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DEPARTMENT OF DEFENSE
AIR FORCE GUIDE SPECIFICATION

ELECTRICAL POWER SYSTEMS, AIRCRAFT

This guide specification is for guidance only.
Do not cite this document as a requirement.

Comments, suggestions, or questions on this document should be addressed to the Air Force Life Cycle Management Center, Engineering Standards Office, AFLCMC/ENRS, 2145 Monahan Way, Wright-Patterson AFB OH 45433-7017; DSN 674-5476, commercial (937) 904-5476 or by email to Engineering.Standards@wpafb.af.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil/.

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AIR FORCE GUIDE SPECIFICATION
ELECTRICAL POWER SYSTEMS, AIRCRAFT

This specification is approved for use by the Department of the Air Force and is available for use by all Departments and Agencies of the Department of Defense within the distribution limitations noted at the bottom of the cover page.

1. SCOPE

1.1 Scope.

This specification establishes the performance requirements and verifications for electric power subsystems (EPS) for aerospace vehicles, including aircraft, helicopters, and missiles.

1.2 Application.

This specification is applicable to aerospace vehicles and is mandatory for use by the Department of the Air Force. Utilization equipments must be compatible with the power quality requirements specified herein.

1.3 Use.

This specification cannot be used for contractual purposes without supplemental information relating to the performance requirements of electric power subsystems for aircraft.

1.3.1 Structure.

The need for supplemental information is indicated by blanks within the specification.

1.3.2 Instructional handbook.

The instructional handbook, which is contained in the appendix herein, provides the rationale for requirements, guidance for the tailoring of requirements, and a lessons learned repository.

1.3.3 Navigation of document.

Microsoft Word® and Adobe Acrobat® versions of this document contain active hyperlinks which appear in blue font. These hyperlinks provide the user a means to navigate within the document and to reference Websites. The simplest way to return to the most-recently-viewed page within a Microsoft Word® document is to utilize the "back arrow" and "forward arrow" after a hyperlink has been selected. These icons may be included in a user's "Quick Access Toolbar" in this manner: select the Microsoft Office Button ; select "Word Options"; and then select "Customize". In the "Choose commands from" list, select "All Commands" and then select "Back"; click "Add"; then select "Forward" and click "Add".

This same method can be employed in the toolbar area of Adobe Acrobat® versions of this document: select "View" and "Toolbars" on the menu bar, and within the drop-down box select "Page Navigation Toolbar" and the "Previous View" Button and the "Next View" Button and click "OK".

1.4 Deviation.

Any projected design for a given application that results in improved system performance, reduced life cost, or reduced development cost through deviation from this specification, or where the requirements of this specification result in a compromise of operational capability, the details of the change should be brought to the attention of the procuring activity for consideration.

2. APPLICABLE DOCUMENTS

2.1 General.

The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks.

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

INTERNATIONAL STANDARDIZATION AGREEMENTS

ASIC AIR STD 25/18	Connectors for 28 Volt DC Servicing Power
NATO STANAG 3109	Symbol Marking of Aircraft Servicing and Safety/Hazard Points
NATO STANAG 7073	Connectors for Aircraft Electrical Servicing Power

DEPARTMENT OF DEFENSE SPECIFICATIONS

MS17793	Schematic Wiring Diagram (External AC Power Connector, Aircraft)

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-1796	Avionics Integrity Program (AVIP)
MIL-STD-1798	Mechanical Equipment and Subsystems Integrity Program
MIL-STD-2161	Paint Schemes and Exterior Markings for U.S. Navy and Marine Corps Aircraft

(Copies of these documents are available online at https://assist.dla.mil/quicksearch/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications.

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

SAE INTERNATIONAL

SAE AS35061	Connector, Receptacle External Electric Power, Aircraft, 28 Volt DC Operating Power
SAE AS90362	Connector, Receptacle, External Electric Power, Aircraft, 115/200 Volt, 400 Hertz

(This standard is available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or online at http://www.sae.org.)

2.4 Order of precedence.

Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 System description.

The electrical power system (EPS) shall provide for the on–board generation, conversion, storage, distribution, diagnostics, and control of the electric power required for all phases of vehicle operation, including ground maintenance.

