning needs can provide insight into further required additions to the weapon system which also help in estimating growth margins.

b. Nuclear survivability. Nuclear survivability shall be in accordance with ___________.

This requirement applies to equipment used on aircraft which are required to operate in, or following, a nuclear event. Typically the nuclear environments to be considered for avionics are electromagnetic pulse (EMP) and transient radiation effects on electronics (TREE).

The environment generated by nuclear effects in the area where the equipment is installed should be determined and used in the specification. Nuclear survivability requirements are usually classified. The blank should be filled in with the document that establishes these requirements.

REQUIREMENT LESSONS LEARNED

The amount of space, weight, power, and cooling allocated to the avionics is rarely enough, and desired capability is frequently sacrificed. If the avionics is to be installed on a nuclear-hardened platform, then the requirements applicable to that platform must also be specified for the avionics. Nuclear requirements cannot be added on later without causing significant redesign of the avionics.

4.2.1.1 **Physical characteristics.** Physical characteristics of the offensive system shall be verified by ___________.

VERIFICATION RATIONALE (4.2.1.1)

The various parts of the system should be inspected to insure they do not exceed their allocated physical limitations. Mission-critical equipments must be designed and tested to verify that they will continue to operate after one or more nuclear events or in a lasting nuclear environment.

VERIFICATION GUIDANCE

Detailed verification (analysis and/or test) should be specified for the applicable environments. In the case of avionics, only the TREE and EMP requirements are applicable.

VERIFICATION LESSONS LEARNED

Nuclear survivability and vulnerability should be verified by analysis and test.

3.2.1.2 **Operational characteristics**

3.2.1.2.1 **Operational conditions.** The offensive avionics system shall perform under the following operational conditions:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.2.1.2.1)

Operational conditions must be specified to provide the derivation of those requirements that will impact the integrity and serviceability of the offensive avionic equipment. This will include such considerations as failure rates, parts selection, maintainability aspects, equipment installation, and overall performance across a broad spectrum of weather conditions. Using these factors, the system design can be improved to meet its useful life.

REQUIREMENT GUIDANCE

Operational conditions applicable to offensive avionics performance should be based on the statement of need or other documented needs of the user. In addition to mission profile, utilization rate, and operational life examples given below, other categories of operational conditions may include such items as alert response times, training restrictions, war reserve frequencies, turnaround time, command and control interfaces, and operations from austere bases.

To insure that design requirements are known, the designer should develop a dialogue with the user so that both parties understand the required operational conditions. To start the dialogue, it may even be necessary for the designer to present a "strawman" mission capability to the user.

Based on user needs and associated deployment and operational concepts, and on system support concepts, specific climatic extremes to be specified may be derived from MIL-STD-210, taking into account climatic values versus associated risk levels.

a. Mission. The offensive avionics shall operate worldwide over a wide range of terrain and climatic extremes. The mission profile to be used for the offensive avionics shall be as stated in the __________ statement of need.

b. Utilization rate. The peacetime utilization rate for the offensive avionics shall be ____________ hours per day based on ____________ flying days per month. Wartime utilization rates are classified and are contained in the ____________ statement of need.

c. Operational life. The offensive avionics shall be planned for an operational life of __________ years. The operational life refers to the time span during which major offensive avionics elements will be a part of the inventory. All modifications and new designs shall be planned and designed for this life, considering the mission and mission scenario defined in the statement of need. Inspections and on/off maintenance requirements shall be considered in achieving this life.

REQUIREMENT LESSONS LEARNED

Meetings with the users have revealed that the acquisition community has not taken into consideration the wide range of operational conditions under which the user would like the avionics to perform. As a result, the equipment is not sufficiently reliable and in some cases cannot be made to work without a redesign to compensate for the operational condition. On the other hand, the manufacturers have stated they could have designed to the desired range of conditions if they had only known what they were.

4.2.1.2 Operational characteristics

4.2.1.2.1 Operational conditions. Offensive avionics integrity in stated operational conditions shall be verified by analysis and tests as follows: ____________.

VERIFICATION RATIONALE (4.2.1.2.1)

Integrity under the operational conditions can be obtained only through an ongoing verification process.

VERIFICATION GUIDANCE

Verification to the extent possible is done by flight test demonstrations during DT&E and OT&E. Those areas not capable of being demonstrated will be verified by analysis.

The overall verification process is an integrated and progressive program that builds to a high confidence in successful performance through development, qualification, and integration testing prior to flight test.

Normally DT&E and OT&E planning and testing are agreed upon by the manufacturer and the government within the terms of MIL-STD-471, MIL-STD-781, and MIL-STD-810.

VERIFICATION LESSONS LEARNED

Unless DT&E and OT&E testing and planning are agreed to early in the program, and performance and test criteria are clearly established, disagreements can arise between the manufacturer and the acquisition community over whether requirements have been met.

3.2.1.2.2 **Nonoperational conditions.** To accomplish the ____________ mission, the offensive avionics shall consider nonoperational conditions in worldwide terrain and climatic extremes. The cold-start reaction times shall be ____________. The following nonoperational conditions shall apply:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.2.1.2.2)

Like the operational conditions, the nonoperational conditions must be included in the design of the system. Exposure to the environments of operation, deployment, storage, transportation, maintenance, and manufacture must all be considered.

REQUIREMENT GUIDANCE

a. The nonoperational conditions shall not limit the utilization rate of the offensive avionics to less than the operational specified rates.

b. The nonoperational conditions shall not limit the operational life of the offensive avionics to less than the specified operational life.

The nonoperational cold-start reaction time can be obtained from the statement of need. Based on user needs and associated deployment concepts, and on system support concepts, specific climatic extremes to be specified may be derived from MIL-STD-210, taking into account climatic values versus associated risk levels.

REQUIREMENT LESSONS LEARNED

The operational community believes that the on/off cycling of systems can play a major part in the overall failure rate. It is necessary, therefore, to design for operational as well as nonoperational conditions in order to increase the reliability of systems.

4.2.1.2.2 **Nonoperational conditions.** Offensive avionics integrity in stated nonoperational conditions shall be verified by analysis and tests as follows: ____________.

VERIFICATION RATIONALE (4.2.1.2.2)

The integrity of the offensive avionics system should also be assessed from a nonoperational standpoint to include such effects as storage, transportation, and maintenance actions.

VERIFICATION GUIDANCE

Verification is usually done by analysis unless climatic chambers are used for nonoperational area simulation.

VERIFICATION LESSONS LEARNED

Failure to establish a test plan for verifying avionics integrity--with clear definitions for satisfactory performance--has resulted in wasteful bickering between the Government and the contractor. The users' expectations must be made clear in the contract.

3.2.1.2.3 **Air-to-air combat.** The system shall be mechanized so that the probability of launching a missile out of bounds shall be no greater than and the probability of missing a valid launch opportunity shall be no greater than ____________. Air-to-air gunnery shall provide a Circular Error Probable (CEP) of no more than ____________ mils.

REQUIREMENT RATIONALE (3.2.1.2.3)

Unaided crewmember judgment is not adequate for modern weapon launch. Computer assistance is necessary.

REQUIREMENT GUIDANCE

The aircraft launch solution must calculate and display the capability of the weapon at rates sufficiently high (20 Hz) to assure an instantaneous view of the engagement as it changes. The accuracy requirement must be based on a simulation of the weapon because: (1) typically the weapon is developed and controlled by an agency other than the developer of the fire control system; (2) the launching of a sufficient quantity of weapons at near boundary conditions to validate the fire control solution is impractical (except perhaps for guns).

It may be desirable to implement the solution such that the aircrew has the capability to override and launch out of bounds.

REQUIREMENT LESSONS LEARNED

Be sure to obtain the most accurate simulation that can be found if more than one has been developed. Ideally, the weapon developer will only allow one to be developed to concentrate resources and avoid potential conflict. Do not restrict computer time for evaluation or development of the aircraft algorithms as this will lead to errors in the solution. Computer-aided analysis can more economically scope the issue than trial and error with hardware. Flight testing will usually confirm the validity of the boundary conditions used in the analysis.

4.2.1.2.3 **Air-to-air combat.** Air-to-air combat performance stated in 3.2.1.2.3 shall be verified by analysis and test under the following conditions: ____________.

VERIFICATION RATIONALE (4.2.1.2.3)

Air-to-air combat perforamnce must be verified in order to ensure the system will work as intended.

VERIFICATION GUIDANCE

Air-to-air combat performance shall be verified by: (1) computer comparison of launch equations versus simulation over entire envelope, and (2) selected live ordinance deliveries near the computer boundaries.

Time and resources do not allow for total verification, including the weapon envelope edges, by actual ordinance delivery. Additional program requirements will usually dictate that many of the weapon launches occur in a region of the envelope where a successful intercept occurs. Therefore careful selection of the verification tests is necessary to be sure the data can be extrapolated to the entire envelope with a high degree of confidence.

VERIFICATION LESSONS LEARNED

3.2.1.2.3.1 **Target location and attack.** The offensive avionics shall provide the locations of multiple airborne vehicles which have signatures of __________ at ranges of __________ NM, flying at velocities of ______ ft/sec to ________ ft/sec over a terrain reflective coefficient of ________ dB and in atmospheric conditions of ___________. The locating sensor(s) shall provide all the data required for attack of ____________ targets under the following conditions: ____________.

REQUIREMENT RATIONALE (3.2.1.2.3.1)

This is the major requirement for establishing offensive sensor(s) system level performance.

REQUIREMENT GUIDANCE

Key parameters for this requirement are: target characteristics or signatures, ranges, coverages in terms of search and detect volumes, and target conditions such as velocity, aspect angle, and altitude. Sensor look up, co-altitude and look down capabilities requires defining the terrain or background conditions and other significant conditions such as atmospheric or weather conditions.

The requirement is a key system level requirement. It establishes basic minimum acceptable levels of performance to which the system will be developed. It should always appear in the system specification and will have corresponding requirements in lower level specifications. All-weather, day and night surveillance capability, with real-time target identification imagery for the aircrew, is achievable. Objectives include: high resolution imagery for multi-target detection, automatic target recognition, passive operation in an electronic countermeasure environment, standoff detection, day and night operation, smoke and haze penetration, cloud and rain penetration, and real-time battle damage assessment.

The simultaneous display of multiple sensors adds significantly to the acquisition capability. In addition to an easy-to-use confidence check, it allows the aircrew to use each sensor type optimally without undue workload or time lost to switch displays. With simultaneous displays, the operator can reduce input uncertainty. For example, a FLIR image can be used to update present position in azimuth at the same time the radar is used to refine the range error. This is similar to operations where a combined radar and heads up display (HUD) of the steerpoint or target also assists in the target verification and final aiming process. If the point of interest is not clearly identifiable in either the radar or FLIR, the combination of these displays may provide the aircrew with enough information to accurately position the sensors.

If sensors are not boresighted properly, considerable effort is required to correlate the information presented. All sensors must be boresighted to the same reference line in order to simplify the transition from one to another or to use two sensors simultaneously.

REQUIREMENT LESSONS LEARNED

When developing this requirement, consideration should be given to the impact of multiple sensors on overall performance. If each sensor is specified individually its performance may be overstated when the contribution of another sensor is included. This is generally known as sensor fusion. To sort this requirement out, one must look at the operational requirement/ mission, establish candidate sensor suites, define possible fusion approaches, consider each sensor mission reliability and availability and assess the effectiveness of that sensor suite. Sensitivity analyses are normally performed as well. Once this is accomplished the system level requirement for the sensor suite has been established and the individual requirements for each sensor can be allocated.

It should also be possible to use all the sensors for acquisition and aiming. When this capability is present, the ability to observe all of the sensor footprints on a single display, such as the F-15 Tactical Situation Display, appears to make sensor management much easier.

4.2.1.2.3.1 **Target location and attack.** Target location and attack performance capabilities shall be verified by the following test methods: ________.

VERIFICATION RATIONALE (4.2.1.2.3.1)

Major system requirements form the basis for accepting the weapon system. Demonstrated performance serves as the rationale to make Air Force decisions. Therefore testing of the offensive sensor suite utilized for the target location and attack function is normally accomplished via flight test. Flight testing is required because many sensors will not operate properly without flight motion and many effects cannot be quantified without flying, such as, target detection and track in clutter, weapon separation errors, etc.

VERIFICATION GUIDANCE

Performance should be verified by a combination of flight test and ground test. This will depend on the mission requirements and the actual avionics system designed. Software verification will be a major part of the test program. Ground testing in the laboratory is critical to successful software development. Testing at subcontractor facilities for software and hardware is utilized extensively and is worth consideration for sensors such as radar and infrared search and track (IRST). It is also standard practice to use dedicated test beds for flight testing sensors like attack radars early in development testing and evaluation (DTE) on the weapon system.

VERIFICATION GUIDANCE

Normally, one will utilize as much ground testing, hot bench mock-up, and simulation of software as possible prior to flight testing. Actual testing against operational target aircraft is performed with instrumented test aircraft and test ranges. As many conditions as possible consistent with the specification should be tested. Use of video recorded data for post-flight analysis is normally essential. Total testing can be extensive to cover the conditions necessary to verify the software and system design adequacy.

VERIFICATION LESSONS LEARNED

3.2.1.2.3.2 **Target identification.** The identification function shall provide for discrimination between friendly and hostile targets. At maximum weapon launch range a hostile target shall be identified as hostile at least _____% of the time. A hostile target shall not be identified as friendly more than _____% of the time. Friendly targets shall be identified as friendly at least _____% of the time. Friendly targets shall not be identified as hostile more than _____% of the time. The identification function shall provide for the identification of neutrals and noncombatants. The identification function shall discriminate types of hostile targets to the following extent: ___________.

REQUIREMENT RATIONALE (3.2.1.2.3.2)

A rule of engagement in the Air Force has been to positively identify the target before attacking to prevent fratricide.

REQUIREMENT GUIDANCE

The capability to identify targets is still being developed. There has been no method of "positively" identifying targets as friend, foe, or neutral from any great distances. The latest approach is to take individual sensor information and, by comparing it with a library of information on threats and military or commercial vehicles, make a declaration of the target. The technology to perform this method of identification, however, is not yet mature and, as weapon systems change, will need to be updated.

In some cases, it may be desirable to specify that the system shall provide identification and acquisition sensor correlation in range and azimuth with no more than X% error or Y% jitter in range and/or azimuth. This requirement should be met at all ranges less than the acquisition range of the sensor. The intent is to provide good situation awareness and to properly allocate resources. The aircrew must have identification data tied to the correct target without ambiguity brought about by target density or maneuvers.

Additional guidance can be obtained from the Combat Identification SPO, ASD/AEIE at Wright-Patterson AFB.

REQUIREMENT LESSONS LEARNED

The information from sensors must be displayed to the aircrew in a concise and easily interpretable manner. The identification information must be correlated with the tracking sensors. Too much information in a high threat density environment can saturate the aircrew with irrelevant information.

Experience has shown that if the identification-to-target correlation varies the aircrew becomes confused and must attempt to enhance the correlation process themselves. Analysis of this issue requires attention to the effects of self-interference, jamming, spoofing, and exploitation.

Radar warning receivers used to obtain information about threats and targets have typically been located on wing tips and tail tips. It is argued that in many instances this gives the best field of view. However, experience has shown that the vibration environments in these locations have caused the subsystems to drastically lose effectiveness or even invalidate the system concept. Noise induced by vibration in flight has proven to be both technically annoying and costly. Moving the subsystems inboard by about 1/3 the length of the wing or tail, as a rule of thumb, will provide a better environment. Suitable locations for the sybsystems should consider the applicable environments.

4.2.1.2.3.2 **Target identification.** Target identification capabilities stated in 3.2.1.2.3.2 shall be verified by the following test methods: ____________.

VERIFICATION RATIONALE (4.2.1.2.3.2)

The algorithms and software development are nearly as complex as those for the radar or electronic countermeasures suite. Therefore, extensive testing is required to insure that faults which would affect mission capability or fratricide risks are minimized.

Additionally, the sensors to perform the identification function are affected by noise environments, sensor sensitivities, and threat characteristics. These effects need to be identified, budgeted, and assured acceptable before integrating the system for flight tests. For instance, going into flight test and discovering that the sensors(s) cannot discriminate among several threats may cause unnecessary delays in the flight test program.

VERIFICATION GUIDANCE

The target identification algorithm should first be analyzed and projections made of the information it will provide to the aircrew under various conditions. The algorithm should then be tested using simulation techniques and the relation between inputs and outputs compared with those predicted by analysis. Simulation inputs should be representative of operational conditions in terms of signal density, threats, and weapon system usage.

After simulation testing, the target identificaiton system should be tested in hardware form in the lab and/or in flight. This testing should use sensor inputs and operational scenarios that the weapon system will see in the field. Testing must be exhaustive enough to characterize the operating envelope. The ability of each sensor to provide the needed target and threat information should be individually ground-tested.

Testing should result in a description of the sensitivity of the information displayed for the aircrew to variations in input data. For example, a change in the density of rainfall should not result in a change in the identification or location of a target, as displayed to the crew.

Effects of changes in signal density, threats, sensor fidelity, jamming, and spoofing should be characterized.

VERIFICATION LESSONS LEARNED

Plan for delays in the flight test. Historically, the sensors and algorithms have not performed to expectations.

3.2.1.2.3.3 Electronic combat performance. The offensive avionics shall operate at ______% of mode specification performance in an electronic combat environment of the electronic combat (EC) level defined by __________ for the modes listed in 3.2.2.10.

REQUIREMENT RATIONALE (3.2.1.2.3.3)

Since the beginning of electronic systems in aircraft, enemies have harassed, countered, spoofed, and exploited the communications and eventually the more sophisticated aviation electronics. Very effective countermeasures have been deployed against specific threats and it is necessary for the designer to search the literature to determine what the countermeasures are to minimize vulnerability.

REQUIREMENT GUIDANCE

For any particular application in addition to determining the countermeasures and projected countermeasures, it is necessary to determine the electronic counter-countermeasures (ECCM) trades, and required performance in an ECM environment. It will eventually become necessary to design a system with specified performance in an ECM environment.

Validated threat information has been compiled, documented, and is available from the Foreign Technology Division (FTD) at AFSC (Air Force Systems Command). In addition, a mission-specific statement of needs will often define particular EC environments. A System Threat Assessment Report should be prepared and used to define the threat requirements. The operational scenarios may also be a source of the expected electronic combat levels.

One concept for enhancing the effectiveness of a system is to prevent the enemy from detecting the presence of the weapons system until it is too late. As far as the avionics is affected, this involves the use of low-probability-of-intercept techniques, possibly passive operation, or terrain follwoing and avoidance to make use of terrain masking.

The remainder of this section will discuss specific subsystem ECCM considerations. Among the primary subsystems will be the radio frequency (RF) and electro-optical (EO) subsystem. Among the most central subsystems associated with the offensive function is the radar. Ultralow sidelobes are a very effective counter-countermeasure to jamming that may be designed into the radar. Additionally, pulse-to-pulse coherent return may be digitally processed to supress clutter, cancel chaff, and adapt thresholds on range and doppler bins. New processing techniques are presently being explored to enhance digital phase coding of a radar pulse. This coding may be used to provide ECCM against chaff return, weather, and ground clutter.

A list of the most frequently used ECCM categories and techniques are as follows:

Spatial Discrimination

- High gain, low sidelobe antenna
- Side lobe cancellation
- Beam deletion
- Polarization
- Home on jam

Frequency Discrimination

- Diplex operation
- Frequency diversity
- Frequency agility

Synergistic Sensor Integration

Operator Assists

Saturation Elimination

- Gain control
- Logarithmic amplifiers
- Guard channel
- Dickie fix

Simultaneous Measurement

- Netted radar system
- Monopulse
- Scan with compensation

Matched Filtering

- Moving target indication
- Staggered PRF
- Jittered PRF
- Sliding PRF
- Phase coding
- Pulse width discrimination

REQUIREMENT LESSONS LEARNED

4.2.1.2.3.3 **Electronic combat performance.** The capability of the offensive avionics shall be verified for performance in an ECM environment to assure that the requirement of 3.2.1.2.3.3 has been complied with. Verification methods shall be employed to show the contribution of each ECCM technique and combinations of techniques, to counter the threat and accomplish the missions as follows: ____________.

VERIFICATION RATIONALE (4.2.1.2.3.3)

The rationale for this requirement is to establish that the system can operate in the postulated hostile environment with a high probability of successfully completing the intended mission.

VERIFICATION GUIDANCE

Verification of this requirement will rely heavily upon simulation of the system capabilities against various electromagnetic environments. Consideration should be given to both friendly and hostile emitters. Simplified flight tests can be accomplished by flying the system against the EF-111, or other even less capable system, and observing the impacts to the offensive avionics system functions and performance.

Limited testing can also be performed against real simulators at China Lake, Eglin AFB, and at the Western Test Range.

Analytical models also exist for various systems such as GPS and JTIDS to access the impacts of various threat environments upon their respective performance.

This is a difficult area to establish how well the system will perform in the actual operational environment. In general, verification will be incomplete and improvements will be limited to minor adjustments of various system components.

3.2.1.2.4 **Air-to-ground combat.** Target location and tracking shall provide the weapon delivery accuracy in the air-to-ground modes specified in table II. The circular error probable (CEP) stated in table II shall result from all sources of error.

REQUIREMENT RATIONALE (3.2.1.2.4)

This requirement reflects the integrated system capability and is a key parameter in system effectiveness. This requirement should specify modes, conditions, and performance level associated with weapon delivery.

REQUIREMENT GUIDANCE

This requirement establishes the basic minimum acceptable levels of performance and should reflect the desired weapon delivery modes or mechanizations consistent with user tactics. Such things as automated maneuvering and attack may need to be considered in detailing these requirement in addition to classical modes such as continuously computed impact point (CCIP).

The CEP definition and allocations of error sources must be agreed upon with the contractor for this to be an effective requirement. In addition, an accuracy control document should be established which identifies the error sources and the error contribution allocated to each source. An example of an error budget for a weapon delivery mode is shown in table II-a.

REQUIREMENT LESSONS LEARNED

TABLE II. Air-to-ground combat.

Delivery Mode	Delivery Conditions (Alt, Angle, Vel)	Weapon	CEP

TABLE II-a. Auto weapon delivery accuracy error budget.

Error Source	Standard Deviation	Along Track	Cross Track
Operator designation error	1.5 PXL	63.0	63.0
Cursor related errors	2.1 PXL	89.1	89.1
Ranging - doppler filter errors	1.0 PXL	42.0	42.0
Output lag error	7.5 ms	4.8	4.8
Aircraft altitude	100.0 ft	5.2	5.2
Radar velocity along-track	0.8 fps	39.1	92.4
Radar velocity cross-track	0.8 fps	39.1	14.1
INS velocity along-track	2.5 fps	3.6	3.6
INS velocity cross-track	2.5 fps	3.6	3.6
INS velocity vertical	2.0 fps	6.5	9.6
Air-to-grnd slant range at update	33.3 ft	4.0	0.0
Ranging device reference (EL)	1.8 mr	8.0	0.0
Ranging device position (EL)	1.8 mr	7.8	0.0
True airspeed	1.7 fps	4.3	0.0
Bomb ejection speed	1.2 fps	3.7	0.0
Bomb release time delay	3.0 ms	2.7	0.0
Pilot steering error	2.5 mr	0.0	4.5
Side slip angle error	1.8 mr	0.0	2.0
Bomb dispersion along-track	5.0 mr	17.4	0.0
Bomb dispersion cross-track	2.0 mr	0.0	9.0
Ballistic fit	2.0 mr	3.0	0.0
Range error probable (REP) in feet		89.0	
Deflection error probable (DEP) in feet			102.0
Circular error probable (CEP) in feet		161.0	

4.2.1.2.4 Air-to-ground combat. Air-to-ground combat performance stated in 3.2.1.2 shall be verified by analysis and test under the following conditions: ______________.

VERIFICATION RATIONALE (4.2.1.2.4)

The rationale for the verification of this requirement is to demonstrate that the combined effects of different sensors, algorithms, profiles, operator effects, etc. meet the overall performance requirement.

VERIFICATION GUIDANCE

Normally verified in flight test. Instrument ranges and aircraft are required. The contractor should have evolved an error budget for each mode of the system and the tests should be structured to verify that the system meets the requirements. It will be difficult to test all possible conditions (such as airspeed, angles of attack, targets, etc.). Therefore, testing must be representative in many cases. It is important to establish, as part of the specification, the definitions of CEP so that the testing can be reported against a clearly defined requirement. Instrumentation and data recording are critical. Test data will have to spearate the system contributions from the pilot's to verify compliance. This will present an interesting problem in operational test and evaluation.

Additionally, try to structure flight tests so that analytical study models used in prior analysis of this system performance can be verified. This involves little more than planning to record the necessary input model parameters during the flight test. Flight test verification of models is extremely helpful in extrapolating the system performance to areas where flight testing is impractical or impossible. Time hacking of all recorded data tends to give more control over the test and provides for increased utility of the information.

The contractor or the Air Force personnel should attempt to verify contractor guidance predictions by using similar existing test data to verify the final prediction model. There is often test data available in the Air Force (the AF participant must find it) with which to compare similar, but not necessarily the same conditions. This data can be used to gain confidence in (or cast doubt on) a given performance model.

The accepted measure of system accuracy is the circular probable error (CEP), which is defined as the radius of the circle around the target for which there is a 50% probability that the system will guide the weapon to it. In general, the errors in each direction will not be equal, and thus in a true sense a circular error cannot be defined. However, the widespread use of the concept of CEP in evaluating systems makes it desirable to consider equivalent CEPs for nonsymmetrical error distributions.

VERIFICATION LESSONS LEARNED

Existing bomber flight data was obtained to verify a given strategic navigation suite. The navigation coordinates recorded on the flight tape were truncated and therefore did not provide the accuracy required to verify the performance model. Had the data been recorded in a more accurate manner, this data could have been used on other Air Force programs, thus providing increased cost-effectiveness in the flight test programs.

Development test and evaluation (DTE) results are more representative of idealized conditions than combat conditions. However, they allow for proving that the basic functions are working. The error budget is useful to allow extrapolation of DTE results to predict what the system will do under combat conditions. Operational test and evaluation (OTE) results will give insight into operational performance and are generally less accurate than DTE results. Various error terms will degrade during levels of high stress. Compliance with the specification will depend on how the requirements were specified relating to testing range conditions, training range conditions, or combat conditions. Since the contractor is not directly responsible for OTE results, requirement compliance and subsequent action is best taken as a result of DTE. Improvements after OTE will usually require an engineering change proposal.

3.2.1.3 Electrical characteristics. The offensive avionics equipment shall operate within its performance requirements with the electrical power provided by the ____________ aircraft and its associated ground power.

REQUIREMENT RATIONALE (3.2.1.3)

Offensive avionics equipment must operate with the electrical power characteristics provided by the aircraft electrical power system. The design of the electrical power system determines the voltage, frequency, and electrical transients to which the equipment could be subjected. Aircraft electrical power systems are designed to provide electrical power characteristics defined in MIL-STD-704. The standard establishes the requirements for conducted electric power characteristics on aircraft at the interface between the electrical power system and the input to electrical utilization equipment. The standard has been coordinated with Army, Navy, and Air Force to insure compatibility between aircraft electrical systems and airborne utilization equipment.

REQUIREMENT GUIDANCE

The blank in 3.2.1.3 should be filled in with the appropriate aircraft on which the equipment will operate (such as B-52H, FB-111, etc.) or the MIL-STD-704 (A,B,C,D) power specification under which it is designed to operate.

It may be desirable to consider other power parameters. The transients on a given aircraft may be different from MIL-STD-704. Also, power dropouts and more probable low voltage conditions due to heavy electrical loading may cause short duration voltage levels below normal operating conditions. If such conditions can or do exist, judgment will be required to determine which equipment must operate through them. As a minimum, none of the equipment should suffer damage by such dropouts. Equipment with memories should not have the memories altered. Equipment may be allowed to enter a shut down process after a given time of low voltage. There should be some specification for equipment recovery time versus power dropout or low voltage duration.

REQUIREMENT LESSONS LEARNED

Avionic equipment which has not been designed to operate over the voltage, frequency, or transient regions of the electrical power system has been damaged or has failed to perform its proper functions. Transistors and diodes which have been subjected to power transients beyond their rated capacity have been destroyed and their associated equipment rendered useless for the mission. Avionics equipments containing memory circuits have lost their memories because they could not tolerate a bus-switching transient.

4.2.1.3 Electrical characteristics. The offensive avionics equipment shall be demonstrated to be compatible with air vehicle and ground power systems as follows: ____________.

VERIFICATION RATIONALE (4.2.1.3)

Demonstration of the compatibility of the avionics equipment with the electrical power system is necessary to assure proper installation and operation of the avionics equipment. Prior to aircraft installation and demonstration, the avionics equipment must pass qualification tests under environmental and operational conditions as selected from MIL-STD-810. These qualification tests will include dielectric strength, insulation resistance, and transient power tests to assure proper operation over the characteristic electrical power curves of MIL-STD-704.

VERIFICATION GUIDANCE

At the system level, a power test should be performed with the expected electrical loading to detect or verify the transient or dropout conditions. Testing should be accomplished to verify specific operation during transients and dropouts.

Proper selection and use of components within their electrical and environmental ratings are vital to the proper operation of avionics equipment. Analysis of the operational circuits should be made to determine the proper range for components and these components should be selected from military standard parts when available. MIL-STD-454 can be used as a guide for general avionics requirements. Environmental stress screening of components is one way to eliminate early-failure components before beginning acceptance tests on avionics equipment.

VERIFICATION LESSONS LEARNED

Lack of knowledge of the power transients that can occur has resulted in inadequate design and improper operation of avionics equipment because the equipment has not been tested to these transient requirements.

3.2.1.4 **Environmental conditions.** The offensive avionics system shall operate as specified herein while exposed to the environments of operational use. The equipment shall not fail or suffer functional degradation during lifetime exposures to the environments of operation, deployment, storage, transportation, maintenance and manufacture. Combined natural and induced environments of worldwide deployment and operation for the offensive avionics equipment are as follows: ___________.

REQUIREMENT RATIONALE (3.2.1.4)

This section establishes the general environmental conditions the offensive avionics system will experience. Other life-limiting factors such as vibration, altitude, acoustic noise, and humidity are addressed by the avionics integrity section (3.3).

This requirement also impacts the power and cooling capabilities of the aircraft on the ground. This is particularly true of tactical and transport aircraft where relatively long-duration ground operation at remote locations is involved. Some system equipment may be required to operate during very adverse temperature extremes. If cooling is not available, the higher temperature operation should be factored into the specification requirements. This may drive a further derating of the equipment or require fan-forced ambient air even though fans have a lower reliability.

REQUIREMENT GUIDANCE

The actual environment will depend on the aircraft type and mission, but it should include storage, on-aircraft nonoperating, on-aircraft operating, cockpit-mounted, and equipment-bay-mounted requirements. The general requirements of MIL-E-5400 (table I) for the appropriate aircraft type and mission can be used if actual data on the specific application is not available. Care must be taken to insure that the performance requirements of MIL-E-5400 and test levels of MIL-STD-810 do not conflict.

Free-convection cooling is preferred where low dissipation and adequate ambient air make it practical. Where forced-air cooling is available, better reliability and lower equipment cost can generally be achieved by using it, and information on temperature, pressure, flow rate, and contamination limits should be inserted in the specification. Use of internal fans and heat transfer is also appropriate in some situations. However fans tend to be unreliable.

When specifying detailed environmental requirements, consider maintenance, manufacture, storage, and transportation environments. When these environments have not been defined, use MIL-STD-810 guidance for estimating these criteria. The equipment should be subjected to the baseline functional tests before, during (unless otherwise specified), and after each environmental test to demonstrate compliance with the requirements of section 3. Equipment designed and tested for one aircraft or even one installation location may need to be redesigned or retested for use in another aircraft or location if the operating environment is substantially different.

a. Rain. The equipment shall withstand exposure to water dripping from overhead structure, equipment, etc., and rain per the extremes of MIL-STD-810 as may occur when exposed to the requirements of (document reference or design criteria).

Cockpit equipment which can be rained on while installed and operating should withstand rain without permanent damage. It should operate at full performance while wet, but not necessarily while it is being rained on. The 45-degree drip-proof requirements of MIL-STD-810 are appropriate for most equipment, since equipment may be rained on during transportation, or rain water may drip on it when equipment bay doors are open.

Equipment should also be designed so that it will shed water, ie., it should not have depressions that hold water where it can eventually seep through cracks, screwholes, etc. Equipment exposed to rain must withstand this environment and, in some cases, must operate in it.

b. Bench handling. The equipment shall operate within specified performance requirements after being subjected to the shocks described in MIL-STD-810, Method 516.3, Procedure VI.

Method 516.3, Procedure VI of MIL-STD-810 describes the various ways that a unit should be dropped to represent the bench handling shocks. Use of a test procedure to describe a performance requirement is appropriate in this case because the shocks are very dependent on equipment size, shape and configuration, and specifying g-levels does not adequately represent the rotational nature of some bench handling shocks. A 15-g, 11-ms half-sine operating shock as described in MIL-STD-810, Method 516 has traditionally been used for many avionics units. However, random-vibration tests and bench handling shocks tend to be more severe and more realistic, so the operational shock test is not always used now. Detailed guidance can be obtained through the Air Vehicle SPO Structural Dynamics Engineer or ASD/ENFSL.

c. Crash safety. Equipment which, if broken loose from its mounts, could present a hazard to personnel shall withstand the crash safety shock requirement of MIL-STD-810, Method 516.3, Procedure V.

MIL-STD-810, Method 516.3, Procedure V provides appropriate crash safety shock levels. Use of a test procedure to describe a performance requirement is appropriate because crash environment is not predictable or measureable on a practical basis. Detail guidance can be obtained through the Air Vehicle SPO Structural Dynamics Engineer or ASD/ENFSL.

d. Sand and dust. Sand and dust conditions of (document reference or design criteria) shall apply.

The penetration of sand and dust into moving parts (gimbals, gears, etc.) can result in abnormal wear and failure. Particles carried by the wind will scratch, abrade, erode, or remove protective paint from exposed surfaces. In addition it can clog up air filters or drain-holes and can pit the exposed lenses of optical systems.

e. Fungus resistance. Fungus conditions of (document reference or design criteria) shall apply.

The system should tolerate exposure to fungus growth as encountered in tropical climates both under operating and nonoperation conditions. Fungus-inert materials should be used. See MIL-STD-454 requirement for further guidance.

f. Salt fog. Salt-sea-atmosphere conditions of (document reference or design criteria) shall apply.

Salt-sea-atmosphere requirements are appropriate for nearly all equipment. Exposure to salt spray is not uncommon, since some bases are located adjacent to sea water. The atmosphere near the ocean will cause galvanic corrosion of exposed metals. Droplets of salt water suspended in the air will evaporate and leave tiny particles of salt. When these droplets or particles accumulate on surfaces and dry, a film of salt remains on the surface. A film of salt on an optical surface will reduce its efficiency over a period of time. When relative humidity is near saturation or a light rain occurs, the salt on the surface will absorb water and form a highly conductive solution. Corrosion by electrolytic action can result when two dissimilar metals are involved, and ccorrosion of a single metal can occur when the solution acts chemically. This solution can provide a conductive electrical path and shortcircuit equipment.

g. Explosive conditions. Explosive atmosphere conditions of (document reference or design criteria) shall apply.

The equipment that must operate in an explosive atmosphere should not cause an ignition of that atmosphere.

h. Acceleration. The equipment shall be designed for normal-operating, limit, ultimate, and crash load factors as follows (document reference or design criteria). Limit load factors for LRUs weighing 20 pounds or less shall be a minimum of 10.0 in each direction. Crash load requirements apply to equipment which if broken loose from its mounts could present a hazard to personnel.

Load factors for equipment should be obtained from the airframe structures organization of the air vehicle SPO or ASD/ENSFL.

i. Sunshine and ultraviolet radiation. No functional degradation or deterioration of finish or materials on parts which may be subjected to prolonged exposure to sunshine shall occur as a result of such exposure over the life of the equipment. The equipment shall deliver specified performance when operating in the maximum heat-dissipating mode in any applicable combination of surrounding air temperature and pressure, and is subjected to solar radiation at an intensity of up to __________ watts per square meter on the exposed projected horizontal area.

This paragraph applies to any equipment which will be exposed to sunshine when operated. Long-term deterioration of finishes and optics may be caused by ultraviolet radiation. An intensity of 950 w/m^2 (88 w/ft^2) has been used with the above requirement, which represents a closed cockpit in the desert. Radiation of 1076 w/m^2 (100 w/ft^2) is appropriate for a canopy-open condition, but should not be used with the maximum temperature.

j. Explosive decompression. The equipment shall not be damaged and shall perform as specified after an explosive decompression of the surrounding air. The pressure change shall be ___________.

Equipment located in the cockpit and equipment bays may be exposed to explosive decompression and should continue to operate. An appropriate air pressure change rate must be inserted.

k. Fluids. Where entrapment of fluids can occur and cause deterioration of equipment or cause equipment malfunction, drain holes shall be provided to prevent such entrapment of fluids. The equipment shall withstand contact with the following fluids without damage or permanent degradation of performance:

(1) Water

(2) ___________

Fluids to which the equipment will be exposed should be listed. The following fluids have been listed for avionics:

(1) Water

(2) JP-4 and JP-5 fuels and NATO equivalents meeting MIL-T-5624; and JP-8 (MIL-T-83133) (ranging from -54°C to +93°C).

(3) Hydraulic fluid (MIL-H-83282 and MIL-H-5606) (ranging from -54°C to +135°C).

(4) Coolants of the fluorocarbon, silicon, glycol, and silicate ester families (ranging from -54°C to +135°C).

(5) Lubricating oil (MIL-L-7808) (from -54°C to +135°C).

(6) Anti-icing and de-icing/defrosting fluid (MIL-A-8243).

(7) Decontamination fluids.

These requirements should be deleted for equipment where meeting them is impractical or of little value. For example, the film used in a film camera or a map reader system is generally not useable after contact with these fluids, but it is expendable and it is not practical to make cassettes watertight.

Most avionics equipments are designed to meet the requirements and provide the desired performance, life, and reliability under any natural combination of the service conditions and environments specified in MIL-E-5400. However, the MIL-E-5400 conditions are generalized. Analysis of conditions on the particular airframe may reveal peculiar values for one or more environmental factors.

REQUIREMENT LESSONS LEARNED

High humidity and high temperature environments have been observed at Eglin AFB, when F-4 canopies left open during maintenance were closed as quickly as practical during a sudden summer thunderstorm. After the storm, maintenance operation continued, with sunshine heating up the closed, wet cockpit.

Sudden summer thunderstorms are common in many parts of the world, and it is not uncommon for canopies and access panels to be open for maintenance, thus exposing equipment in the cockpit and equipment bays to driving rain, and dripping water.

If the offensive avionics system cannot be made inherently capable of withstanding the operational environment specified, then an environmental control system must be provided to maintain service conditions compatible with the parts and subsystems. The environmental control system must be capable of maintaining the internal temperature, pressure, and humidity for the equipment at levels necessary to achieve system performance and reliability and to minimize life cycle cost. It should be capable of maintaining the proper environment during all phases of flight and flight attitudes, ground static, and taxi conditions when mounted in the aircraft. Ground cooling capability should be self-contained to provide ground cooling prior to flight operations. The control system should provide adequate environmental control for steady-state operation at cruise Mach and for transient operations at high Mach. The environmental control system (ECS) should maintain the required temperatures and humidity under extremes of high humidity, and particularly, high temperature. Lower temperature operating conditions will extend the life of the equipment.

Cooling provisions should be simulated during temperature-altitude tests. Separate cooling air tests are generally performed on forced-air cooled equipment to measure flow rate, pressure drop, and susceptibility to dirt and water contamination.

It is important to account for any special cooling apparatus in tests to demonstrate compliance with cooling requirements. If the equipment needs a fan to meet the cooling requirements, it is important that all acceptance tests be run with the fan in operation and that any fan failures be counted as relevant failures.

In the event air vents are required, they should be protected as necessary to preclude entry of harmful foreign materials. The use of supplemental devices, such as fans, integral coolant loops, or other such apparatus, is not good design practice. Forced-air cooled equipment can utilize finned cold plates, electronic modules can be connected thermally to the cold plates, and the airflow path through the plates can be sealed to prevent the cooling air or water from entering any module. If the box is not sealed, then outlets for water drainage due to condensation must be provided in the box. All circuit cards should be vertically oriented to prevent short circuits due to moisture collection on the cards.

4.2.1.4 **Environmental conditions.** Compatibility of the offensive avionics with the intended environmental conditions shall be verified by analysis and test utilizing the following methods:

a.
b.
c.
d.