3.2 Performance requirements.

3.2.1 Electric power characteristics.

The electrical power system shall provide electric power to the terminals of the power utilization equipment in accordance with the following characteristics: ____________.

3.2.2 Capacity.

The EPS shall be capable of supplying all electric power requirements for all modes of vehicle operation plus additional capacity to provide for growth loads as follows: ____________.

The buses, conductors, and circuit breakers should be capable of handling the load growth provisions.

3.2.3 Uninterruptible power.

Fly–by–wire flight controls and other flight critical subsystems and components which cannot tolerate power interruption, shall be provided with power from full–time redundant power sources. During flight each redundant power source shall be fully active and shall be either powering the critical loads or capable of assuming such loads without power interruption in the event of failure of other sources.

a. Uninterruptible power __(is) (is not)__ required.

b. A minimum of ____________ failures of sources of uninterruptible power shall be accommodated without interruption or degradation of power to flight–critical loads. This requirement shall be met without crew action or automatic reconfiguration of the power system.

3.2.4 Emergency power.

An independent emergency power source shall be provided to supply all essential loads in the event of failure of the primary power source(s).

a. The power rating and total available energy shall be sufficient to supply all loads identified as essential for control of the vehicle and personnel safety.

b. The transfer of essential loads to and from the emergency power source shall be accomplished without transients of a magnitude hazardous to the vehicle or personnel.

c. A convenient means of verifying the operational readiness of the emergency power source prior to flight shall be provided.

d. Other emergency power requirements are as follows: ____________.

3.2.5 External ground power.

The EPS shall accept power from an external source for ground operations as required. The EPS shall be compatible with MIL-STD-704 quality power supplied by the following external electrical power sources: ____________.

a. The EPS shall be capable of handling the maximum external power required for ground operations while maintaining power characteristics in accordance with 3.2.1.

b. The EPS shall provide protection to prevent unsuitable external power from being applied to the aircraft.

c. The EPS shall provide for the power transfer from the external power source to the on-board power source(s) and in the reverse direction in a manner consistent with the transient and power interruption requirements of 3.2.1. Power transfer is required as follows: ____________.

d. Receptacles for 28–volt DC external power shall be in accordance with either SAE-AS35061or ASIC AIR STD 25/18, and shall be connected in accordance with NATO STANAG 7073. Receptacles for 115 volt, 400 Hz external power shall be in accordance with SAE-AS90362, and shall be connected in accordance with either MS17793 or STANAG 7073. Receptacles shall be isolated from aircraft power circuits when the mating plug is disengaged to ensure that dangerous voltages are not present.

e. External power receptacles shall be accessible from ground level and shall be located to minimize hazards to ground personnel. They shall not be located in or near hazardous areas such as air inlet or exhaust, APU or JFS exhaust, propellers or propeller blasts, or fuel servicing or vent areas.

f. The receptacle should be designed such that should ground maintenance personnel forget to remove the plug, the power cable and plug will pull out of the receptacle when the aircraft moves forward.

g. External power receptacles shall be covered by hinged access doors that will automatically remain closed when the receptacle is not in use. The access door shall be identified in accordance with MIL-STD-2161 and NATO STANAG 3109.

h. Other external ground power requirements are as follows: ____________.

3.2.6 Auxiliary power.

The EPS shall be capable of generating, controlling, and distributing power from on–board auxiliary power units for ground or airborne operations as follows: ____________.

3.2.7 Power distribution.

Electric power shall be distributed from the various power sources to the aircraft loads in a safe and effective manner.

a. The buses and distribution circuits shall be configured so normal EPS operation loads receive power from the aircraft primary power source(s), ground power, or an auxiliary power source as applicable.

b. In the event of an EPS failure that reduces the amount of available power below total aircraft requirements; non–flight critical and/or pre-selected loads shall be automatically disconnected as required.

c. Flight critical loads shall have first priority to primary power and shall be supplied from the emergency power source when primary power is not available.

d. The power quality requirements of 3.2.1 shall be maintained.

e. Convenient means shall be provided for disconnecting ground power from those equipments not requiring power during ground operation.

f. Other requirements for electric power distribution are as follows: ____________.