VERIFICATION RATIONALE (4.2.1.4)

Compliance must be verified to assure that the equipment withstands the environment, both operationally and nonoperationally, including the flight environment, flight line activities, and the logistic supply chain.

VERIFICATION GUIDANCE

The equipment design must be compatible with the environments generated by the operation and usage of the aircraft and ground transportation, including flight line. The equipment should be tested to determine the performance during exposure to these environments, as given in MIL-STD-810. The test results should be correlated with the environmental design requirements of 3.2.1.4.

a. Rain. The equipment shall be subjected to the rain test in accordance with MIL-STD-810 method 506.2, except that .

The MIL-STD-810 rain test, with modifications to suit the applications, is generally appropriate.

b. Bench handling. The equipment shall be subjected to a shock test in accordance with procedure VI of MIL-STD-810, method 516.3.

MIL-STD-810, method 516.3, procedure VI gives bench handling appropriate guidance.

c. Crash safety. Cockpit equipment shall be subjected to the crash safety test as described in procedure V of MIL-STD-810, method 516.3.

For ultimate and crash accelerations, stress analysis or test of a structural mock-up is often an appropriate alternative to test of actual equipment. The actual equipment should be tested for normal and maximum shock values.

d. Sand and dust. The equipment shall be tested in accordance with MIL-STD-810, method 510.2.

A test in accordance with MIL-STD-810, method 510, procedure I can be used. A test is generally not needed on equipment which has no moving parts or optical windows, since it can be determined by inspection that it will not be affected. Equipment using forced-air cooling should be subjected to a "sand and dust in the cooling air" test if small or complex air passages are used, or if the cooling air passes over components or connectors.

e. Fungus resistance tests. Fungus resistance tests shall be required only on those parts, subassemblies, or assemblies which use fungus nutrient materials in their construction. If no fungus nutrient materials are used, a certification to this effect shall be provided. The tests shall be accomplished with the Fungus Test method 508.3 of MIL-STD-810. After exposure, the equipment shall be evaluated as follows:

(1) The equipment shall be visually examined for fungus growth or corrosion. Evidence of fungus growth or of corrosion indicates improper selection of materials or inadequate protective finishes and shall be cause for rejection.

(2) Equipment functional dielectric tests shall be made on electrical items. Any drying permitted shall be compatible with operational use. In the testing sequence, where fungus and salt spray are to be performed on the same specimen, the fungus test shall be performed before the salt spray test to prevent erroneous results caused by the remaining salt deposits which can retard fungus growth.

A test using MIL-STD-810, method 508, procedure 1 should be required only for parts which use fungus nutrient materials.

f. Salt fog. The equipment shall be subjected to salt fog testing in accordance with MIL-STD-810, method 509.2.
Testing based on MIL-STD-810, methods 509 for salt fog is generally appropriate.

g. Explosive atmosphere. The equipment shall be subjected to an explosive atmosphere test in accordance with MIL-STD-810, method 511.2, procedure ____________.

An explosive atmosphere test using MIL-STD-810, method 511 is generally appropriate. Equipment which is hermetically sealed, contained in a pressurized container, or consists of sealed solid-state devices may not require a test if analysis indicates that no ignition sources are exposed to the atmosphere.

h. Acceleration. The equipment shall be tested to normal, limit, ultimate, and crash accelerations in accordance with MIL-STD-810, method 513.3. Test load factors shall be as specified in 3.2.1.4.1. The equipment shall be operating during normal and limit acceleration tests.

i. Sunshine and ultraviolet radiation. Equipment which is subject to exposure to sunshine shall be tested in accordance with MIL-STD-810, method 505.1, procedure ____________, except that the test duration shall be __________ hours rather than 48 hours. The failure criteria of MIL-STD-810 shall apply with the additional consideration that any observable change in appearance (e.g. texture or color) of surface finishes or markings shall be considered a failure. Cockpit equipment, and optical windows or appropriate parts thereof, shall be subjected to a __________-hour exposure to UV radiation of an intensity of ____________ w/m^2. The failure criteria of MIL-STD-

810 shall apply; furthermore, any observable change in appearance (e.g., texture or color) of surface finishes shall be considered a failure.

MIL-STD-810, method 505, procedure 1 provides an appropriate sunshine test. Most long-term damage due to sunshine exposure appears to be caused by ultraviolet radiation. A test using 5000 hours of exposure to UV radiation at an intensity of 100 w/m^2 has been used to simulate a lifetime of UV exposure.

j. Explosive decompression. Cockpit or other pressurized equipment shall be subjected to an explosive decompression test or analysis. The initial altitude shall be ____________ and the final altitude ____________. The rate of change of pressure shall be at least ____________. The chamber and equipment internal pressure variations versus time shall be recorded during the test. The equipment shall be visually inspected and functionally tested following the exposure and the results compared with the pre-exposure data obtained in accordance with MIL-STD-810. Improper functional performance or physical damage resulting from the exposure shall constitute test failure.

The flight altitude and cabin altitude corresponding to the greatest pressure change should be inserted.

k. Fluids. Analysis of design data or performance of submersion tests shall be used to determine compliance. Verification is required to assure that equipment is not damaged by normal contact with fluids.

VERIFICATION LESSONS LEARNED

Significant degradation of wavelength-sensitive filters has been experienced. As a result of field degradation of display filters on F-4 WILD WEASEL aircraft, filter tests were performed and certain laminated filters were found to degrade. Holographic optical elements from the LANTIRN HUD program were also tested for approximately 900 hours at 150 watts/meter squared, which was intended to represent three years of sunshine. These elements contain a layer of dichromated gelatin, and test results showed minimal degradation.

The environmental control system itself should be tested to insure proper functioning under environmental extremes produced by aircraft operation. Faulty control system operation can have disastrous consequences on many subsystems because of the domino effect of failure.

3.2.1.4.1 Thermal design. The offensive avionics equipment shall employ internal thermal design techniques which minimize high temperature operating environments. Specific design requirements are as follows: ____________.

REQUIREMENT RATIONALE (3.2.1.4.1)

The thermal design requirement is necessary in order to assure that the offensive avionics contractor places proper importance on internal thermal design of his equipment. It is important to minimize the thermal resistance between each component and the heat sink. Also, the thermal design philosophy should stress trying to minimize equipment life cycle cost (LCC). The thermal protection requirement is necessary in order to prevent unnecessary overheat of the avionics equipment due to an ECS failure.

REQUIREMENT GUIDANCE

Internal thermal design techniques which minimize the thermal resistance between each component and the heat sink and result in minimum life cycle costs should be employed. Alternate approaches to defining this requirement are to either limit component temperatures to levels necessary to meet reliability requirements, to employ temperature sensing devices, or stipulate temperature limits for various components, such as 110°C for semiconductors. These alternate approaches are less desirable because they do not stress trying to optimize thermal design and minimize life-cycle cost.

The thermal protection requirement could be either for automatic shutdown of the offensive avionics or activation of a caution or warning light in the cockpit.

REQUIREMENT LESSONS LEARNED

Past experience shows that many cases of poor avionics reliability can be traced to poor internal thermal design rather than inadequate cooling from the aircraft ECS. Poor thermal design results in high component temperatures and inefficient use of the coolant provided by the ECS.

Avionics reliability is strongly influenced by the operating temperature of the equipment. The reliability is decreased as the temperature of the components is increased. MIL-HDBK-217 shows the reliability versus temperature for many different types of electronic equipment. Avionics reliability can be improved substantially by maintaining the components at temperatures appreciably below the maximum allowable. Studies indicate that avionics reliability can be improved by holding the components at near constant temperature.

Past experience has shown that the main concern has been to maintain avionics component temperatures within their acceptable minimum and maximum limits. This approach results in designing the avionics cooling system with only sufficient cooling capability to maintain avionics components just at or below maximum allowable temperatures under hot-day conditions. Also, many past systems allow the coolant temperature to fluctuate throughout a wide range. The fluctuating temperatures at maximum limits has adversely affected avionics reliability on past systems.

4.2.1.4.1 Thermal design. The thermal design requirements of 3.2.1.4.1 are verified as follows: ____________.

VERIFICATION RATIONALE (4.2.1.4.1)

Verification is necessary to ensure that the equipment has been designed to operate across the operating environment without damage.

VERIFICATION GUIDANCE

Analytical thermal analyses and thermal verification tests should be conducted on all offensive avionics equipment. The analytical thermal model should compute the junction temperatures, case temperatures, part ambient temperatures, and other temperatures as required for each part in the equipment for all operating conditions. Part temperatures should be used to determine the part failure rates using MIL-HDBK-217 type data or similar manufacturer data. The thermal verification test is used to verify the analytical thermal model. The test should be conducted on prototype or preproduction equipment representative of the design to be released for production. The thermal verification test should be conducted as described in DOD-STD-1788. A laboratory test should be conducted to demonstrate adequacy of the thermal protection provisions.

VERIFICATION LESSONS LEARNED

Past experience shows that many cases of poor avionics reliability can be traced to not verifying the adequacy of the thermal design of the equipment. Analytical thermal analyses and thermal verification tests are excellent tools for assessing the adequacy of the thermal design of avionics.

3.2.1.4.2 **Mechanical design.** The offensive avionics equipment shall be designed to withstand and function in the vibration, shock, acceleration, and acoustic noise environments. Specific design requirements are as follows: ______________.

REQUIREMENT RATIONALE (3.2.1.4.2)

These environments represent significant problems in the installation, operation, and reliability of offensive avionics equipment.

REQUIREMENT GUIDANCE

Equipment items, structures, substructures and components should be designed to assure that:

a. Static and fatigue strength of all elements is sufficient to preclude failure.

b. Relative motions of the various elements do not affect function or result in failure.

c. Resonant frequencies of the units and their elements are separated so as to minimize the amplification of input motions.

REQUIREMENT LESSONS LEARNED

Surveys of Vietnam combat aircraft avionics reliability problems showed that 17 percent of all environmentally induced failures were vibration related.

4.2.1.4.2 **Mechanical design.** Design analyses and engineering tests shall be conducted to verify that the requirements of 3.2.1.4.2 are achieved. Analyses and tests shall be

VERIFICATION RATIONALE (4.2.1.4.2)

Consistent reliability can only be achieved by well-designed equipment. The complexity of avionics equipment is such that good design can only be achieved through an understanding of the structural load paths and the dynamic characteristics of the equipment. The required analyses and tests are necessary to achieve that understanding.

VERIFICATION GUIDANCE

Fill the blank by reference to documentation which lists the tests and analyses, scopes the effort and goals of each, and schedules the entire development effort. The following general guidance should be used as a guide in this effort.

a. Analyses. Early analyses should be simple beam, plate, etc. models which allow gross estimates of the suitability of proposed configurations. As the design proceeds these models should be refined into more commplex classical models and eventually into finite element models capable of predicting detail modal response to dynamic inputs and detailed stress distribution for static inputs.

b. Tests. Tests should parallel and be integrated into progress of the design and design analyses. MIL-STD-810 should be used as a baseline for test techniques, procedures, tolerances, and data reduction. Test criteria should be tailored to specific test objectives. Testing should utilize wideband random vibration primarily. Acoustic noise, narrowband random vibration, sinusoidal vibration, shock, and acceleration (steady load) may be appropriate for specific tests or as secondary excitations. Tests should be conducted on selected items from component, subassembly, brassboard, engineering model, and preproduction hardware. Tests should be designed to provide diagnostic information and to evaluate performance and life under stress. In general both goals should be pursued in each test but sometimes more limited objectives are appropriate, such as when troubleshooting. Diagnostic information should include vibration mode shapes, frequencies and damping, relative motions between elements, stresses, and static deflections. A recommended method of evaluation under stress is to increase test severity progressively until failure occurs or performance deteriorates.

VERIFICATION LESSONS LEARNED

Experience has shown that design of structures for static and dynamic loading requires supporting analyses. The detailed understanding of stress and strain distributions necessary for good design cannot be acquired otherwise. Further, the state-of-the-art in analysis, particularly dynamic analysis, is such that testing is required to verify and calibrate the analyses.

3.2.1.5 Transportability. Transportability requirements for the equipment shall be as follows: __________.

REQUIREMENT RATIONALE (3.2.1.5)

The rationale for this requirement is to insure that shipment and handling of sensitive electronic equipment are considered in its design. Labels should be applied to identify equipment sensitive to electrostatic discharge.

REQUIREMENT GUIDANCE

The environmental requirements for transportability are addressed in 3.2.1.4 and 4.2.1.4. Equipment designs which result in a transportability problem as defined in paragraph 3.2.3 of MIL-P-9024 shall be avoided to the extent practicable. Mobility of equipment for transporting purposes shall be defined in terms of ease of packaging, handling, loading, securing, and unloading.

REQUIREMENT LESSONS LEARNED

4.2.1.5 Transportability. Transportability requirements stated in 3.2.1.5 shall be verified as follows: __________.

VERIFICATION RATIONALE (4.2.1.5)

Verification is required to assure that equipment can be transported without damage, and the necessary safeguards have been taken to provide adequate handling.

VERIFICATION GUIDANCE

This type of verification can be performed by inspection and analysis of the design and previous experience with similar equipment.

VERIFICATION LESSONS LEARNED

3.2.1.6 **Electromagnetic compatibility (EMC).** The offensive avionics system, when installed on the aircraft, shall comply with the system electromagnetic compatibility requirements of MIL-E-6051. These requirements shall apply to the intrasystem, intersystem, and mission electromagnetic environments.

REQUIREMENT RATIONALE (3.2.1.6)

MIL-E-6051 outlines the overall requirements for system electromagnetic compatibility including control of the system electromagnetic environment, lightning protection, static electricity, bonding, and grounding. It is applicable to complete systems, including all associated subsystems and equipments. It is also applicable to new avionics equipments being installed on existing aircraft. One of the severe technical problems encountered on the F-15E was radio frequency (RF) incompatibility among the baseline F-15D systems, new RF systems added, and GFE RF systems.

REQUIREMENT GUIDANCE

The offensive avionics system and all associated subsystems and equipment should be designed to achieve system compatibility. The prime or integration contractor designated in the contract should establish an overall integrated electromagnetic compatibility program for the system. Details of the program should be included in a system EMC control plan.

REQUIREMENT LESSONS LEARNED

To achieve system electromagnetic compatibility, subsystems and equipments must be designed to operate in a hostile electromagnetic environment which is generated by intrasystem and intersystem radiated and conducted noise emissions, intentional signal transmissions, direct and induced lightning effects, static electricity discharges, and nuclear electromagnetic pulse (NEMP) effects. Protection measures against these hazards must be designed into the equipments and subsystems and not added after the fact.

4.2.1.6 **Electromagnetic compatibility (EMC).** The offensive avionics system, when installed on the aircraft, shall conform to the requirements of 3.2.1.6 when tested in accordance with the quality assurance provisions of MIL-E-6051.

VERIFICATION RATIONALE (4.2.1.6)

MIL-E-6051 outlines test requirements to demonstrate system electromagnetic compatibility.

VERIFICATION GUIDANCE

The offensive avionics system must be tested to demonstrate system compatibility. The prime or integration contractor should develop and prepare an EMC test program for the system. Details of the program should be included in the system EMC test plan which is submitted for review and approval by the procuring activity.

VERIFICATION LESSONS LEARNED

The complexity of EMC problems requires a full-scale program tailored specifically to mission requirements, including the intended electromagnetic operational environment. Effective use of EMC analysis and modeling techniques can uncover potential problem areas and determine specific areas which should receive emphasis during testing. A computer program which has been found to be particularly useful is the Aircraft Inter-Antenna Propagation with Graphics program which calculates coupled levels between various antenna-connected equipments.

3.2.1.6.1 **Electromagnetic interference (EMI).** The electromagnetic interference requirements of the offensive avionics shall be as follows:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.2.1.6.1)

Electromagnetic interference (emission and susceptibility) characteristics of individual equipments and subsystems must be controlled in order to obtain a high degree of assurance that these items will function in their intended installations without unintentional electromagnetic interactions with other equipments and subsystems. The electromagnetic environment in an aircraft is complex and extremely variable depending upon the various operating modes and frequencies of the onboard equipment. Also configurations of aircraft are continuously changing due to installation of new or upgraded equipment. Electromagnetic compatibility requirements provide a high level of confidence that equipment will continue to operate compatibly under all these changing conditions. The following detailed requirements will provide appropriate control of electromagnetic interference characteristics:

REQUIREMENT GUIDANCE

Part 1 of MIL-STD-461B concerns general requirements. Part 2 covers equipment installed on aircraft (internal or external to the airframe). The specific requirements for this class of equipment are listed under CE03, CE06, CE07 (conducted emissions), CS01, CS02, CS03, CS04, CS05, CS06, CS07 (conducted susceptibility), RE02, RE03 (radiated emissions), and RS02 and RS03 (radiated susceptibility) with appropriate clarification, modification, or addition as cited in the accompanying notes. The wording provided below assumes that the offensive avionics system includes antenna-connected transmitters and receivers. CE03, CE07, CS01, CS02, CS06, RE02, RS02, and RS03 are applicable for all equipments and subsystems. CE06, CS03, CS04, CS05, and CS07 are additional requirements for antenna-connected receivers. CE06 and RE03 are additional requirements for antenna-connected transmitters. MIL-STD-461B is self-tailoring. Requirement levels are adjusted in the document depending upon installation location and characteristics of antenna-connected receiving and transmitting equipment. MIL-STD-461B is in the process of being revised. The new revision will allow deletion of some of the above notes. ASD/ENACE should be contacted for the latest revision.

a. Electromagnetic emissions and susceptibility. The offensive avionics system shall meet the requirements of Parts 1 and 2 of MIL-STD-461B for Class A1b equipment as specified or modified below:

CE03 (1),(2),(7)	CS01	RE02 (3),(7)	RS02 (4)
CE06	CS02 (6)	RE03	RS03 (6)
CE07 (5)	CS03		
	CS04		
	CS05		
	CS06 (4)		
	CS07		

Note: The numbers in parentheses above refer to the notes below which take precedence over MIL-STD-461B.

(1) The CE03 requirement is applicable for AC and DC leads which obtain power from other sources or provide power to other equipment and subsystems. This requirement is not applicable to interconnecting leads.

(2) CE03 limits in figure 2-3 of MIL-STD-461B should be redrawn such that the end points of the line segments are 140 dBuA/MHz at 0.015 MHz and 50 dBuA/MHz at 2.0 MHz.

(3) Radiated transients resulting at the instant of operation of a normal switch shall not exceed the applicable limit of figure 2-10 of MIL-STD-461B by more than 20 dB. Any other transient condition shall meet the applicable limit of figure 2-10.

(4) The procedure and limits or requirements RS02 and CS06 shall apply except that both of the following spikes will be used and values of E( ), t( ), and pulse repetition frequency (PRF) shall be:

-Spike #1: E1 = 200 volts; t1 = 10 microseconds ±-20%
-Spike #2: E2 = 200 volts; t2 = 0.15 microseconds ±-20%

(5) For CE07, a line impedance stabilization network (LISN) as described in figure 7 of MIL-STD-462, Notice 3, shall be connected to every AC and DC power lead within one meter of the unit under test. A storage oscilloscope with a minimum bandwidth of 100 MHz shall be used to measure the transients at the coaxial output of the LISN terminated in a 50-ohm resistive load.

(6) Susceptibility signals (CS02 and RS03) shall be modulated such that they will produce maximum effect on the test sample. If there is no worst-case modulation, signals shall be modulated as follows:

-Below 400 MHz: 1000 Hz, 80% AM or 1000 Hz square wave.
-Above 400 MHz: pulse modulation at 1000-Hz pulse repetition rate and 10-microsecond pulse width.

(7) Only one bandwidth shall be used in any particular frequency band of the measurement receiver. The use of different bandwidths within a frequency band to measure broadband and narrowband emissions independently is not permitted. Measurement receiver bandwidths shall be determined for each requirement according to following approach:

- At the end point of each frequency band, use the following equation to calculate the impulse bandwidths at which the measurement receiver outputs for the broadband and narrowband limits are identical:

Bandwidth (MHz) = Antilog10 (NB Limit - BB Limit)/20

- From available receiver bandwidths, select the bandwidth which is closest to the calculated bandwidth. This bandwidth shall be used over the entire band. A discussion of broadband and narrowband emissions and factors which must be considered in selecting a single bandwidth for any particular frequency range is presented in Application Note ASD/ENA-TR-80-3, May 1980.

MIL-STD-461B provides standardized electromagnetic interference control requirements for electronic equipments and subsystems. These requirements have evolved through many years of experience in determining types of required controls and necessary limits.

The transient susceptibility requirement exposes equipment and its cables to a series of transient pulses which simulate the induced effects of static electricity discharges, lightning strikes, nuclear electromagnetic pulses, and other fast switching transients. The test signal can excite resonant effects which enhance noise inputs to susceptible equipments.

b. Transient susceptibility. No change in indication, malfunction, or degradation of performance shall occur in any equipment or its loads when subjected to an impulse-type electromagnetic field generated by a type MS25271 relay (or equivalent) when wired for continuously self-interrupted operation on a 28-volt DC power source, as described in section 4 of this specification.

This requirement is commonly known as the "chattering relay" test and is used by most of industry to assure that equipments are immune to the effects of impulsive type noise. The requirement is not presently specified in MIL-STD-461, but it is under consideration for inclusion at its next revision.

REQUIREMENT LESSONS LEARNED

The limits specified in MIL-STD-461B have been established empirically through many years of experience. Compliance with these equipment level requirements provides a high degree of confidence that the system will perform as required when installed on the carrier aircraft. Violating the limits does not necessarily result in incompatibilities. However, the greater the noncompliance with the limits, the higher the probability of interference. In some instances, the requirements may be tailored to meet special installations.

Experience has shown that the transient susceptibility test is a simple, inexpensive technique for determining if equipment EMI design measures are adequate. It is especially effective for wide bandwidth, high impedance circuits (for example, digital circuits).

4.2.1.6.1 **Electromagnetic interference (EMI).** The offensive avionics system shall conform to the requirements of 3.2.1.6.1 when tested in accordance with the following:

a.
b.
c.
d.

VERIFICATION RATIONALE (4.2.1.6.1)

Testing is required to demonstrate compliance with electromagnetic interference requirements. Testing is required to demonstrate that the transient susceptibility requirement has been met.

VERIFICATION GUIDANCE

Select test methods from MIL-STD-462, Notice 2, for each of the radiated and conducted emission and susceptibility requirements of 3.2.1.6.1 a. The verification requirements for emission and susceptibility may be elaborated as follows:

a. Electromagnetic emissions and susceptibility. The offensive avionics system shall meet the requirements of MIL-STD-461B as specified or modified in 3.2.1.6.1.a when tested in accordance with the procedures of MIL-STD-462, Notice 2.

b. Transient susceptibility. The offensive avionics system shall conform to the requirements of 3.2.1.6.1.b for transient susceptibility when tested according to the following procedure. The offensive avionics system shall be set up on and bonded to a ground plane in accordance with MIL-STD-462 practices. A type MS25271 relay (or equivalent) shall be wired for continuous self-interrupted operation on a 28-volt DC power source. Measurements shall be made across the relay coil to verify that a peak-to-peak voltage of at least 600 volts is developed during continuous operation. A 10-microfarad feed-through capacitor bonded to the ground plane shall be connected to the 28-volt DC power. The negative power lead shall be bonded to ground. No suppression components (shielding, diodes, or the like) shall be attached to the relay or its wiring. An unshielded No. 18 AWG "antenna" wire shall be connected between the relay coil and a normally closed contact of the relay. The total length of the "antenna" wire shall be 6 meters. The "antenna" wire shall be taped to three sides of each LRU of the unit under test and shall be taped to and parallel (a minimum length of 2 meters) with all power, signal, and interface leads. The "antenna" wire should form a rectangular loop. It may be necessary to conduct the test several times to include all the leads and LRU's under test. All cables and leads shall be approximately 5 cm above the ground plane. The relay shall be operated for at least 5 minutes for each of the following 4 configurations:

(1) Normal power polarity, normal "antenna" wire polarity.
(2) Reversed power polarity, normal "antenna" wire polarity.
(3) Normal power polarity, reversed "antenna" wire polarity.
(4) Reversed power polarity, reversed "antenna" wire polarity.

Reversed "antenna" wire polarity requires interchanging the relay coil and the normally closed contact connections of the "antenna" wire.

The above test method for transient susceptibility is a standardized compilation of various techniques presently used by industry to perform this test. It is the result of a laboratory evaluation which found that the generated electromagnetic environment varied substantially from technique to technique.

VERIFICATION LESSONS LEARNED

The test methods specified in MIL-STD-462 have been developed through many years of experience and provide a satisfactory means for obtaining the data needed to demonstrate compliance with MIL-STD-461B requirements.

Recognition of the transient susceptibility test as being a valid evaluation of transient upset and the need to standardize has resulted in the test being included in a proposed Notice to MIL-STD-462 which is presently being circulated for review.

3.2.1.6.2 **Lightning protection.** The offensive avionics system shall meet the lightning protection requirements of DOD-STD-1795.

REQUIREMENT RATIONALE (3.2.1.6.2)

Lightning currents and voltages can cause structural damage to aircraft and can burn out unprotected electronics. In some instances, flight safety may be jeopardized.

REQUIREMENT GUIDANCE

Lightning protection requirements need to be considered for portions of systems which are external to an aircraft's metallic structure (including portions installed behind nonmetallic structure) and which may be damaged due to direct lightning interaction or may conduct lightning currents or voltages inside the aircraft. Evaluate the trade-off between the probability of lightning attachment to the installation area and the cost of protection or repair. Lightning protection is particularly important for aircraft with flight critical electronics such as fly-by-wire flight control systems or essential electronic engine controls.

REQUIREMENT LESSONS LEARNED

Based on a study of Air Force lightning mishap reports over a thirteen-year period (1970 - 1982), it was found that electrical/electronic equipment or components sustained damage in less than ten percent of all incidents. The damage was generally not critical to flight safety--due to backup instruments and equipments--but did result in mission abort if primary flight indicators, navigation, or communications were lost. Newer aircraft, such as F-15's and F-16's, are generally less susceptible to lightning-related effects because of increased awareness and application of good lightning protection measures, application of more stringent lightning qualification tests and test procedures, and a better understanding of the aircraft/ lightning interaction process.

4.2.1.6.2 **Lightning protection.** The offensive avionics system shall conform to the lightning protection requirements of paragraph 3.2.1.6.2 when verified in accordance with DOD-STD-1795.

VERIFICATION RATIONALE (4.2.1.6.2)

This requirement is to insure that lightning protection measures adequately protect the offensive avionics system.

VERIFICATION GUIDANCE

Consult DOD-STD-1795.

VERIFICATION LESSONS LEARNED

3.2.1.6.3 **Electrical grounds.** The grounding scheme of the offensive avionics system shall be designed to minimize ground loops and common current returns for signal and power circuits, provide effective shielding, and protect personnel from electrical hazards to include the following:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.2.1.6.3)

Grounding techniques can strongly influence performance both within the system itself and as it interacts with other equipment. Ground loop coupling of noise signals due to multiple current return paths for signals and common impedance coupling due to power and signal currents flowing in a shared path are recognized causes of electromagnetic interference problems. Grounding of wire and cable shields in a manner that works for the particular application is essential to preserve the effectiveness of shields.

REQUIREMENT GUIDANCE

Electrical bonding of equipment to structure in the aircraft installation normally protects personnel from shock hazards. This ground path may not be present during maintenance operations. By providing a connector pin tied to the chassis, a ground path is available through wiring to protect personnel from dangerous voltages or currents that may appear on the chassis.

The following requirements may be added as needed:

a. Safety ground. A wire of minimum length connected internally to the equipment chassis shall be provided on a pin on each primary power connector. No circuit shall utilize this wire as its return.

This requirement insures that a mechanism is provided to ground the equipment through normal wiring to prevent a shock hazard to personnel.

Most aircraft presently use aircraft structure as a return for primary power currents. An exception is the B-1 aircraft which uses separate wires for current return. There has been a general trend recently by aircraft manufacturers not to allow primary power users to ground neutrals and returns inside equipment. If this restriction is imposed, the aircraft integrator maintains the flexibility of either grounding the return to structure near the equipment or running a separate current return.

b. Primary power grounding. Primary power returns shall not be grounded internally to the chassis of any equipment. A separate pin shall be provided on each primary power connector as a current return for each source of primary power supplied by the aircraft electrical power system.

This requirement provides control of the path by which the power return current flows through the aircraft.

Established grounding practices in a particular aircraft need to be considered since they may result in specialized grounding requirements such as wire or cable shield grounding techniques.

REQUIREMENT LESSONS LEARNED

System level grounding problems have been particularly troublesome with analog circuit interfaces such as audio and video which include aircraft power frequencies with their bandpass. Ground loops present large areas for magnetic flux coupling of power currents into the circuits. These problems can be averted by eliminating the ground loop through the use of single-point grounding for both types of circuits together with the use of triaxial cable for video.

4.2.1.6.3 Electrical grounds. Proper grounding topology shall be verified by inspection of the design drawings and examination of the actual hardware.

VERIFICATION RATIONALE (4.2.1.6.3)

Design drawings will show the grounding topology; examination of the hardware will confirm that the designs were accomplished.

VERIFICATION GUIDANCE

Verification of the grounding topology can be adequately demonstrated by inspection of the hardware drawings and examination of the actual hardware, with no need to conduct any specific tests.

VERIFICATION LESSONS LEARNED

Both inspection of the design drawings and examination of the actual hardware are needed to verify proper grounding topology.

3.2.1.6.4 **Electrical bonding.** All metallic components of the offensive avionics system shall be electrically bonded to each other in accordance with the class R requirements of MIL-B-5087. A defined electrical bonding path from each LRU chassis to aircraft structure shall be provided in accordance with the class R requirements of MIL-B-5087.

REQUIREMENT RATIONALE (3.2.1.6.4)

Class R bonding (rf potentials) requirements are described in section 3.3.5 of MIL-B-5087. Adequate electrical bonding is required for proper equipment operation when installed in the aircraft.

REQUIREMENT GUIDANCE

The basis of good electrical bonding is intimate contact between metallic surfaces. These surfaces should be smooth and clean with no nonconductive finishes in the contact area. The fastening method should exert enough pressure to maintain surface contact in the presence of mechanical deformations, shock, and vibration. The bond should be protected from moisture and other corrosion causes. MIL-B-5087 specifies bonding requirements for metallic structures. Methods and procedures remain to be developed for composite structure vehicles to meet rf bonding requirements.

REQUIREMENT LESSONS LEARNED

If good electrical bonding is not obtained, proper operation of the equipment on the aircraft cannot be assured. Electrical bonding is also required to prevent shock hazard to personnel.

4.2.1.6.4 **Electrical bonding.** The electrical bonding requirements of 3.2.1.6.4 shall be verified by measurements. An approved milliohmmeter shall be used to measure the DC resistance of all bonds.

VERIFICATION RATIONALE (4.2.1.6.4)

A test is required to demonstrated that specified electrical bonding is obtained.

VERIFICATION GUIDANCE

Electrical bondings are typically evaluated with a DC resistance measurement for reasons of convenience. However, the goal is to achieve a low impedance path also at radio frequencies. Problems typically occur at radio frequencies rather than at DC.

VERIFICATION LESSONS LEARNED

Poor electrical bonds have contributed to a substantial number of aircraft problems. Electrical bonding is typically one of the first items checked during investigations of electromagnetic compatibility problems at the aircraft level. These problems generally result from electrical potential differences existing on the box chassis with regard to aircraft structure. Depending on circuit design, these potential differences may be superimposed on intentional signal waveforms resulting in circuit degradation.

3.2.2 Functional subsystem characteristics

3.2.2.1 Voice communication. The offensive avionics system shall provide voice communications between aircraft and aircraft, aircraft and ground crew, aircraft and ground, and among crew members. The specific frequency band and range coverage are as listed in table III.

TABLE III.

Frequency MHz	Omnidirectional Range NM	Secure Voice Yes or No

REQUIREMENT RATIONALE (3.2.2.1)

Communication capability is required for the aircrew to communicate with each other, air bases, forward air controllers, refueling tankers, escort aircraft, defense suppression aircraft, command and control posts or aircraft, and friendly defensive systems. Reliable clear and secure two-way voice functions must be provided to accomplish communication with these elements. Sufficient isolation should be provided during secure voice operation to assure compliance with TEMPEST requirements.

REQUIREMENT GUIDANCE

The frequency coverage, or tuning range, must be specified for the intended RF band coverage. These frequency excursions must conform to band plan standards as specified in MIL-STD-188C. Intercom systems provide voice communications between crew members. An external intercom station should be provided for maintenance personnel. Voice operation of the airborne radio subsystem should be implemented by connection to the aircraft intercom system for voice input to and voice output from the radio unit(s). Impedance matching to the aircraft intercom shall be maintained for both microphone and headset circuits. Normal push-to-talk operation should be utilized unless special voice activated circuitry is included.

The communications range required of the radio subsystem will depend on both the intended use in the air vehicle and the propagation characteristics of the frequency band selected. The intended use will establish the operating frequency of the frequency band in which the radio subsystem must communicate, but the propagation characteristics of the communications frequency(s) selected will establish definite limitations on the communications range to be expected or achieved.

Radio frequencies throughout the frequency spectrum have varying and different propagation characteristics which extend from transmissions which tend to follow the surface of the earth to transmissions which exhibit characteristics similar to light. Transmissions in the very low frequency (VLF) bands (30 KHz to 300 KHz) tend to travel along the surface of the earth and could conceivably, with sufficient radiated power, provide communication to a receiving station anywhere on the earth. The low and medium frequency bands are not normally used for communications by the Air Force. The high frequency (HF) bands (3 KHz to 30 MHz) are used extensively and the propagation characteristics of these frequencies are very different from the VLF frequencies in that the transmitted radio frequency energy is reflected from the ionosphere and returns to the earth at some distance from the transmitter. This distance, called the skip distance, can be very great in terms of miles around the earth. Also at these frequencies, the ground wave portion of the transmissions is rapidly absorbed by the earth and/or the earth's vegetation. This means that an aircraft located in the United States could conceivably communicate with another aircraft in Panama or South America but could not communicate with his neighbor a hundred miles away. At the ultra high frequency band, the propagation characteristics tend to resemble, the properties of light in that RF transmissions can be received only over line-of-sight distance, i.e., from an aircraft to the horizon or from one aircraft to another as long as line-of-sight conditions are maintained.

Other factors also enter into establishing a range requirement for a radio set., i.e., the absorption factor of various bands of frequencies with respect to the atmosphere and/or atmospheric conditions at the time of the transmissions. As a general rule up to and including the UHF band of frequencies, the higher the frequency, the greater the absorption factor concerned. Absorption factor is a measure of how easily or rapidly the transmitted energy is absorbed and consequently lost to the natural surroundings of the transmitter antenna. With respect to an aircraft, the surroundings are the "air" or atmosphere, including clouds, smog, rain, snow, etc. When the atmosphere has a high moisture content, the absorption of the higher operating frequencies is particularly severe. As an example, when trying to communicate on UHF frequencies in jungle terrain in the wet seasons, the transmitted energy is practically all absorbed and communications are virtually impossible unless the transmitter antenna is elevated well above the terrain.

The purpose of discussing propagation characteristics to some extent in this handbook is to provide some basis for establishing the range criteria for a communication subsystem in a given air vehicle. Range requirements cannot be arbitrary numbers selected because communications are desired over certain distances. All the above factors, i.e., operating frequency, propagation characteristics, etc., must be considered before the range requirement can be included in the specification.

After the range of the communications has been estimated, the engineer can calculate the required RF power output of the transmitter, taking in consideration such factors as propagation in free space, coaxial line losses in the aircraft, antenna gain, etc. This power output then will be used as a design characteristic. The communications range can be especially important in the design and development of a radio subsystem for communications because the range will determine the transmitter power output and also the receiver sensitivity. There are very definite and practical limits to the power output and sensitivity of any radio subsystem. Therefore, the choice of operating frequency and range is very essential to successful communications for a new radio subsystem.

REQUIREMENT GUIDANCE

The intended use of the air vehicle will to a large degree determine the type of communications required and therefore the operating frequencies. There are, however, in use in the Air Force standard operating frequencies, bands which have been assigned for specific purposes. As an example, the frequency band 225.000 Megahertz (MHz) to 399.975 MHz is used for command and control communications throughout the Air Force and all aircraft carry at least one radio subsystem that will provide communications on these frequencies. Operating frequency bands used for military communications are well-defined and documented in MIL-STD-188 and Air Force Manual 100-31. These documents define the frequency bands, band limits, and the required frequency spectrum.

Communication systems involving security of transmission of data, the requirements of NSA (National Security Agency) documents NACSIM-5100, Compromising Emanations, and NACSIM-5203, Guidelines for Facility Design and RED/BLACK Installation, should be considered. These documents should also be used as guidelines in the resultant specifications. Recent developments in crypto security hardware and software can simplify security adapter designs to the extent that plug-in security chips can be made part of the integral airborne radio subsystem design, thus reducing the need to consider security boxes external to the radio system itself. Such integral security system designs greatly simplify the air vehicle wiring and reduce the possibility of compromising emanations due to cross-coupling in the vehicle wiring bundles. The dissemination of security codes is a key element of secure data transfer. The system mission and utility must not be degraded by the selection of a security system involving a cumbersome or inefficient code dissemination method. Additionally, the design of the communication system radio frequency bandwidth must be compatible with those bandwidth requirements of the security adapters chosen for the network. Bandwidths of up to 20 KHz per channel are common among NSA designed secure voice systems.

Interphone system requirements derive from the fact that direct voice input (microphone/headset) is seldom directly connected to the radio set. Other voice audio functions are needed within the weapon system which require microphone amplifiers, headset amplifiers, switching functions, keying circuits, tone generation, etc.

The communication requirements specified here are the installed operating characteristics of the equipment, operating with the appropriate antennas. The antenna losses and installation become critical when using off-the-shelf equipment since the output power and input sensitivity are fixed. The military specifications for antennas include both specific groups and components and the general requirements for antenna installations in aircraft.

REQUIREMENT LESSONS LEARNED

Experience has shown that precise range requirements for a radio subsystem cannot be accurately specified. Technical and propagation factors as discussed in the guidance paragraph above inevitably combine to make predictions unreliable. It is better therefore to make estimates for the case of "normal" conditions and prepare to accept degraded performance for the instances of disturbed or anomalous propagation conditions.

Recent experience with communications systems in weapon systems reveals that selection of frequency coverage and the methods of achieving the ability to quickly tune to a variety of channels has become an important technical adjunct to the design of anti-jam frequency hopping communication systems.

A C-5 was parked at Terrjon AFB, Spain, in such a position that an intervening building prevented UHF communications with the command post approximately one mile away. The C-5 made contact with Croughton, England, via HF radio and was patched through to the Spain command post by AUTOVON land line.

4.2.2 Functional subsystem characteristics

4.2.2.1 **Voice communication.** Verification of the voice communication function shall be by ___________.

VERIFICATION RATIONALE (4.2.2.1)

The frequency tuning range must be verified to insure compliance with the frequency band plan applicable to the chosen type of communication system, i.e., HF, UHF, VHF, L-Band, SATCOM, etc.

VERIFICATION GUIDANCE

The operation of the voice and data transmission security system must be tested as a whole for compliance to specifications and for compatibility with other members of the network when operating in the secure voice or data mode.

The range requirements specified should be verified by tests or calculation to insure that the design of the communication system is adequate to meet the purposes of the intended weapon system.

Verification should be made in the laboratory. If the communications system is new, testing should be done on developmental models. Proper operation on all of the available frequencies should be verified.

An excellent physical verification of the voice operation of the communication system could be accomplished by establishing listening tests using a hot mock-up consisting of the radio unit and an intercom set. Parameters such as levels of harmonic distortion and frequency response could be tested using tone inputs to transmitters and harmonic wave analyzers connected to the outputs of the receiver sections. All input and output circuits would have to be terminated in their proper impedances for these tests.

Verification of the voice encryption capability and system compatibility is best accomplished by actual interface of the communications equipment with an actual operating secure voice adapter in a hot bench mock-up in the laboratory. These tests should be accomplished at the time of first article testing. Obtaining the secure voice adapter for such tests will be one of the most difficult tasks to accomplish. Application to the procuring agency for the communications equipment well in advance of the testing schedule to obtain a test model of the adapter is highly recommended. These test security devices are ultimately obtained directly from NSA or from the military security service for the agency involved. These test units may be obtained for a temporary period for test purposes only. Special test key variables are required and should be ordered simultaneously with the basic test encryption units.