3.2.8 Control and protection.

The electric power subsystem shall include all control and protective functions necessary for safe and effective operation.

a. Routine operations of the EPS such as normal start–up, shut–down, paralleling, and voltage and frequency regulation which require no crew decisions shall be performed automatically.

b. The crew shall be provided with the instruments and manual controls necessary for effective control of the EPS for normal and abnormal operation. This shall include indications of all system faults and malfunctions which affect flight safety or mission effectiveness.

c. Automatic protective functions shall be provided for abnormal conditions of the electric power subsystem which require a prompt predetermined response and for which no crew decisions are needed. Faults and malfunctions shall be detected, isolated, and de-energized in a manner which eliminates the hazardous condition with minimum effect on the safety and performance of the aircraft.

d. All distribution circuits including generator feeders, bus ties, and load circuits shall be protected against short circuits and overloads throughout their total length. Each load circuit shall be individually protected to prevent a single fault from affecting more than one critical function.

e. Multiple–wire feeder circuits shall be used as necessary to meet reliability and vulnerability requirements.

f. Redundant power circuits and components shall be routed/located separately to minimize vulnerability. Means shall be provided for detecting the failure of each redundant component.

g. Distribution buses shall be enclosed within junction boxes to reduce vulnerability. The junction boxes shall be located to take maximum advantage of the protection offered by aircraft structure.

h. Other requirements for control and protection are as follows: ____________.

3.2.9 Major components.

Criteria shall be established for major components of the EPS as necessary to enable the requirements of the integrated subsystem to be met.

3.2.9.1 Aircraft wiring.

The design and installation of wiring associated with the electric power subsystem shall be as follows: ____________.

3.2.9.2 Batteries.

Batteries which are components of the vehicle electric system shall be capable of providing the specified battery power under the environmental and operational conditions to which they will be subjected.

a. Battery design and performance shall be in accordance with: ____________.

b. A battery relay shall be installed in each battery circuit to enable the flight crew to isolate the battery from the rest of the electric subsystem. The battery relay shall be controlled by a crew station battery switch. Any circuits which must remain connected to the battery with the battery switch OFF shall be connected directly to the battery through suitable fuses or circuit breakers.

c. On–board charging of batteries shall be controlled to enable the battery to become fully charged without excessive gassing or heating throughout the entire range of specified battery temperatures. The charging rate shall be sufficient to maintain the battery in a state of charge which will meet the battery power demands of normal ground and airborne operation of the aircraft. Battery charging shall be provided as follows: ____________.

d. Each battery shall be located and installed so that it can be readily inspected and easily removed from the aircraft without removing other components except for a readily opened access panel or door.

e. The location and design of the battery installation shall be such that the release of heat, smoke, gases, electrolyte or other products of a severe battery failure will not damage adjacent components or structure, endanger personnel, or adversely affect crew performance.

f. The battery and/or battery compartment shall be ventilated to prevent the accumulation of explosive mixtures of gases. All vent tubes leading to the exterior of the aircraft shall be designed to preclude the collection of rainwater and other liquids for all ground and flight environments.

g. The installation shall provide for maintaining battery temperature within the limits specified for battery operation. Any heater or thermal insulation required for low temperature operation shall be provided as part of the aircraft's battery compartment and not as an integral part of the battery.

h. Other battery requirements are as follows: ____________.

3.2.9.3 Generators.
Generator systems shall be in accordance with ____________.

3.2.9.4 Converters.

a. DC to AC converters (inverters) shall be in accordance with: ____________.

b. When equipment that is essential for safe flight derives power from an inverter, a spare inverter shall be provided. Changeover from the main inverter to the spare shall be automatic in the event of main inverter failure. Spare inverters may be used as operative units to supply power to nonessential loads, but these loads shall be dropped in the event of main inverter failures.

c. AC to DC converters shall be in accordance with: ____________. When the outputs of two or more AC to DC converters are parallel to supply a common DC bus, no single unit shall be loaded beyond its rating for the worst–case load unbalance or failure mode which can occur.

3.2.9.5 Other.
Requirements for other major components are as follows: ____________.

3.2.10 Environmental conditions.
The EPS and its components shall be capable of withstanding and operating under the following environmental conditions to which they are subjected during all phases of aircraft operation: ____________. Performance shall be as follows: ____________.