Verification of communication range is not an exact science. Range may be estimated when effective radiated power, receiver sensitivity and receiver noise figure, antenna height, line losses and frequency of operation are known. These calculations are then subject to a further variable due to anomalies in the transmission medium. These anomalies vary from day to night, season to season, sun spot cycle, rain absorption, etc. It is recommended that the range be estimated using the above listed factors and then tested by actual setup on a test range instrumented to measure receive power at the range specified. Actual ranges achieved will vary from those specified. It is recommended that the procuring agency be prepared to accept deviations of 15 percent from the best estimate calculations possible for the system design.

VERIFICATION LESSONS LEARNED

Verification of band or frequency usage is most easily done by comparing an unknown or new design to the operating characteristics of a known good design of differing manufacture. All transmit channels may also be verified by using frequency counters and a corresponding monitor receiver tracking the same set of radio frequency channels.

Calculations for the propagation of the UHF radio on the F-15 aircraft were estimated and specified in the air vehicle specification. These estimations, although accurate, could not predict the inefficiencies of the aircraft antennas under all flight conditions. As a result, the range estimations were not completely achieved. Eventually the performance was accepted, realizing that the specified range goal was not achievable at a reasonable cost.

3.2.2.2 Data communication. The offensive avionics shall provide the following data communications:

a.
b.
c.

REQUIREMENT RATIONALE (3.2.2.2)

Data communications may be needed to pass mission information, weapon data, or status information from the offensive system to a command and control system, targeting system, or operating base. In some cases, it may be desirable to send maintenance related data to ground prior to landing to shorten sortie turnaround time. Also see 3.2.2.1 requirement guidance.

REQUIREMENT GUIDANCE

The data communications requirements should be specified in terms of compatibility with other operational systems, such as JTIDS or PLSS.

The Joint Tactical Information Distribution System (JTIDS) is a secure data and voice command, control, and communication network which employs a time division multiple access (TDMA) protocol for information interchange. Each JTIDS terminal must maintain an accurate time reference for net synchronization. The accurate time reference is used to precisely measure times of arrival (TOA) of received messages, relative to synchronous transmit time and to establish a relative navigation solution. Range error is largely determined by the time of arrival measurement error characteristics. The bearing error is predominantly a function of the JTIDS terminal separations and geometry and is controlled by the JTIDS measurement selection and weighting protocol programmed into each terminal.

JTIDS terminals come in three versions, class 1, class 1A and class 2. Class 2 is recommended for tactical aircraft, Class 1A for command and control aircraft, and Class 1 for surface-based command and control systems.

TEMPEST requirements will also apply to data communications if any classified data is to be transmitted. The data in a mission plan or aircraft flight status information may be classified. See 3.2.2.1 requirement guidance.

REQUIREMENT LESSONS LEARNED

See 3.2.2.1 requirement lessons learned.

4.2.2.2 <u>Data communications.</u> Verification of the data communication function shall be by ____________.

VERIFICATION RATIONALE (4.2.2.2)

Since the aircraft system is attempting to communicate with other systems, possibly moving, compatibility with the other systems will need to be demonstrated. See 4.2.2.1 verification rationale.

VERIFICATION GUIDANCE

The data communications system may also need to be tested to applicable portions of NACSIM 5100 and 5203. See 4.2.2.1 verification guidance.

VERIFICATION LESSONS LEARNED

See 4.2.2.1 verification guidance.

3.2.2.3 **Radio navigation.** The offensive avionics shall provide the following radio navigation functions:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.2.2.3)

Radio navigation is essential for Air Force weapon systems. A variety of radio navigation systems is currently in use.

REQUIREMENT GUIDANCE

Tactical Airborne Navigation (TACAN) provides navigation information, including bearing and range to the ground transmitting station. The TACAN range and bearing information may be used to update the present position of the integrated navigation function.

The global positioning system (GPS) provides position, velocity, timing, altitude, and status information to the aircraft from satellite transmission. Position accuracy is on the order of $\pm$ 18 meters in the horizontal axis and $\pm$15 meters in the vertical axis measured from earth center coordinates. Velocity accuracies are around $\pm$0.1 meters per second. Time is accurate to 55 nanoseconds.

VHF omni range (VOR) is a line-of-sight, enroute, ground-based navigation aid which radiates two signals: (1) a reference phase signal that has a constant phase irrespective of the direction from which the signal is received, and (2) a variable phase signal whose phase varies as a direct linear function of the azimuth of the observer. Since a VOR system radiates a fairly wide beam, nearby obstacles can cause reradiation of the signals, resulting in bearing inaccuracies.

Radio navigation equipment is a rather slowly evolving technology since the complementary ground or space station must be developed and installed concurrently. If space, weight, and power permit, standard or off-the-shelf equipment is usually selected. This places additional emphasis on antenna installation and performance in order to achieve the accuracies and range required. Antenna installation is addressed in 3.2.2.1.

Current Air Force policy should be checked before specifying the use of TACAN. It is being phased out and replaced by GPS.

VOR capability may be required in order to interface with civilian airport facilities.

REQUIREMENT LESSONS LEARNED

4.2.2.3 **Radio navigation.** Verification of the radio navigation function shall be by ___________.

VERIFICATION RATIONALE (4.2.2.3)

These equipments are largely off the shelf and compatibility with aircraft installation and ground systems should be verified.

VERIFICATION GUIDANCE

Functional performance should be demonstrated and compatibility with the air vehicle should be verified by testing. Performance of the specific equipment should be verified in lower tiered specifications. RF compatibility will need to be maintained among all electronic subsystems.

VERIFICATION LESSONS LEARNED

This area requires further investigation and will be added at a later date.

3.2.2.4 **Self-contained navigation.** The offensive avionics system shall provide a self-contained navigation capability. The performance parameters shall be ___________.

REQUIREMENT RATIONALE (3.2.2.4)

The selection of navigation equipment is based on the accuracy requirements of the offensive avionics system which, in turn, are based on mission requirements. The length (time and distance) of the mission, the time allowed for startup, warmup to roll, and the weapon delivery accuracy all contribute to the navigation accuracy requirements.

REQUIREMENT GUIDANCE

In this case the blank should be filled with actual performance requirements or a reference that defines a standard inertial navigation system (INS).

The Air Force currently is using the "standard INS" when it meets program requirements. In many systems, combined equipments are used to provide the required navigation performance. Such systems as doppler inertial (referring to doppler radar combined with inertial navigation), doppler inertial stellar (doppler inertial with star sextant) and doppler, inertial, GPS (for a system using doppler radar, INS, and the global positioning system) are used for these navigation systems.

The accuracy of the self-contained navigation system must be good enough to place the point of interest, such as the target or update point, within the field of view of the sensors used to locate and attack targets. Single-seat offensive systems also need a highly accurate navigation system. In addition, precise navigation will reduce the operator workload by keeping the navigation equipment within an acceptable error budget.

REQUIREMENT LESSONS LEARNED

In the past many inertial navigation systems were tested and some were found to have better navigation accuracy than specified. This was usually due to the hand picking and calibration of test articles. The better figure would then be used as the representative or advertised performance of INS. This figure should not be used since all units will be manufactured and tested to the specified or contractual value which would be more representative of the actual production units. The INS velocity resolution is sometimes more critical than overall position accuracy; such is the case in weapon delivery calculations and synthetic aperture radars.

4.2.2.4 **Self-contained navigation.** Self-contained navigation capability shall be verified by analysis and test as follows: ____________.

VERIFICATION RATIONALE (4.2.2.4)

DOD policy requires that all inertial navigation systems performance shall be verified by the Central Inertial Guidance Test Facility at Holloman AFB, New Mexico. Testing includes position accuracy, velocity, and attitude.

VERIFICATION GUIDANCE

Compatibility with the rest of the aircraft systems will have to be demonstrated. Analysis of navigation accuracies will have to be performed to assess impacts on other avionics and sensor systems.

VERIFICATION LESSONS LEARNED

Testing requires many flight test hours and sufficient funds must be programmed to support the effort.

3.2.2.5 **Offensive avionics integration.** The offensive avionics system shall integrate the constituent subsystems to provide functional redundancy, mission reliability, optimal sensor information, and aircrew situational awareness. Performance of constituent avionics subsystems shall be ____________.

REQUIREMENT RATIONALE (3.2.2.5)

The offensive avionics should be integrated within the necessary hardware and software to process sensor data; perform all mission computations; provide selection for all flight modes, including navigation, communications, and stores management; and provide outputs to the control and display equipment. The overall integrating approach must provide failure identification and failure recovery for safety of flight and mission essential functions.

The architecture of the system should provide physical and functional redundancy to maximize survivability. A single point failure should not degrade system level performance. In the event of multiple single point failures, the offensive system should provide the capability to automatically revert to a degraded mode of operation.

A well integrated offensive avionics system will also accommodate new sensor techniques without major redesign.

REQUIREMENT GUIDANCE

A primary goal of the integration of the offensive avionics is to achieve the design of a system that is usable in the intended environment. Often, in an attempt to provide backup capabilities and the flexibility to handle every scenario, the system becomes too complex. This complexity results because there are too many backup modes, too much flexibility, and too many sequence-dependent and interlaced operations. Today's operational environment demands simple switchology for mode transition and initialization. Many present systems incorporate separate modes or submodes, rather than provide consistent levels of system operation that allow the aircrew to step through a single procedure with simple, definite, and predictable results.

Aircraft sensors should be integrated such that all the system controls are managed by a single interface with the aircrew. For example, during acquisition of a target, the aircrew should not have to independently slew each sensor to the desired point, initialize them as required, and condition the mission computer and each sensor for the search and acquisition tasks.

The offensive avionics architecture should provide the level of redundancy which is required to achieve a high probability that the mission will be completed successfully. Given a reliability for the system components and the required mission completion success, a system architecture can be derived by making the major contributors to mission completion success redundant. The timing requirements and performance requirements following a failure in a redundant system must be defined. In addition to the subsystem elements themselves, the method of communicating data between subsystems must be addressed, such as MIL-STD-1553. The integration requirements may force the contractor to develop interface boxes to convert signals between subsystems into the proper format. There should be a section of the specification which covers the interface equipment.

The blank in the requirement paragraph should allocate specific requirements to the various subsystems to the extent possible.

REQUIREMENT LESSONS LEARNED

The integration of the offensive avionics must include installed performance impacts, especially if the avionics contractor is not responsible for aircraft wiring, power, radomes, fit, vibration, interference compatibility, etc. Failure to address installed performance can result in reduced performance of the system.

4.2.2.5 **Offensive avionics integration.** Verification of the offensive avionics integration compatibilities shall be by inspection, analysis, demonstration, and test as follows: ___________.

VERIFICATION RATIONALE (4.2.2.5)

Verification of the integrated system is required to show that all of the parts operate together and that the system level performance, accuracies, and functions are achieved.

VERIFICATION GUIDANCE

Verification of the system will include lab tests, aircraft ground tests, and flight tests. The verification of redundancy requires that failures be induced in parts of the system. A study should be performed to determine what type and quantity of failures should be induced.

Methods of verification should include avionics integration laboratory testing and installed avionics system ground tests.

a. Avionics integration tests. An avionics integration laboratory (AIL) shall be used to demonstrate and test functional performance of a subsystem or an integrated group of subsystems in simulated missions in laboratory environmental conditions. Where any subsystem is not an integral part of the laboratory operation, its functions and interfaces shall be simulated. The laboratory shall include a functional mock-up of the cockpit suitable for evaluation of cockpit instruments, controls, and displays. The AIL shall also be used for solving problems encountered during the flight test program, for performing compatibility checks between support equipments and primary mission equipments, and for validation of the operational flight program.

b. Avionics installed system ground tests. Avionics system level demonstration and tests shall be performed in a functional test fixture which may be either an actual aircraft or an aircraft mock-up. Checks, demonstrations, and tests to be performed in the functional test fixture shall include: fit checks of new or modified equipment, power susceptibility tests, preliminary EMC tests, cockpit lighting checks, and flight test instrumentation compatibility checks.

VERIFICATION LESSONS LEARNED

The testing for redundancy is not as simple as it might seem, particularly in the case of a multiple computer architecture. In these cases critical data is shared and dynamic. It is therefore very sensitive to what is occurring at the instant of the failure. Testing should include failures at as many points in the envelope of avionics performance as possible.

3.2.2.6 **Computers and multiplexing.** The offensive avionics system shall use __________ computers and __________ data bus architecture. The input/output, throughput, and memory capability shall be sufficient to accomplish the avionics tasks with adequate spare capacity. Identical computers and microprocessors shall be used to the maximum extent possible. The following detailed multiplex characteristics shall apply:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.2.2.6)

Air Force standardization policy requires use of standard computer architectures, multiplex bus interfacing, and higher order languages unless compelling rationale exists for the use of other approaches.

The proliferation of computers, interfacing techniques, and software has resulted in costly acquisition and support costs for offensive avionics systems. The use of MIL-STD-1750 instruction set architecture for 16-bit computers and NEBULA for 32-bit computers (MIL-STD-1862) is an attempt by the Air Force to control this proliferation. Another issue is the use of microcomputers as embedded items within avionics subsystems. Attempts to standardize on one or two types of microcomputers within a weapon system can certainly have long-range cost and supportability savings that should be encouraged.

Because of the increased complexity of multisystem interfaces and the need to reduce wiring weight and complexity, multiplex data bussing has become the accepted technique for use in aircraft avionics. Various multiplexing techniques also increase the signal transfer capability and reliability.

Current Air Force policy is to make maximum use of the MIL-STD-1553 multiplex bus. System considerations such as bus loading and the amount and type of data to be interfaced will indicate the number of busses and which equipment should be on each bus.

In addition, the Air Force now requires all new aircraft and stores to use MIL-STD-1760 (Aircraft/Store Electrical Interconnection System) for the aircraft-to-stores electrical interconnection. This standard has an impact on the stores management system.

REQUIREMENT GUIDANCE

Computer architecture, languages, and interface mechanisms are all controlled by Air Force policy. Deviation from the policy requires approval.

Any microprocessor selected should be military qualified and selected from MIL-M-38510.

The primary system integrator should perform trade studies to:

a. Determine the general data bus architecture based upon fault tolerant isolation of redundant equipment, functional partitioning, mission requirements, etc.

b. Size the system to estimate the bus loading and worst-case throughput requirements of the bus controller based upon mission and growth requirements.

c. Determine worst-case latency (staleness) of data based upon the chosen architecture under normal operating conditions as well as fault conditions. This should also include data transfers across multiple data bus networks.

The following detailed multiplex requirements should be specified to promote standardization and interchangeability.

a. MIL-STD-1553 detail requirements. Merely calling out MIL-STD-1553 as an applicable document is not sufficient to specify this requirement. A suggested approach would be to specify the requirement and then identify any options or additions to the requirements of the standard. Proposed paragraphs for this approach are as indicated below.

(1) Communications and interfaces. All serial digital communication and interfaces between avionic subsystems shall conform to the requirements of MIL-STD-1553. Equipment defined in this specification shall meet the requirements of MIL-STD-1553 as well as the options and additions which are required for this system as defined below. References in parentheses are to paragraphs in MIL-STD-1553. The most recent Air Force applicable Notice to MIL-STD-1553 shall also apply to this specification.

(2) Unique address. All remote terminals shall be capable of being assigned any unique address from decimal address 0 (00000) through decimal address 30 (11110). There shall be two acceptable methods for establishing the address of the remote terminal. The first and preferred method shall be to establish the address through pin programming of an external connector which is part of the system wiring and connects to the remote terminal. Seven dedicated pins shall define the address coding. Five pins shall define the remote terminal address. The sixth pin shall be used as parity for the remote terminal address. Odd parity shall be used. The remote terminal shall not respond to any messages if the address parity is not valid. The seventh pin shall be a return line and be used to program the address and parity pins to a logic zero. An open address or parity pin shall be a logic one. The second method shall be to obtain the address from a software program that has been externally loaded to the remote terminal or subsystem. Sufficient checks of this method shall be made to ensure the detection of any single-point failure of the method and/or RT address. The RT shall not respond to any messages if it has determined that its unique address is not valid. The second method requires advance review and approval by the procuring activity and should be used only on an exception basis.

(3) Illegal commands. If the illegal command option is not implemented, then the terminal shall respond "in form" to any valid command over the data bus, i.e., respond with status and the proper number of data words as defined by the command word. The content of the data words may be undefined.

(4) Variable message block. Each RT or subsystem shall be able to transmit a subset of any message defined for it (i.e., send the first n(i) words in a message, where n is the defined number of data words for that message and i less than n. This shall be done by varying the word count up to the maximum defined for the particular message (i.e., subaddress and T/R bit).

(5) Sample consistency. The subsystem design shall ensure that every message transmitted over the bus by the subsystem contains only mutually consistent samples of information. Different words used to transmit multiple precision parameters shall all be members of the same sample set. Functionally related parameters updated at the same rate shall all be members of the same sample set. Suitable buffering and transmission control logic shall be provided to prevent the transmission of a partially updated message that would contain mutually inconsistent data.

(6) Data form. Digital data shall be transmitted in a form compatible with the message and word formats defined in MIL-STD-1553. All word formats, parameter representations, coding, and documentation shall conform to the requirements and recommendations of Section 80 of MIL-HDBK-1553.

(7) Subaddress assignments. Subaddress 10000 (16) through 11110 (30) shall be used first for subaddress assignments. Only when this selection of subaddresses is depleted for an RT/subsystem may subaddress 00001 (1) through 01111 (15) then be used.

(8) Subsystem status and control. Each remote terminal or subsystem shall, upon command, transmit its self-test and status information. Status here refers to mode, state, health, or identification information for the complete RT, including all subsystems associated with that RT. Subaddress 10100 (20) shall be reserved for this function. The RT shall be capable of transmitting at least one data word for this subaddress. The first data word transmitted by the RT shall be all zeroes to indicate that the RT and subsystem(s) have no failures or faults and nonzero if there are any failures or faults. Any nonzero value shall also be reflected, as appropriate, via the subsystem flag or terminal flag. Subsequent data words may be used to expound on the failures or faults and to transmit mode, state, or identification information. Data associated with a receive command with the above subaddress shall initiate a self-test, specify the particular type of test, or control the mode or state of the RT and/or subsystems, within the requirements and constraints imposed by the remote terminal or subsystem specification.

b. System data bus requirements. Listed below are suggested paragraphs and requirements to be implemented as system level data bus requirements.

(1) General bus requirements. A MIL-STD-1553 multiplex data bus(es) shall be used for information transfer and integration among all elements of the avionics suite. A backup bus control function shall be provided to maintain bus message traffic between the elements in the event of failure of the primary bus controller. In the event of an inflight primary bus control fail-

ure, the backup control function shall be automatically activated and the crew alerted. Manual override shall also be provided in the cockpit so that the crew can force the system into primary or backup bus control if deemed necessary. All terminals connected to the bus shall use transformer coupled stubs and shall provide dual redundant data paths. The multiplex system architecture shall incorporate fault tolerant techniques where possible. Physical separation of redundant equipment and buses as well as multiple sources of similar information shall be considered. This may also include multiple bus architectures. The multiplex system shall be able to accommodate a 50-percent growth based upon worst-case mission requirements. This shall include, as a minimum, the number of remote terminals on a bus, bus loading, bus throughput, and bus controller processing capability.

(2) Address assignments. RT address 00000 (0) shall not be assigned as a unique address until all other allowable combinations of address have been assigned.

(3) Data requirements. The integrated multiplex system shall be documented with the use of a Multiplex System Interface Control Document (ICD). The ICD shall reflect the multiplex system requirements and any equipment-unique requirements or deviations from the system multiplex requirements. The description of the data (source, destination, format, content, and update rate) shall be documented. The bus control process (i.e., bus traffic and transmission rates) shall be described for primary and backup control as well as the procedures for passing control from primary to backup. The ICD shall meet the requirements and recommendations of Section 80 of MIL-HDBK-1553.

REQUIREMENT LESSONS LEARNED

Past experience has proven that it is necessary to provide a statement in the specifications that the system and equipment shall meet the requirements of the standards. Otherwise the designer may misinterpret the requirement as merely a set of goals or guidelines. This approach would not be conducive to standardization. Also, a minimal set of additional requirements, which do not change any of those in the standard, can prove beneficial to the overall flexibility and integrity of the design, especially in light of retrofits, ECPs, and system monitoring. The proposed additions could be incorporated into a design at little or no additional cost if known early in the design phase.

It is important to note here that these requirements do not modify or rewrite the basic requirements of the MIL-STD, but only amplify or add to the existing requirements. It is dangerous to rewrite or paraphrase the standard wholly or in part. This practice has almost always resulted in inadvertent changes to the initial intended requirements.