Environment	Requirement	Performance
Low Pressure		
High Temperature		
Low Temperature		
Temperature Shock		

Environment	Requirement	Performance
Temperature/Altitude		
Humidity Fungus		
Vibration		
Dust		
Salt Fog		
Sand and Dust		
Rain		
Acoustic Noise		
Explosive Atmosphere		
Shock		
Gunfire		
Temperature, Humidity, Vibration, Altitude		
Acceleration		
Vibro–Acoustic, Temperature		
Nuclear Exposure		

3.3 Electromagnetic interference.
The electromagnetic interference requirements for the EPS shall be as follows: ____________.

3.4 Integrity.
The integrity program requirements shall be in accordance with MIL-STD-1796 for electronics and MIL-STD-1798 for mechanical equipment and subsystems.

3.5 Maintainability.
The EPS maintainability requirements shall be as follows: ____________.

3.6 System safety.
The system safety requirements for the EPS shall be as follows: ____________.

3.7 Interface requirements.
The EPS and its components shall interface with the other aircraft subsystems as necessary to provide the performance specified herein. In addition, the following detailed interface characteristics are required: ____________.

3.8 Supportability.

3.8.1 Integrated diagnostics and testability.

The EPS shall be designed and constructed to permit system status and unambiguous location of faults to be reported within ____________ and ____________, respectively. Diagnostics/testability design and fault isolation times shall be constrained by operational and safety requirements, including maintenance system operational requirements, and life cycle cost.

3.8.1.1 Fault detection/isolation.

The EPS design shall facilitate complete and efficient fault detection and isolation at all levels of maintenance. The system design requirement is 100 percent for fault detection and isolation to an appropriate replaceable, adjustable, or repairable assembly or part. This shall be accomplished using an optimized combination of any or all of the fault detection/isolation methods listed herein. The fault detection/isolation capability shall consist of ____________.

3.8.1.2 Packaging, handling, storage, and transportation (PHST).

The EPS, its subsystems and components shall be designed with PHST characteristics that allow it to be readily transported in the logistics environment at the lowest life cycle cost. The PHST characteristics that will be established as requirements include ____________.

3.8.2 Tools.

Tools required to perform on aircraft organizational level maintenance functions shall be limited to those on the STAM2 list. Tools required to perform intermediate level functions shall consist of ____________.

4. VERIFICATION

4.1 General.

The verifications (inspections/analyses/tests) specified herein shall verify the ability of EPS to meet the requirements of section 3 herein. All verifications shall be the responsibility of the contractor; the Government reserves the right to witness or conduct any verification.

4.2 Performance requirements.

Overall performance of the EPS shall be verified by the following tests of the integrated subsystem.

a. Laboratory tests of a subsystem mockup which accurately simulates the aircraft installation. Testing shall include the most adverse electrical loading, environmental, fault, and endurance conditions required of the subsystem.

b. Aircraft ground and flight tests of the installed EPS under the most adverse conditions of electrical loading, cooling, and flight maneuvers. Failure modes which are not hazardous to personnel or the aircraft shall be simulated.

4.2.1 Electrical power characteristics.
EPS compliance with the requirements of 3.2.1 shall be verified by analyses and tests as follows: ____________.

4.2.2 Capacity.
The ability of the EPS to meet the capacity requirements of 3.2.1 shall be verified by analyses and tests as follows: ____________.

4.2.3 Uninterruptible power.
Compliance with the requirement for uninterruptible power shall be verified by analyses and tests as follows: ____________.

4.2.4 Emergency power.

a. The capability to supply all essential loads shall be determined by analyses and tests as follows: ____________.

b. Compliance with the load transfer requirements of 3.2.4.b shall be verified by analyses and tests as follows: ____________.

c. Compliance with the operational readiness requirements of 3.2.4.c shall be verified by analyses and tests as follows: ____________.

d. Compliance with other emergency power requirements shall be verified as follows: ____________.