The recommended system requirements are mostly common sense requirements but tend to be put aside more often than desired. Some systems provide no backup control when many elements of the total system may still be functional after a bus controller failure. Likewise, there should be "up front" analysis and growth provisions built into the initial design. Not all systems have been properly "sized" and analyzed prior to the final design, thus resulting in changes which should not have been necessary. It is important that the bus be treated like all other wiring interfaces and properly documented in an interface control document (ICD). If organized properly, it can serve as a top-level document which can be used to describe the bus system operation as well as serve as the requirements document for the bus controller and each equipment with respect to data bus and data format requirements.

If this data is not provided to the government, then it would be impossible to troubleshoot or modify the system at a later time. This data should not be assumed to be deliverable or obtainable as a part of the delivered operational flight program (OFP).

4.2.2.6 <u>Computers and multiplexing</u>. Verification of the requirements of 3.2.2.6 shall be as follows: ___________.

VERIFICATION RATIONALE (4.2.2.6)

Verification is needed to insure compliance with Air Force policy and military standards in order to improve equipment, interface commonality, and compatibility.

VERIFICATION GUIDANCE

Comparison of processor, language, and bus controller with a list of those which conform to the standards will simplify verification requirements. Items which have not been validated as conforming to the standards should be sent to the appropriate agency for verification. Programs have frequently used so-called standard items (nonvalidated) only to learn during integration that the item contains errors (did not fully comply with the standard) which caused unexpected results thereby requiring design changes in order to work with the system.

All new, modified, or untested designs must be tested to insure compliance with MIL-STD-1553. Any hardware or software changes made in a unit may inadvertently make it noncompliant with the standard. The detailed test plan should be based on ENASD 81-1 Systems Engineering Avionics Facility (SEAFAC) Test Plan/Test Report for MIL-STD-1553 or ENASF 85-1. Copies of this test plan are available from ASD/ENASF, Wright Patterson AFB, Ohio 45433. Ideally such testing should be done for both prototype and production versions of a given unit.

The failure to conduct thorough MIL-STD-1553 compliance tests on individual units prior to system integration results in lengthened integration and flight test activities, slipped schedules, and high costs for design and construction error correction. In addition, future system growth options may not be possible due to noncompliance problems which are too costly to correct; or worse yet, problems may remain undetected until the future modifications are attempted.

VERIFICATION LESSONS LEARNED

See 3.2.2.6 requirement lessons learned and MIL-C-87232, Airborne Computational Systems.

3.2.2.7 **Software.** The offensive avionics operational software shall consist of all computer programs and data necessary to implement and integrate the offensive avionics. The support software shall include the compilers, assemblers, linkage editors, loaders, and simulators required to support the offensive avionics software development, integration, flight test, and operational maintenance efforts.

REQUIREMENT RATIONALE (3.2.2.7)

The software, as a minimum, should provide for (1) the preparation, processing, and transfer of the required mission data information; (2) the operational monitor and control of the avionic system elements; and (3) the operational integration of the interfacing avionic subsystems to the extent necessary to achieve the level of integrated operation called for in this specification. The support software should include all the items (compilers, assemblers, linkage editors, loaders, and simulators) required to support the offensive avionics software development, integration, flight test, and maintenance activities throughout the life of the system.

REQUIREMENT GUIDANCE

Detailed guidance is provided in MIL-C-87232, Airborne Computational Systems, and in the Software Acquisition Engineering Guidebooks (Airborne System) ASD-TR-78-6 thru -8 and ASD-TR-79-5024 thru -5028 and ASD-TR-80-5021 thru -5028.

REQUIREMENT LESSONS LEARNED

See the Software Acquisition Engineering Guidebooks (Airborne System) ASD-TR-78-6 thru -8 and ASD-TR-79-5024 thru -5028 and ASD-TR-80-5021 thru -5028.

4.2.2.7 **Software.** The software functional capabilities shall be verified as follows: ____________.

VERIFICATION RATIONALE (4.2.2.7)

See the Software Acquisition Engineering Guidebooks (Airborne System) ASD-TR-78-6 thru -8 and ASD-TR-79-5024 thru -5028 and ASD-TR-80-5021 thru -5028.

VERIFICATION GUIDANCE

See the Software Acquisition Engineering Guidebooks (Airborne System) ASD-TR-78-6 thru -8 and ASD-TR-79-5024 thru -5028 and ASD-TR-80-5021 thru -5028.

VERIFICATION LESSONS LEARNED

See the Software Acquisition Engineering Guidebooks (Airborne System) ASD-TR-78-6 thru -8 and ASD-TR-79-5024 thru -5028 and ASD-TR-80-5021 thru -5028.

3.2.2.8 Information processing requirements. The software shall efficiently operate within the throughput, precision, accuracy, and stability constraints imposed by the real-time information processing and man-in-the-loop requirements of the offensive avionics system. At ____________ the software shall use no more than ______% of the throughput and ______% of the memory for each general purpose computer and no more than ______% throughput and ______% of the memory for each embedded microprocessor. All software shall be written in ____________, an Air Force-approved higher order language (HOL).

REQUIREMENT RATIONALE (3.2.2.8)

Air Force policy requires the use of standard higher order languages. The selected higher order language should be identified in the last blank.

The system should be designed with enough flexibility to improve, fix, and add functions and capabilities. Early in the system design, accommodations need to be made for these contingencies. Any additional system requirements typically impact the computational system.

REQUIREMENT GUIDANCE

For a very complex system a 50% to 100% margin in memory and throughput is not unreasonable through development. If the system is likely to grow even more with many potential improvements, then a 100% to 200% margin through development may be necessary. Very dedicated tasks with little potential for enhancement may get by with a 25% to 50% margin. Rate of growth in memory usage will usually exceed throughput usage. A milestone should be identified --such as IOT&E, FCA/PCA, IOC--when the computer reserves are effective. Since this is a contractual reserve, the contractor should track how well he is meeting this requirement throughout the design phase. Estimates are likely to vary considerably during the conceptual design phase to CDR. His approach to monitor and maintain the required spare capacity should be identified in a software development plan.

Approved Air Force higher order languages are identified in DOD directive 5000.31, which include JOVIAL J73, as defined in MIL-STD-1589, and ADA, as defined in MIL-STD-1815. In some cases the procuring agency should be prepared to accept waivers to the language requirement for such reasons as lack of development tools, or existing software in another language. Overall design philosophy and requirements are identified in DOD-STD-2167 and its companion handbook MIL-HDBK-287.

REQUIREMENT LESSONS LEARNED

Histories of various aircraft systems have repeatedly demonstrated that the margin is never enough and it will be fully utilized with demand for more. Code will frequently exceed available memory and require optimization (such as LANTIRN, F-16 MFD, F-111 TFR). Examples of program growth for some system main operational flight programs are F-111 (8K to 16K to 48K), F-16 (24K to 64K), Wild Weasel (32K to 64K to 128K).

4.2.2.8 Information processing requirements. Information processing requirements shall be verified as follows: ____________.

VERIFICATION RATIONALE (4.2.2.8)

Compliance with higher order language requirements, and available spare memory and throughput should be verified.

VERIFICATION GUIDANCE

The verification for memory margin can be determined by examination of the object code to determine the amount of memory utilized. Throughput margins can be estimated by analyzing the functional interrelationships and calculating the time required to perform them. Some software development systems do provide the capability to actually time the code being executed.

Further verification guidance is contained in MIL-C-87232, Airborne Computational Systems.

VERIFICATION LESSONS LEARNED

The ability to verify this requirement, particular in systems that overlay memory or that have highly complex functional interactions, is dependent upon determining the actual worst-case processing loads. The worst-case throughput loading may not be related to heavy memory usage.

3.2.2.9 Fault management. The offensive avionics system shall incorporate a comprehensive and effective fault detection, isolation, and reporting capability in support of a ____________-level maintenance concept. During the mission, continuous noninterruptive self testing shall be utilized to alert the aircrew and the offensive avionics system to malfunctions. Before or after the mission, maintenance personnel shall be able to utilize operator-initiated built-in-tests and interrogate recorded faults. The offensive avionics system shall perform a self-test (ST) while other operational requirements are being performed. As a minimum the self-test shall provide ______% detection of true faults with no more than ______% false alarms. A built-in-test (BIT) capability is required for each subsystem. The BIT shall provide ______% detection, and ______% isolation to the ____________ level of all avionics failures with no more than ______% false failure reports.

REQUIREMENT RATIONALE (3.2.2.9)

The system fault management and reporting should be designed from the overall maintenance concept down through the system into each LRU and SRU.

Equipment self-test is more easily implemented on equipment containing a digital processor and generally provides confidence that the equipment is properly working. Self-test is defined as continuous noninterruptive testing of a system or equipment (or background task). Built-in-test (BIT) is defined as interruptive testing and is a capability intended to do away with complex organizational-level test equipment (to the extent possible) and allows for the fastest possible correction of problems on the aircraft.

For aircraft having the capability of storing maintenance data, self-test and built-in-test detected failures should be reported in order to allow rapid maintenance and an improved sortie rate. This is particularly important in finding faults which are intermittent or only occur in certain flight conditions.

REQUIREMENT GUIDANCE

Centralized fault recording and reporting are highly desirable, and achievable. Equipment status (go/no-go) is normally all that is required by the aircrew. However, some mission critical sensors may shut down due to thermal or voltage overloads. In this case, the general cause of equipment failure is important because the aircrew may be able to bring the equipment back on-line to finish the mission. This may require recycling power and resetting the master fault indicator.

High levels of fault detection and isolation to the faulty LRU are important in reducing unnecessary LRU replacements and improving aircraft availability. A 95% detection, 90% isolation, and 5% false alarm rate can be achieved in equipment which is digital, and processor controlled. Isolation to the faulty SRU is also required in some cases. The system specification for the KC-135 required fault isolation of 90% to one SRU, 95% to two SRUs, and 100% to three SRUs. Low false alarm rates are required to provide aircrew confidence in the system.

REQUIREMENT LESSONS LEARNED

Additional design and test guidance has been developed by RADC and is documented in the RADC testability notebook, RADC TR-79-309.

Some systems have tried to push the detection, isolation and false alarm rate to 99%, 95% and 1% respectively. However this has rarely been achieved and has never been achieved at all at the system level.

It is very easy to overload the aircrew with too much fault information. The overall scheme should keep in mind the different information required by aircrew and maintenance personnel.

4.2.2.9 **Fault management.** The adequacy of the fault management design shall be verified as follows: ____________.

VERIFICATION RATIONALE (4.2.2.9)

Appropriate detection and false alarm rates must be verified to assure that the user will have confidence in the system and its equipment, and to insure that he does not rely unknowingly on degraded equipment. This is particularly true of those system elements which can impact flight safety. The terrain following modes of operation on the F-111 and B-1 are examples of such elements.

VERIFICATION GUIDANCE

Since the fault management approach is integrated throughout the system, specific tests and demonstrations will need to be developed to verify this requirement. Equipment-level tests and demonstrations will need to be conducted to insure that the LRU is capable of detecting its own faults, and able to report the fault. System-level tests and demonstrations will be required to insure that the fault management design is able to detect, record, and report equipment status to the aircrew and maintenance personnel.

Data taken from the equipment maintainability demonstration can be used to help verify that the equipment meets the LRU or SRU detection and reporting criteria. Avionic integration laboratory and flight tests are required to verify that the fault management design meets the requirements and properly interfaces with each item of equipment. In the laboratory environment faults can be simulated or actually induced to verify the fault management design. If faults are introduced in the flight test, then they must be carefully controlled and monitored to preclude mishap.

VERIFICATIONS LESSONS LEARNED

3.2.2.10 **Avionics modes.** The offensive avionics system shall provide all the modes required to perform the intended missions. These modes shall include, but shall not be limited to, the following:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.2.2.10)

The offensive avionics systems must accommodate all the modes or functions to perform air-to-air weapon delivery, air-to-ground weapon delivery, navigation, system initialization, steering, position updating etc. In many cases various levels of redundancy are provided to insure mission success. Most of the basic modes have various submodes or alternate means of providing the required capability. In addition, depending on the level of integration or types of equipment, different performance levels will also be achieved depending on the mode or submode selected.

System modes can be categorized in many ways depending on system architecture and equipment availability. Representative modes might be as follows.

a. Mission data entry (automatic and manual)

(1) Destination route points
(2) Target location points
(3) Offset aim points
(4) Weapons stores location and identification
(5) Terminal target data
(6) Data erasure

b. Navigation modes

(1) Inertial
(2) Inertial-inertial
(3) Inertial-doppler
(4) Inertial-inertial-doppler
(5) Inertial-global positioning satellite (GPS)
(6) Inertial-doppler-GPS
(7) Inertial-ground navigate
(8) GPS
(9) GPS-doppler
(10) Stellar inertial

c. Steering modes

(1) Instrument landing system (ILS)
(2) Microwave landing system (MLS)
(3) Airborne instrument low approach (AILA)
(4) TACAN
(5) Manual course
(6) Manual heading
(7) Tanker rendezvous
(8) Terrain following/terrain avoidance (TF/TA)

d. Mission sequencing

(1) Automatic route point sequencing
(2) Manual route point sequencing

e. Fix-taking

(1) Visual ground overfly
(2) Visual air overfly
(3) Radar present position
(4) Fixpoint identification (RF or imaging sensor)
(5) Fixpoint override

f. Air-to-air combat

(1) Missile
(2) Gunnery

g. Air-to-ground combat

(1) Level visual bombing
(2) Radar (direct or offset)
(3) Moving target

h. Altitude calibration

(1) Low altitude
(2) High altitude

i. System checkout

(1) Pre-mission checkout
(2) Post-mission checkout
(3) Selected built-in-test

j. Inflight training

REQUIREMENT GUIDANCE

a. Mission data entry mode provides the capability to enter mission data into the offensive systems automatically or manually. Automatic mission data is provided by (1) digital tape units (F-15, F-16, B-1, B-52), which are magnetic cassette tapes that can be inserted in the cockpit, or (2) flightline data transfer units (F-111), which are paper tape or magnetic tape units which connect to a port on the mission computers. The latter method is more cumbersome and less versatile. Manual data entry provides the aircrew the capability to modify previously entered data. This is important in the event of a change in mission objectives after takeoff.

The data stored in or entered in the offensive avionics system consists of the destination route points (which define the route or path to be flown by the aircraft), target location points (which defines the actual location of the target the system is going to attack), offset aim points (which identify an attack point offset from the actual flight path), stores location of each weapon, and the identification of the weapon on the stores station. Terminal target data may also be included. This might be an image of the target to be attacked that a autonomous weapon needs to identify and lock onto to hit a particular part of the target (such as a bridge support).

Classified data should be erased in emergency conditions, or when the aircraft is unguarded on the ground and when equipment is pulled for maintenance action. Provisions must be made for equipment (such as central processors, smart weapons or embedded processors such as in a multifunction display) in the system capable of containing classified data for erasure. Erasure requirements should be as specified per AFR 205-16. Solid state random access memories generally requires only power removal, but electrically alterable prom and core memories requires multiple cycling.

b. Navigation modes provided by the system depend greatly upon the navigation sensors and degree of integration. Accuracy of the navigation capability is also highly dependent upon the sensors and how the sensors are integrated.

The B-52 offensive avionics system (OAS) has a doppler, an INS, and a GPS that are integrated together. As a stand-alone sensor the GPS provides the most accuracy. The B-1B uses an INS and a doppler with a Kalman filter to smooth errors. The FB-111 uses two standard INS(s), a doppler, and a Kalman filter. The INS(s) are usually set to a common fixed position and are allowed to separately run free after that. Position accuracy in this system is greater then that provided by the INS itself. The F-16C uses a single high accuracy INS. GPS is also being installed in the F-16. The two together with a Kalman filter provide very accurate position information.

Most of the modes are self-explanatory. The ground (inertial) navigate mode is provided for use on the ground while the aircraft is stationary. The purpose of this mode is to use the aircraft zero velocity to bound inertial navigation position and velocity errors. This mode should be automatically deselected once aircraft motion is sensed.

Given a reconfigurable set of navigation sensors, a mode hierarchy should be established. This hierarchy should function automatically to provide the greatest system accuracy at all times unless overridden by the operator. Each mode should have a specified accuracy. For example, given a doppler--inertial --inertial system with an inertial failure the system should reconfigure into a doppler inertial mode and notify the aircrew of an inertial failure. While the system should always be capable of reconfiguring, manual override must be provided to allow the aircrew to train in less frequently used modes.

c. Steering modes are also dependent to various degrees upon the offensive avionic equipment. The ILS and MLS are self-contained systems that provide the capability of flying approaches to runways equipped with transmitters. Localizer and glideslope steering and deviation signals are provided to aircrew displays. The AILA steering mode provides the pilot with roll and pitch steering commands to acquire and maintain a synthetic localizer beam and glideslope beam intersection. This mode provides ILS-like steering cues for approach runways not equipped with operational ILS transmitters.

The tactical air navigation mode (TACAN) enables the aircraft to display continuous indication of the aircraft distance and bearing from any selected TACAN station located within a line-of-sight distance.

Manual course is a backup mode that provides lateral steering commands to acquire and maintain a manually selected magnetic course, which is to be set on the horizontal situation indicator. The manual heading mode provides the capability of flying any desired heading. The heading marker on the horizontal situation indicator is set to the desired heading. The aircraft is then flown to center the bank steering base on the attitude director indicator and the optical display sight.

The tanker rendezvous mode provides the steering capability to a tanker for air refueling rendezvous. In this mode the radar set, usually operating in conjunction with a beacon interrogator, supplies a signal to indicate the necessary steering commands.

The TF/TA mode provides the capability to automatically perform terrain following and terrain avoidance by projecting terrain data along the flight path. TF/TA may be manual, semi-automatic, or fully automatic. This mode requires extensive interaction with the navigation and flight control subsystems. Terrain following determines the vertical maneuvering of the aircraft. Terrain avoidance determines the lateral maneuvering of the aircraft. The latter is normally accomplished through a predefined corridor by following the terrain in such a manner as to maximize terrain masking features or avoid obstacles. Some of the parameters that may be specified in TF/TA include horizontal set clearance, vertical set clearance, ride level, roll limits, acceleration, maximum bank angle, flight path angle limits, and maximum lateral deviations.

d. Mission sequencing provides the capability to navigate from the current steerpoint to the next steerpoint. Provisions must be provided to interrupt the sequence in the event of mission change or cancellation. In addition the capability to manually route the aircraft or change sequence must be provided. Those aircraft with requirements to penetrate into enemy territory and avoid enemy defenses require a higher number of mission sequence points or waypoints than those aircraft dedicated to close air support. Sixty-four to 128 points is not unreasonable.

e. Fixtaking functions or modes consist of the employment of the radar set map mode, other imaging sensors or visual sighting methods to update the system altitude, present position, or location of a target of opportunity (reconnaissance update). These modes are used to correct or bound other navigation errors due to equipment loss or temporary outage. The greater the redundancy of equipment the less frequently these modes will be required.

The visual ground mode provides the capability to perform a present position update prior to takeoff while the aircraft is at a well defined position. This is frequently a point on the runway that has been surveyed to establish precise location. While similar to ground navigate mode, the aircraft may actually be moving at relatively low airspeed.

Visual air overfly mode provides a means of updating present position by flying over a point of known geographic coordinates, such as a bridge or crossroads. This mode allows reinitialization, or updating of the navigation subsystem if it exhibits excessive error characteristics or was out of operation for some reason.

The radar present position mode provides the capability of updating the present position by positioning the radar cursors on a well defined ground feature. The manual tracking control terms generated to position the radar cursors become the input for the update. The magnitude of these terms can be displayed to the aircrew for evaluating their reasonableness prior to inserting them as present position corrections.

Fixpoint identification (RF or imaging sensor) provides a capability to record in the system a target observed with the radar or other imaging sensor. The cursors are placed on the target and the target coordinates are stored for later use. These coordinates may then be recalled for steering or attack.

Fixpoint override is a submode that allows the operator the capability of changing the fixpoint quality of a target that has been entered through the mission data load. The fixpoint quality is a scaled number that describes the goodness of the target location accuracy.

f. Air-to-air combat modes may provide for both missile and gun firing. Air-to-air missile modes give the pilot targeting data to provide optimum engagement conditions for weapon release and generates all the appropriate weapon interface signals without pilot intervention. Steering and cuing data will be provided for each type of selected weapon. This data should inform the pilot of degrading or improving conditions and the maneuvers he must accomplish for improvement. The weapon system must coordinate and control all the avionics equipment to provide the required signals, such as radar, navigation, and communications, as needed by the weapon. Prelaunch cuing should include time to intercept, launch ranges (min and max), steering requirements, time to fire, and probability of kill. Postlaunch cuing should advise the pilot of continued steering necessary to provide weapon data and how long before disengagement can be accomplished.

Air-to-air gun modes must operate extremely fast to accommodate the dynamics of a gun engagement. Rapid and accurate assimilation of target data (velocity, heading, number of g's) is necessary to predict target position for bullet impact and present pilot data to allow him to set up the aircraft to meet the firing requirements.

g. Air-to-ground combat modes provides the aircraft with the computational and control functions necessary to generate release signals for the delivery of air-to-ground weapons. Steering indications direct the aircraft to the correct target release point or orientation for the bombs and missiles. In most weapon delivery cases, cues are provided to the aircrew. These include time-to-go to weapon release, release symbol for computer generated release, and safe-and-in-range indications. Automatic weapon release can be inhibited if predicted lateral miss distances exceed some predetermined value (4200 feet for the FB-111).

The level visual bomb mode provides the capability to deliver gravity weapons against designated ground targets through the use of an optical display sight. The computational system should provide data to position the cursor in azimuth and elevation on a continuously computed impact point (CCIP). When the center of the cursor is positioned over the target, the aircrew depresses the weapon release button. The system then computes steering commands to drive the CCIP to the point designated by the cursor.

The radar mode (direct or offset) provides the capability to place radar cursors on the computed location of the target or some point offset from the target. Lateral steering commands are generated by the system and at the expiration of the time-to-go the system automatically releases the weapon.

The moving target mode provides the operator with the capability to designate a moving target and for the system to generate delivery computations. The desired target is designated by the radar (or imaging sensor) joystick. Lateral steering to the target location will be commanded and the system will compute target location and velocity.

h. Altitude calibration provides the aircrew the capability to calibrate the system altitude. Low altitude calibration is usually performed with the radar altimeter. High altitude calibration is usually performed by the radar set since the accuracy of the radar altimeter is decreased above 5000 ft.

i. System checkout provides the offensive avionics system with a mode that allows aircrew and maintenance personnel to initiate built-in test throughout the system and interrogate reported faults.

Pre-mission checkout is a mode that permits the operational crew to turn the system on and initiate built-in-test in all of the equipment. The status of each piece of equipment is reported to cockpit displays as each LRU completes its test.

Post-mission checkout provides the capability to interrogate any status or failure data reported to the fault collection and reporting subsystem. Various levels of detail, such as LRU identification, types of fault, number of faults, times relative to takeoff, etc., may be reported to maintenance personnel on cockpit displays.

Selected built-in-test is a mode that allows the aircrew or maintenance personnel to force a particular subsystem into self-testing mode. A good example of the use of this mode would be self-test of the terrain following radar prior to performing an actual terrain following operation. Since built-in-test and normal operating modes are frequently mutually exclusive, the test must be locked out during actual flight operation. In the case of the standard INS, invoking built-in-test would end the navigation solution thereby destroying present position information. Selected built-in test should not be confused with self-test which runs continually in background mode.

j. The inflight training mode could provide simulated air-to-air and air-to-ground attack. All normal controls and displays are operational with simulated interaction with on-board stores. An evaluation of the training exercise should be provided by collecting data on aircrew performance.

The F-15 programmable armament control system (PACS) provides for training with any permitted load, without the use of any store or external devices except for training units that contain an electro-optical (EO) seeker. When a store with an EO seeker is used for training, the training unit is carried on any authorized station and the PACS will simulate the store using the video from one of the seekers. For safety, when in the training mode, the PACS will not send any signals to the station, except where the training unit is installed and the signals are limited to those necessary for the seeker operation. By simulation any mix of authorized armament is allowed and the aircraft can be loaded or reloaded in flight, providing an unlimited weapons capability for training purposes. From the cockpit all onboard systems will appear as in a normal weapon engagement.

REQUIREMENT LESSONS LEARNED

In some cases the mode implementation approach may need to be directed. This was done on the FB-111 Avionics Modernization Program, which updated the controls, displays, navigation, communications, and mission computers. The rationale for this was to reduce aircrew retraining by keeping the old modes intact even though the system architecture had changed.

The F-15 air-to-ground weapon delivery algorithms have also been specified on another program because of their known performance. Mode selection and implementation risks can be reduced by building upon proven techniques and experiences.

4.2.2.10 **Avionics modes.** The ability of the offensive avionics system to support all the avionic modes shall be verified by ___________.

VERIFICATION RATIONALE (4.2.2.10)

It will be necessary to show that the offensive avionics system supports all the modes and that the modes are compatible with the aircraft and all intended missions.

VERIFICATION GUIDANCE

Verification of this requirement will vary by modes. Some modes can be verified by demonstration such as system checkout; other modes such as fix-taking will have accuracy requirements which will require verification by analysis and flight test. Hierarchical functions should be demonstrated.

VERIFICATION LESSONS LEARNED

3.2.2.11 **Growth.** The following ___________ (modes, characteristics, performance, etc.) shall permit growth in the design of the equipment. The extent to which the design will include provisions for growth shall be as follows: ___________.

REQUIREMENT RATIONALE (3.2.2.11)

The impact of changing technology and missions requires upgrading, expansion, or addition of operational functions and equipment. Additionally, in many instances, external stores containing specialized equipments can be added to the aircraft, resulting in new mission modes or improved capabilities over what had been previously shown. The system architecture should provide enough flexibility to readily accommodate mission changes. The actual hardware design should accommodate growth (in addition to spare requirements) in terms of space for components or modules as well as the power for them. The computer hardware and software subsystems should also provide growth for memory, input/output, and processing.

Pre-planned product improvement (P3I) is often included in program management direction and even where not specifically directed should be a consideration in system early design. Under P<3>I concepts, basic provisions (such as for cooling, wiring, and group A mounting) are included in the basic contract to make future addition of most-probable growth items less costly than would be the case without pre-planned retrofit.

REQUIREMENT GUIDANCE

In any development it is necessary to keep abreast of future developments and build into the equipment and architecture as much growth capability as possible (within cost and size limitations). Growth (either in size or in number) should be planned for such items as control and display pages and formats, computer memory space and input/output channels, multiplex busses, off-line storage devices, and communication systems. In some cases increased capacity and additional capabilities can be provided by form, fit, and function replacements which may not require major system modification. The overall architecture should be flexible enough to incorporate "block" updates and preplanned product improvements.

New concepts such as high speed data busses, standard modules, common signal processors, and integrated avionics racks are also being developed to promote incorporation of future requirements.

REQUIREMENT LESSONS LEARNED

Many of the standardization efforts, such as MIL-STD-1750 computers and MIL-STD-1553 multiplex bus, were developed with the intent of accommodating future requirements and lessening the impacts of changing requirements and equipment retrofits.

Both the military and the commercial aerospace industry have demonstrated that the concept of the multiplex data bus has lessened the impact of integration of new system components and subsystems. MIL-STD-1553 has become the standard interface criterion for military avionics systems. ARINC 429 and 575 are commercial avionics data bus systems concepts.

Use of MIL-STD-1553 results in growth and retrofit capabilities which are substantially easier to accommodate than other methods such as the multiple ARINC buses or discrete wiring. When coupled with the architecture, data throughput, and spare memory provisions discussed in 3.2.2.6, growth of the system is much more cost effective and manageable with a little advance planning and use of accepted military standards.

4.2.2.11 Growth. The required growth capability shall be verified by ______________.

VERIFICATION RATIONALE (4.2.2.11)

Verification of this requirement is necessary to ensure that planned or potential changes to the system can be incorporated with least change to the existing design. Many potential upgrades are known and programmed for in advance.

VERIFICATION GUIDANCE

See 4.2.2.6 and 4.2.2.9 Verification Guidance. (This area also requires further investigation which will be added at a later date.)

VERIFICATION LESSONS LEARNED

3.3 **Avionics integrity.** The offensive avionics system shall be developed to the requirements of ____________ to meet the design durability and system life requirements. The life values to be met are service life, expected operating life, and failure-free operating period within the total environment of the air vehicle.

a. Service life. The avionics shall be designed to last for ____________ years with economical maintenance before retirement from inventory or salvaging.

b. Expected operating life (EOL). The avionics shall operate for hours within the service life.

c. Failure-free operating period (FFOP). The avionics shall operate for a minimum of ____________ hours before failing for the first time, and for follow-on failure-free operating periods after replacement of life-limited parts and materials.

REQUIREMENT RATIONALE (3.3)

The avionics integrity requirements stated above supersede the traditional reliability requirements. The change to the failure-free operating period will require increased emphasis on product integrity through design, manufacture, and life management.

REQUIREMENT GUIDANCE

The Avionics Planning Baseline document can be used to determine the number of years for operation (service life). Avionics are routinely used 10-15 years before replacement or major enhancement. The statement of need can be used to help establish the expected operating life and failure-free operating period.

a. Service life. The number of years that the avionics system is expected to be in operational usage should be inserted in the blank.

b. Expected operating life. The number of operating hours the equipment is expected to be used during its service life should be inserted in the blank. The number is calculated by multiplying the service life, in years, by the estimated yearly oepration, in hours.

c. Failure-free operating period. A minimum failure free operating service should be established for the offensive avionics system (OAS) and inserted in the blank. This is the minimum time period, stated in operating hours, between pre-programmed maintenance actions or inspections. Each component of the offensive avionics system should have a failure-free operating period which is an integral multiple of the failure-free operating period stated above.

REQUIREMENT LESSONS LEARNED

Avionics integrity must be considered in each step of the design and development process. Techniques used to determine and evaluate the design should include analysis, parts selection, derating, and appropriate application of AFSC Design Handbook guidelines. Electrical or electronic parts should not be used at more than 50 percent of the ratings applicable to their most adverse continuous operating environments, except that capacitors may be used at voltages up to 60 percent of the ratings applicable to their most adverse environments. In establishing the most adverse environments for such parts, suitable allowances should be made for temperature differentials due to heat dissipation paths and adjacent heat dissipating components. Where it is necessary to use variable devices (adjustable devices other than operator controls), protection for the adjustment should be provided to minimize the possibility of degradation by vibration, tampering, or aging.

Insulation, grounding straps, coatings, seals, connectors, and wiring should also be evaluated as part of the avionics. They should be evaluated in the same environments as the LRUs. These components often cause the hard to find intermittent failure.

4.3 Avionics integrity. Verification of the offensive avionics integrity requirements of 3.3 shall be in accordance with the avionics integrity specification.

VERIFICATION RATIONALE (4.3)

Avionics integrity testing is needed to verify that the design, parts, assembly, and manufacturing techniques are adequate to provide the needed durability.

VERIFICATION GUIDANCE

The actual testing criteria, (types of test, samples, length of test failure and restart criteria, etc.) will be developed under the avionics integrity program established by the contractor in conjunction with his Avionics Integrity Master Plan.

Types of tests may include vibration, temperature, altitude, acoustic noise, humidity, and environmental stress screening. MIL-STD-1796, Avionics Integrity Program (AVIP), provides detailed guidance on the required verifications.

a. Service life. The service life is the longest period of time specified. The service life can be demonstrated through analysis and test. The analysis is required prior to the critical design review so that it can affect the design and the establishment of manufacturing process control criteria, and inspection and test criteria. Life testing should be completed before production release of parts and materials.

b. Total operating life. Total operating life can be verified by placing the product in a Combined Environmental Reliabilty Test (CERT) that simulates the environments that the product will see in operational usage. The test time may be shortened by eliminating periods of operation that are considered benign. The verification can be shown as having been met if the unit operates under the CERT for the total expected operating hours without failure, when maintained as planned for operational usage.

c. Failure-free operating period. The failure-free operating period can be verified through CERT testing. The system shall be put on test and run until the specified FFOP or failure. The programmed inspection or rework will be accomplished and the test continued through the equivalent total operating life.

VERIFICATION LESSONS LEARNED

3.4 **Maintainability.** The offensive avionics system maintainability shall be as follows:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.4)

The maintainability of the offensive avionics system should be a prime consideration during equipment and installation design, and should minimize both operation and maintenance costs.

REQUIREMENT GUIDANCE

Generally, the system/subsystem should be designed to permit the accomplishment of required operational maintenance with skill level (3 to 5) personnel. Operational maintenance concepts consist of two or three levels of maintenance (organizational, intermediate, and depot). This concept should be backed up with optimum repair level analysis during system design. LRUs should be designed for fast removal and replacement, rapid fault isolation, and maximum accessibility. Intermediate level maintenance consists primarily of repairing LRUs returned from the flightline, and can be accomplished by removing and replacing SRUs, subassemblies, or units. The equipment design should include accessible test equipment connections which can be utilized without removing the equipment. Internal and external test points must be incorporated into the equipment for connection of the required test equipment during bench testing, calibration, and trouble shooting.

a. Maintenance times. Maintenance times should be specified based on an analysis of equipment complexity, deployment concept, mission turnaround requirements or sortie rate, and maintenance time budget. This can be a very subjective area, and the actual requirement inserted in the specification may be based on the opinion of an engineer who has experience on recent maintainability of similar equipment. The times specified should be short enough to require good design practice and encourage innovative approaches to easy maintenance, but long enough to allow reasonable performance, reliability, and cost.

This requirement can be phrased as follows:

"Design shall be such that the unscheduled active corrective maintenance times at the organizational and intermediate levels shall not exceed the following:

(1) Mean Corrective Maintenance Time
Organizational Level _____ hours
Intermediate Level _____ hours

(2) Maximum Corrective Maintenance Time (95th Percentile)
Organizational Level _____ hours
Intermediate Level _____ hours."

b. Testability considerations. The testability features to be included in the design of offensive avionics system equipment should provide the capability to detect and isolate 100% of the avionics system faults by a combination of automatic and manual methods. On-aircraft fault detection and isolation will primarily be accomplished by built-in test (BIT), supplemented, when required, by support equipment. Off-aircraft fault detection and isolation will be accomplished by a combination of BIT and either automatic or manual test equipment. Partition of fault detection and fault isolation capability between BIT and support equipment should be accomplished in accordance with MIL-STD-2165, tasks 201, 202 and 203. Integration of BIT and support equipment capabilities, selection of support equipment, and development of test program sets for automatic test equipment should be accomplished in accordance with the modular automatic test equipment (MATE) system procedures, standards, and tools selected for use and documented in the MATE application baseline.

System warm-up time should not be included in the determination of the organizational level maintenance corrective times. Intermediate level maintenance will consist of LRU checkout and fault isolation to the SRU (shop replaceable unit) level through the use of appropriate intermediate level support equipment. Each LRU should contain sufficient test points in test connectors and operating connectors to allow fault isolation to a single SRU or functionally-related group of SRUs without disassembly of the LRU. Direct probing of circuit functions for LRU test/fault isolation should be avoided when practicable. Functional packaging/circuit partitioning of SRUs should be accomplished, to the maximum extent practicable, in support of an intermediate level LRU maintenance corrective time.

c. Handling considerations. The equipment should be designed and constructed such that on-vehicle maintenance can be performed in environments of any humidity up to 100 percent relative humidity; in temperatures of -65°F (-54°C) to + 160°F (+ 71°C); and in specified sand and dust by personnel wearing clothing, such as heavy gloves, required by that particular environment. Required maintenance, such as testing, removal, replacement, and hookup, should be possible over this expected range of flightline environments with only external cleaning or wiping allowed.

The system must be designed so that protective equipment is not needed for installation or for transport between the local maintenance and/or supply facility and the vehicle. The system mounting provisions for vehicle installation should permit removal and replacement in five minutes or less by one man using standard tools.

The design of the system should be such that no alignments or adjustments are required when replacing one or more LRUs.

d. Design for maintenance. Elements within system should be designed to group functionally related elements within common SRUs so as to minimize interconnections between SRUs and to simplify fault isolation to a single SRU. All functional parts can be contained in separately removable plug-in SRUs.

SRUs should be designed such that all replacement SRUs, when installed, are immediately operable at design accuracy without requirements for continuity testing or functional adjustment or calibration of the replacement SRU except as approved in writing by the procuring activity. If such adjustments are approved, they should be distinctly labeled and accessible with the SRU installed in its normal position and without disturbing any other SRU or part.

The source of the maintenance guidelines comes from the design drawings and military specifications and standards as implemented by the field technicians in the operating commands. Because of the technical complexity and sophistication of electronic units, testability, use of built-in-test functions, and failure location techniques are more than ever required to provide an accessible level of maintenance in operational units.

e. Scheduled maintenance. The equipment shall be designed to minimize scheduled preventive maintenance. Scheduled maintenance should not be allowed for any parts replacement unless it is established that such parts have a limited life. Batteries are representative of such an item.

f. Accessibility. The equipment should be designed and constructed such that it can be removed and replaced without removing or disconnecting any other assembly. If removal of the system structure--that is, covers--covers, is required for access, such removal should not affect electrical or mechanical strength to the point that damage to the equipment, its assemblies, subassemblies, or electrical harness will occur during normal bench handling.

g. Interchangeability. Interchangeability should conform with applicable provisions of MIL-E-5400. All parts, subassemblies, units, LRUs, etc., having the same manufacturer's part number must be directly and completely interchangeable with each other with respect to installation and performance. (LRUs which are replaceable at the organizational level should not require harmonization or adjustment.) The equipment design and construction should incorporate features such that it is mechanically and electrically impossible to install equipments incorrectly and to attach cables, tubes, electrical plugs, and any other such items in an improper manner. Mechanically keyed, different, sized connectors, and the like, can be incorporated to eliminate all such possibilities.

h. Policy. AFSCR/AFLCR 800-23 requires AFSC and AFLC organizations that acquire, modify, or replace automatic test systems for logistic support to use the modular automatic test equipment (MATE) system procedures, standards and tools selected for use and documented in the MATE application baseline unless a waiver is granted. For that reason, coordination with the MATE focal point, ASD/AEG, should be accomplished early in the process of defining the MATE application baseline. The program office may choose to define a MATE application baseline in the RFP or may provide more general guidance, including the current MATE system baseline to be applied, and require offerors to propose the MATE application baseline they plan to follow.

REQUIREMENT LESSONS LEARNED

The requirement for a program to be implemented early in the program acquisition life cycle results from learning on many systems acquisitions that maintainability features are an integral part of the equipment design which are closely related to other interdisciplinary program requirements such as design engineering, reliability, and logistic support. The optimum specification and design of maintainability features, to satisfy system performance requirements, including logistic supportability, requires a planned and disciplined approach to achieve the desired results.

The need for an integrated maintenance approach also results from lessons learned on modern weapon systems where overreliance on automated diagnostic approaches resulted in serious deficiencies in the system diagnostic capabilities. These deficiencies, in turn, resulted in unacceptably long maintenance down times, high cannot-duplicate failure rates, high retest okay rates between maintenance levels, and consequently severe spares shortages.

Total system diagnostic capability with appropriately selected support equipment to provide an integrated diagnostic capability that satisfies system supportability requirements in a life cycle cost effective manner is a very complex process involving many different disciplines and a host of lessons learned. The MATE Guides have captured most of these lessons learned and combined them into a structured acquisition process together with appropriate standards, tools and procedures to tailor and implement the process in a large variety of acquisition situations.

4.4 **Maintainability.** The requirements of 3.4 shall be verified by analysis, demonstration, and test as follows ____________.

VERIFICATION RATIONALE (4.4)

Maintainability directly impacts the time the aircraft system is available to perform its intended missions. The faster the system can be repaired, the faster the aircraft can be turned around to conduct another sortie. In addition, the easier the equipment is to maintain, the fewer the items that will be in the supply pipelines.

VERIFICATION GUIDANCE

Maintainability demonstration testing should be conducted in accordance with MIL-STD-471, to demonstrate that the maintainability requirement specified has been satisfied. The conditions of the maintainability demonstration and the tasks demonstrated should represent those which can be expected to occur in the operational environment. A single simulated or induced fault or failure may be counted as maintenance action at both organizational and intermediate levels when practical. In some cases, the testing to determine compliance can be integrated with other quality assurance tests.

To adequately and quickly verify maintainability requirements, the verification should be in three distinct phases. Phase 1 would be verification of BIT requirements on preproduction units as early in the program as possible so corrective action can be taken before production. Phase 2 would be verification of the mechanical disassembly of the LRU at the "I" level into SRUs, modules, or subassemblies. The mechanical handling of the LRU at the "O" level can be verified at this time also. This also would be completed very early in the program so corrective action could be implemented in production units. Phase 3 would be verification of intermediate test times and fault isolation techniques using automatic test equipment. By the very nature of intermediate test equipment, this would take place late in the program on production equipment when "I" automatic test equipment is available.