4.2.5 External ground power.

a. The capability of the EPS to accept and distribute the maximum external power requirements while maintaining the required power quality shall be determined by analyses and tests as follows: ____________.

b. Protection of the aircraft against unsuitable external power shall be verified by analyses and tests as follows: ____________.

c. The required power transfer characteristics shall be verified by analyses and tests as follows: ____________.

d. Compliance with the design requirements for external power receptacles and their installation shall be determined by inspection.

e. Compliance with other external ground power requirements shall be as follows: ____________.

4.2.6 Auxiliary power.

Compliance with the requirements of 3.2.6 for EPS operation with on–board auxiliary power shall be verified by analyses and tests as follows: ____________.

4.2.7 Power distribution.

Compliance with the power distribution requirements of 3.2.7 shall be verified by analyses and tests as follows: ____________.

4.2.8 Control and protection.

Compliance with the EPS control and protection requirements of 3.2.8 shall be verified as follows: ____________.

4.2.9 Major components.

4.2.9.1 Aircraft wiring.

Compliance with the requirements of 3.2.9.1 for the design and installation of wiring shall be verified by inspection.

4.2.9.2 Batteries.

Compliance with the battery requirements of 3.2.9.2 shall be verified by analyses, tests, and inspection as follows: ____________.

4.2.9.3 Generators.

Compliance with the requirements of 3.2.9.3 shall be verified by analyses, tests, and inspection as follows: ____________.

4.2.9.4 Converters.

Compliance with the requirements of 3.2.9.4 shall be verified by analyses and tests as follows: ____________.

4.2.9.5 Other components.

The compliance of other components with the requirements of 3.2.9.5 shall be verified by ____________.

4.2.10 Environmental conditions.

The capability of the EPS and its components to perform as required under all specified environmental conditions shall be verified by analyses and tests as follows: ____________.

4.3 Electromagnetic interference.

Compliance with the electromagnetic interference requirements of 3.3 shall be verified by tests as follows: ____________.

4.4 Integrity.

Compliance with the integrity requirements of 3.4 shall be verified by analyses and tests as follows: ____________.

4.5 Maintainability.
Compliance with the maintainability requirements of 3.5 shall be verified by analyses and demonstrations as follows: ____________.

4.6 System safety.
Compliance with the system safety requirements of 3.6 shall be verified by analyses and tests as follows: ____________.

4.7 Interface requirements.
Compliance with the EPS interface requirements of 3.7 shall be verified as follows: ____________.

4.8 Supportability.

4.8.1 Integrated diagnostics and testability verification.
In–process verification that the EPS satisfies the diagnostics and testability requirements and constraints shall be accomplished by ____________. Final verification shall be accomplished by ____________.

4.8.1.1 Verification of fault detection/isolation.
In–process verification that the EPS, its subsystems and equipment satisfy the fault detection/isolation requirements shall be accomplished by ____________. Final verification shall be accomplished by ____________.

4.8.2 Packaging, handling, storage, and transportation.
The PHST requirements shall be verified by ____________.

4.8.3 Tools verification.
In–process verification of tool requirement and selection shall be accomplished by review of the tool lists, drawings, and justifications for modified and special tools. Final verification of the adequacy and completeness of tools shall be accomplished by ____________.

5. PACKAGING

5.1 Packaging.
For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM product, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use.

The requirements in this specification are intended for the development of electrical power systems required by aircraft equipment and subsystems designed to perform combat and support missions in environments unique to military weapons systems. The handbook section (Appendix A) provides rationale, guidance, and lessons learned information that can be used in tailoring requirements to a specific aircraft application.

6.2 Acquisition requirements.

Acquisition documents should specify the following:

a. Title, number, and date of this specification.

6.3 Definitions.

6.3.1 Abnormal operation.

Abnormal operation occurs when a malfunction or failure in the electric system has taken place and the protective devices of the system are operating to remove the malfunction or failure from the remainder of the system.

6.3.2 Electrical power system (EPS).

An electric power system consists of a main power source, emergency power source, stand-alone power conversion equipment, control and protection devices, energy storage devices, and a distribution network (wire, cables, connectors, etc.). The main power source is derived from generators driven by the propulsion system. Emergency power is derived from batteries, ram air turbines, or independent auxiliary power units.

6.3.3 Emergency operation.

Emergency operation is the operation of the electric system following the loss of the main generating equipment. Emergency operation occurs when a limited electric source, independent of the main system, is used to power a reduced complement of distribution and utilization equipment selected to maintain flight and personnel safety.