The phases of maintainability verification should take place at logical milestones in the design process. The current practice of lumping maintainability verification into one demonstration late in the program does not allow for corrective action if needed.

VERIFICATION LESSONS LEARNED

A demonstration to show compliance with the intermediate level maintainability requirements and to systematically gather BIT information can be performed. This demonstration should be accomplished in accordance with MIL-STD-471 using test method 4. For the purpose of this demonstration, the "functional level of maintenance" can be at the SRU level and the "maintenance task(s)" should not extend below the SRU level (see MIL-STD-471, table I, page 24). The circuit element (piece part) "failed" must be randomly selected based on the relative frequency of circuit element malfunction within the selected SRU. (NOTE: The SRU is randomly selected in accordance with MIL-STD-471.) The BIT capability shall be verified by analysis and data gathered during the maintainability demonstration test and flight test. Data to determine the failure criteria can be obtained in two ways. One is by recording the unit's BIT ability to indicate or fail to indicate the existence of a malfunction when sample failures are introduced as required in the maintainability demonstration above. The other is by recording (1) BIT capability to indicate or fail to indicate the malfunction and (2) false failure indications occurring during the environmental tests and all other system tests.

3.5 **System safety.** The offensive avionics system safety requirements shall be as follows: ____________.

REQUIREMENT RATIONALE (3.5)

To assure optimum safety, the contractor's design effort should include the application of safety engineering principles throughout all phases of his design and development activities. Equipment and software design features which adequately control or eliminate hazards should be given precedence over corrective or protective features which increase operational complexity. The use of safety devices, warning provisions, and special procedures should be limited to those applications demonstrated by analysis to provide significant improvement in system effectiveness.

During system design, consideration must be given to the health and safety criteria, including the effects of adverse explosive, mechanical, and biological effects. As a part of the safety criteria, the possible toxicological effects of the system or subsystem parts on the user must be examined. Any safety analysis conducted should include the possible adverse effects of electromagnetic radiation, such as radar or laser energy. Because of the possibility of eye damage from laser reflections, particular care must be taken during the development and use of laser systems.

REQUIREMENT GUIDANCE

The safety management principles are given in MIL-STD-882, MIL-STD-454, and MIL-E-5400. Design data, checklists, and other information are given in AFSC Design Handbook 1-6. Personnel hazard protection standards are outlined in MIL-STD-1472. Laser eye protection data and safety thresholds can be obtained from AFMRL, Brooks AFB, Texas.

Handles and grasp areas should be provided to assure that equipment can be easily handled and to minimize damage and personal injury dropping. Provisions for handles should be in accordance with MIL-STD-1472.

Equipment installed in the cockpit must also be designed so that excessive noise does not interfere with pilot or maintenance personnel performance. Noise levels should not exceed 75 dBA where possible.

The system should be designed to operate in both normal and degraded modes to preclude hazardous conditions from occurring. Automatic reconfiguration should be employed to the maximum extent possible. The aircrew must be notified any time a hazardous situation exists, during normal or degraded operation.

The equipment must be designed to have an acceptably low risk that any feature which would permit a failure, malfunction, misadjustment, or misassembly to produce a category I (catastrophic) or category II (critical) hazard, as defined in MIL-STD-882, affecting personnel, the system, or adjacent or interfacing subsystems throughout the entire life cycle, including disposal.

No written warning or caution, however presented (e.g., maintenance manual, operating procedures manual, decal on the equipment, acronym), shall serve as the only means, or in lieu of a design feature, to preclude a critical or catastrophic hazard.

The system should be designed so that hard-wired authority exists over all safety-critical functions. Any hardware, software, and control wiring associated with stores management should be isolated from other aircraft functions to prevent inadvertant actions with the stores.

The equipment should meet the electrical overload protection requirements of MIL-E-5400. In addition, all parts and circuits of an LRU which are likely to carry an overload due to any failures, open circuits, or grounding of any wiring external to the LRU should be capable of withstanding such overload without permanent damage to the LRU.

The equipment must be designed to preclude chain reaction failures, including those resulting from external short circuits caused by inadvertent grounding of external wiring during installation, test, or other causes. LRUs should be designed for safety and ease of handling during installation and maintenance.

REQUIREMENT LESSONS LEARNED

Design features which eliminate or adequately control hazards must be given precedence over corrective or protective features which increase equipment complexity. The use of safety devices, warning provisions, or special procedures must be limited to those applications demonstrated by analysis to provide a significant improvement in system effectiveness. All safety devices, warning provisions, and procedures should be developed so that failures, malfunctions, and errors cannot result in hazards. Operation and maintenance factors should be included in the selection of safety design features.

Noise from avionics is generally caused by high speed cooling fans. In some cases, noise created by equipment bay units is also a problem since maintenance personnel must be able to converse while performing bench checkout. Another major source of noise is the environmental control unit. On some fighter aircraft the environmental control unit produces so much noise during takeoff that the pilot cannot hear the control tower.

4.5 <u>System safety</u>. The verification of the safety requirements of 3.5 shall be accomplished as follows: ____________.

VERIFICATION RATIONALE (4.5)

All equipment should be inspected to insure compliance to safety principles and personnel hazard protection standards.

VERIFICATION GUIDANCE

Personnel exposure protection from acoustic noise should be verified on the "A" scale of a standard sound level meter at slow response. If the alternate octive band analysis method is used, the equivalent A-weighted sound level may be determined from AFR 151-35. This test can be waived if the equipment does not produce significant noise.

A hazard analysis should be conducted to determine operating features which are, or can be, hazards. The analysis should show, as a minimum, that any single point failure will not result in cumulative type or "domino" failures.

VERIFICATION LESSONS LEARNED

Equipment is frequently designed with poorly located handles and centers of gravity resulting in excessive equipment damage and personnel injury. Maintenance personnel should be involved in the review of all system safety and hazard analysis.

3.6 **Human engineering.** The offensive avionics system shall consider human engineering requirements as follows:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.6)

The purpose of human engineering in system programs is to obtain optimum usability, reliability, maintainability, and efficiency in man-machine systems. Human engineering principles, procedures, and criteria must be judiciously applied during system analysis and design to achieve the most effective apportionment of system functions among the human operator and the various system components. Human engineering principles must also be applied throughout the design and development of the system to obtain effective, compatible, and safe man-equipment and man-facility interactions.

REQUIREMENT GUIDANCE

This requirement should insure that the system can be operated by operators ranging from 5th through 95th percentile in size and that experience and projected training of the operator is considered when designing the equipment.

a. The design and construction of the system components shall be in accordance with ____________ and with the applicable design criteria of ____________.

Human engineering requirements are contained in various military specifications and standards. The most commonly specified documents are as follows:

(1) MIL-H-46855. This specification is the basic management specification for applying human engineering principles and procedures. It provides the SPO with positive management control of the contractor's efforts. It requires the contractor to plan and implement a human engineering effort that insures that the required operator performance is achieved during all phases of the system's operation--including maintenance--and that the demands on manpower resources, skill level, training, and cost are reduced.

(2) MIL-STD-1472. This standard applies to the design of all systems, subsystems, equipment, and facilities. It includes specific design criteria and requirements for the following:

- Control display integration
- Visual displays
- Audio displays
- Controls
- Labeling
- Anthropometry
- Ground workspace design
- Environment
- Designs for maintainability
- Design of equipment for remote handling
- Small systems and equipment
- Operational and maintenance ground vehicles
- Hazards and safety
- Aerospace vehicle compartment design

This standard must be specified in all cases where the required system operation depends on effective man-machine interaction.

(3) AFSC DH 1-3. This Human Factors Engineering (HFE) Handbook presents design criteria, experience data, principles, philosophy, requirements guidance and HFE information. The material in the Handbook deals with:

- Preliminary system analysis required to estimate man-machine combinations that will satisfy system requirements
- Personnel/equipment data and analysis
- The application of human engineering principles to system design
- Life support and biomedical requirements
- Estimating qualitative and quantitative personnel requirements
- Planning, designing and developing training program and equipment
- Generating effective job performance aids for operator and maintenance personnel
- Criteria for continuous evaluation of all elements of the HFE program during the system life cycle

In general, the handbook provides guidance and information on all the interrelated aspects of HFE from the conception of a system through its development to integration in the operational inventory. The handbook should be specified whenever required system performance depends on effective man-machine interaction.

b. The system design shall be such that the performance of any task required for operation or maintenance of the system equipment is within the capability of the 5th percentile female through the 95th percentile male Air Force personnel who have been appropriately trained to perform the required task.

The design of the equipment must take into account the range of physical attributes between the 5th percentile female through the 95th percentile male operators. If not, the equipment may be too large or heavy for the female operator and the control clearances, head and leg room may not be adequate for the male operator. Improperly designed equipment that does not take into account the anthropometric differences in operators will be fatiguing to operate and, in some cases, be impossible to operate as required.

The mission may necessitate unique human engineering requirements that will have to be explicitly specified. Early design, layout, and continuing evaluation of the crew station throughout the design phase will promote operator utility.

REQUIREMENT LESSONS LEARNED

It is essential that human factors engineers be integral members of the design team from concept development through deployment. Failure to include them from the beginning is a common error in system specifications. The most common result is a system which cannot be operated or maintained as the hardware or software designer imagined. Attempts to correct human engineering errors can be expensive, time-consuming, only partially satisfactory, or sometimes impossible, necessitating the scrapping of a design.

It is important to require that suitable rationale be provided for designs involving man-machine interfaces. Since there is no such thing as an "average man," human engineers have a difficult time quantifying why they have recommended a particular design rather than another; however, it can be done. It is also necessary to examine the conditions, sample sizes, etc. that are associated with citations that are used to justify design decisions.

4.6 **Human engineering**. The compliance with requirements of 3.6 for human engineering shall be verified by ___________.

VERIFICATION RATIONALE (4.6)

Compliance with the human engineering requirements will be verified when proper operation of the system is demonstrated, to include maintenance and support aspects.

VERIFICATION GUIDANCE

Verification of the suitability of the human engineering design will encompass a wide range of measurements, tests, and experiments, to include laboratory tests, functional mockups, dynamic simulation, engineering design and development tests, acceptance tests and system test and evaluation program. Each test should be structured to build upon the previous test or experiment in a controlled manner to eliminate as much subjectivity as possible. Where possible, actual physiological measurements should be taken.

VERIFICATION LESSONS LEARNED

A number of programs, including the KC-135 Fuel Savings Advisory Program and the F/FB-111 Avionics Modernization Program, utilized hot bench mockups of the cockpit equipment to determine if the proposed arrangement of the equipment, the control of the equipment, and the display paging would provide the required system performance. A number of problems, omissions, and errors were identified early enough in the program to allow design modifications that insured proper system operation.

3.7 __Interface.__ The offensive avionics system interfaces shall meet the following requirements:

a.
b.
c.
d.

REQUIREMENT RATIONALE (3.7)

In many cases it is necessary to specify various specific interfaces the offensive avionics system will have to operate with. This includes such items as an electrical interface with the flight control system, actual mounting and boresighting of equipment, hardware and software interface to mission data loading equipment, man and machine interface requirements that permit actual system control, weapon interface to common weapons, and a cooling approach that does not exceed the available capacity.

Inadequate specification of interfaces frequently results in incompatibility between systems and subsystems. These are usually resolved in an engineering change proposal (ECP), with attendant cost and delays. Such problems can be avoided by giving the designer a good definition of the interfaces.

REQUIREMENT GUIDANCE

Within practical limitations, the system must ensure that no single failure of the integrating system can cause the loss of mission essential data. Coordination is required to verify that all installation and interface aspects, such as antenna locations, equipment mountings and locations comply with established aircraft safety and performance limitations.

The following interfaces should be specified as needed:

a. __Electrical interface.__ The equipment shall be compatible with the input signals, and provide output signals as described in ____________.

For new systems, where the interface is not well defined, a generalized interface description or philosophy should be developed, along with a statement of who will further define the interface. For equipment which is being retrofitted into an existing system, an Interface Control Document or equivalent document describing the existing interfaces should exist. It should be referenced and provided to bidders.

In some cases, the Air Force acts as integrator and in others the contractor performs aircraft installation and integration. If the contractor is required to integrate the offensive avionics system, he must be given the proper data and design configuration information.

b. Mechanical interface. The offensive avionics system shall be designed to be __________ mounted. Mechanical boresighting of the __________ shall be within __________.

The offensive avionics equipment must be compatible with aircraft installation. Any mounting details which are known should be inserted. Hard mounting (no shock mounts) is generally required for avionic equipment which can be designed to tolerate vibration and shock. Gimbles, antennas, and inertial navigation systems will require mechanical boresighting. The tolerances maintained in boresighting the equipment will effect performance.

c. Hardware and software interface. The hardware and software interfaces shall be designed with sufficient flexibility to accommodate system timing and control changes, subsystem interactions, data sequence transmissions, data quantities transmitted, and protocol changes without hardware modification.

The approach to the offensive avionics system integration should provide the capability to switch between like equipment types, data transmission sequence, and amount of data to be transmitted without requiring the hardware, connectors, and wiring to be changed.

Integration of software as well as hardware should be considered. Cognizance of MIL-STD-1553, -1750, -1760, and software related information and exchange systems must be included.

d. Man and machine interface. The offensive avionics system shall provide the aircrew with all the necessary controls and displays for access to all necessary aircraft and mission data to effectively manage aircraft functions and resources at all times.

The system man and machine interfaces must be designed to provide the operators information and control of all the functions, even with multiple equipment failures, in a timely manner. In addition, system controls utilizing multifunction displays should not exceed four levels of paging depth.

e. Weapons interface. The weapon interface shall provide for aircraft-to-store interoperability and minimum impacts to aircraft and store interface integration. Electrical interfaces for interconnecting aircraft and stores shall be in accordance with MIL-STD-1760.

MIL-STD-1760 is an aircraft-to-store electrical interconnection system standard for use on all aircraft and stores. Application of the standard will enhance aircraft and store interoperability and prevent excessive aircraft modification when integrating a store to the aircraft.

f. Environmental control system. The offensive avionics system shall be compatible with the air vehicle environmental control system as follows ___________.

The cooling compatibility requirement is necessary in order to assure that the offensive avionics are designed to be compatible with cooling available from the host aircraft. Cooling is necessary in order to maintain the internal component temperatures at levels necessary to achieve required reliability and performance.

In order to achieve compatibility between the offensive avionics and the host aircraft environmental control system (ECS), the following interface cooling requirements should be defined: coolant type (air or liquid), coolant flow rate, coolant supply temperature, coolant moisture content, coolant contaminant level, coolant supply pressure, maximum allowable pressure drop, allowable coolant leakage, maximum temperature rise of coolant, and coolant inlet/outlet connections. The values for these interface cooling requirements are dependent upon the host aircraft and normally vary from one aircraft program to another. For new aircraft designs, DOD-STD-1788 may be used as guidance for air cooling interface requirements. For high power density avionics, liquid cooling should be considered. As many of these interface cooling requirements as possible should be defined early in the offensive avionics development program. Definition of the cooling requirements should be a cooperative effort between offensive avionics and ECS engineers.

REQUIREMENT LESSONS LEARNED

Proper documentation of all the interfaces is an excellent means of tracing signal flow throughout the system and potential design problems can often be identified. A properly prepared ICD can fully characterize a system.

Methods of equipment mounting will affect maintenance and pull times. If special tooling is required for equipment removal, life cycle costs will be higher.

Continued refinement of man-machine interfaces should be expected.

The mixing of old and new stores with MIL-STD-1760 is a complex technical design problem.

Incompatibilities have resulted from adding avionics to an existing aircraft or designing avionics equipment without considering or complying with the coolant characteristics of the host aircraft. These incompatibilities result in either poor avionics reliability due to inadequate cooling or the need to incorporate an expensive modification to the host aircraft ECS.

4.7 Interface. The interface requirements specified in 3.7 shall be verified by inspection, analysis and tests as follows:

a.
b.
c.
d.

VERIFICATION RATIONALE (4.7)

Verification is required to insure the offensive avionics system will interface with all other air vehicle systems.

VERIFICATION GUIDANCE

a. Electrical interface. The presence and function of all electrical interfaces shall be verified by exercising each input and monitoring each output signal for correct response as part of the acceptance test procedure.

An exercise of all system and equipment functions is generally required for acceptance. Specific verification of details, such as tolerances on voltages, is needed on signals which are critical or not well understood.

Acceptance tests should exercise all interfaces. One may elect to perform laboratory tests to verify interface detail (such as voltage tolerances or levels).

b. Mechanical interface. Inspection and ____________ shall be used to verify compliance.

The mechanical interfaces should be verified by analysis and demonstration for installation and interchangeability of units in the aircraft.

A dimensional tolerance analysis comparing the two sides of the interface may be required for complicated or precision interfaces. Boxes mounted vertically in cockpits can bend relative to their mounting plate under forces caused by aircraft maneuvers.

c. Hardware and software interfaces. The interface approach shall be verified by ____________ that the hardware and software can provide flexibility without hardware redesign.

Inspection of code, and analysis of timing diagrams or drawings can be used to show compliance with these requirements.

d. Man-machine interface. The offensive avionics system man-machine interface shall be verified by ____________.

The ability of the aircrew to handle all of the tasks should be verified by a workload analysis. Actual human interaction with the system can be verified by demonstration. Repeatability of interaction results, particularly under stress, can be verified by well developed and controlled laboratory experiments.

e. Weapons interface.

(This area requires further investigation and will be added at a later date.)

f. Environmental control system. Thermal interface compatibility shall be verified by ____________.

The avionics contractor should conduct analyses early in the development program to assure compatibility of the offensive avionics with the aircraft ECS cooling interface. Laboratory and flight tests are necessary to verify compatibility of the full offensive avionics system with the characteristics of the aircraft cooling interface.

VERIFICATION LESSONS LEARNED

Interaction of equipment in a system integration lab (SIL) environment has often produced effects which were not provided for or understood when interface control documents were developed. Interface documentation problems and mistakes are frequently found during hot bench mock-up. Aircraft checkout and integration tests will also identify interface problems due to documentation and actual wiring conflicts. Actual flight testing may cause outputs to take on values not experienced during laboratory testing.

Past experience has shown a number of cases of avionics failures due to free water being delivered to internal portions of the equipment by the cooling air. The use of cold plate heat exchangers is an effective means of cooling avionics while eliminating possible moisture problems since the cooling air does not enter the internal portions of the equipment.

50. PACKAGING

5.1 Deliverable items. All deverable items shall be prepared for shipment as directed by the procuring activity.

This statement should be included in all specifications involving deliverable hardware, software, or data. Verification of the transportability requirements (4.2.1.5) should be completed prior to shipment.

60. NOTES

6.1 Intended use. The offensive avionic system is intended to be for use in the ____________ aircraft.

This statment relates this specification to a specific weapons system. Additional clarifying remarks applicable to intended use may be added. Direct quotes from the statement of need or the operational concept may be helpful.

6.2 **Definitions.** This section should be used to facilitate a common understanding between the government and the contractor of important terminology which does not have a single definition widely accepted throughout the defense community, or which requires specific interpetation in the context of the specification. The following are examples of terms which may need explicit definition. Misunderstandings due to inadequate early definitions of these items has led to changes in contract scope or direction, or to program delays.

a. Weapon delivery accuracy (CEP)
b. Probability of arrival
c. Processing throughput
d. Flight critical avionics
e. Mission critical avionics
f. Alert response time (what actions are included)
g. Turnaround time (what actions are included)
h. Initial operating capability (for this system)

As a specific example, the following definition of CEP has been used for some systems:

$$CEP = 0.564\ Sx + 0.615\ Sy$$
if Sy less than Sx and Sy/Sx is less than 0.28

$$CEP = (0.82 * k - 0.007)\ Sy + 0.6745\ Sx$$
if Sy less than Sx and Sy/Sx is less than 0.28

if Sx is less than Sy, reverse Sx and Sy
$k = Sy/Sx$ and S indicates the standard deviation

6.3 **Subject term (key word) listing.** The following list is provided to facilitate identification of this document during retrieval searches.

Avionics

Avionics, offensive

Navigation

System integration

Target location and attack

Weapon delivery

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-O-87243(USAF)	Offensive Avionics System

3a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS *(Street, City, State, ZIP Code)*

4. TYPE OF ORGANIZATION *(Mark one)*

- ☐ VENDOR
- ☐ USER
- ☐ MANUFACTURER
- ☐ OTHER *(Specify)*: ______

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional

b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional

c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional

8. DATE OF SUBMISSION *(YYMMDD)*

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