6.3.4 External power source.

The ground or shipboard power source used to provide power for aircraft startup and ground check and/or maintenance of utilization equipment.

6.3.5 Normal operation.

Normal operation occurs when the system is operating as intended without any fault or malfunction which degrades performance beyond established requirements. It includes all system functions required for aircraft operation except during the electrical starting of the propulsion engines. Electric starting of an auxiliary power unit is considered a normal operation. Normal operations include switching of utilization equipment, engine speed changes, synchronizing and paralleling of power sources, and operation from external ground power. The transfer operation is considered to be a normal function of the electrical systems, but it may produce power interruptions.

6.3.6 Uninterruptible power.

Electrical power that is available at the input to utilization equipment in the event of a failure within the electrical system. This power is available without interruption time for circuit breakers, etc. It requires continuous power from more than one independent source.

6.3.7 Utilization equipment.

Utilization equipment is any electrical or electronic device that requires electrical power for its operation.

6.4 Subject term (key word) listing.

avionics integrity

batteries, aircraft

generators, aircraft

wiring, aircraft

power, electrical, emergency, aircraft

6.5 International standardization agreement implementation.

This specification implements (insert the document number and title of the international standardization agreement(s)). When amendment, revision, or cancellation of this specification is proposed, the preparing activity must coordinate the action with the U.S. National Point of Contact for the international standardization agreement, as identified in the ASSIST database at https://assist.dla.mil.

6.6 Responsible engineering office.

The office responsible for development and technical maintenance of this appendix is AFLCMC/EZFA, 2145 Monahan Way, Wright-Patterson AFB OH 45433-7017; DSN 785-8617, commercial (937) 255-8617 or by email to ASC.ENF.MAILBOX@wpafb.af.mil. Any information obtained relating to Government contracts must be obtained through contracting officers.

6.7 Changes from previous issue.

Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

ELECTRICAL POWER SYSTEMS,
AEROSPACE VEHICLES
HANDBOOK FOR

A.1 SCOPE

A.1.1 Scope.

This appendix provides the information necessary to tailor sections 3 and 4 of the basic specification (AFGS-87219B) for a specific application. This appendix is a mandatory part of the specification.

A.1.2 Format.

Each requirement of section 3 of the basic specification is discussed in section A.3 of this appendix. The order, paragraph numbering, paragraph titles, and text of section 3 are repeated exactly in section A.3 to facilitate study. To insure that a performance or design requirement from section 3 and its associated verification requirement in section 4 are tailored as a unit, they have been placed next to each other in section A.3.

The discussion of each requirement is divided into three parts:

a. Rationale – The reason why this requirement exists; the purpose that this requirement advances.

b. Guidance – Instructions and principles for setting the values that are left blank in the basic standard, or for omitting the requirement altogether.

c. Lessons Learned – Summaries of field experience relevant to this requirement.

A.1.3 Responsible engineering office.

The responsible engineering office (REO) for this appendix is the Air Force Life Cycle Management Center, AFLCMC/EZFA, 2145 Monahan Way, Wright-Patterson AFB OH 45433-7017; DSN 785-8617, commercial (937) 255-8617 or by email to ASC.ENF.MAILBOX@wpafb.af.mil.

A.2 APPLICABLE DOCUMENTS

A.2.1 Government documents.

INTERNATIONAL STANDARDIZATION AGREEMENTS

ASIC AIR STD 25/18	Connectors for 28 Volt DC Servicing Power
NATO STANAG 3109	Symbol Marking of Aircraft Servicing and Safety/Hazard Points
NATO STANAG 7073	Connectors for Aircraft Electrical Servicing Power

DEPARTMENT OF DEFENSE SPECIFICATIONS

JSSG 2009	Department of Defense Joint Services Specification Guide, Air Vehicle Subsystems
JSSG-2010	Department of Defense Joint Service Specification Guide, Crew Systems
MIL-DTL-6162	Generators and Starter-Generators, Electrical Direct Current, Nominal 30 Volts, Aircraft, General Specification for
MIL-E-7016	Electric Load and Power Source Capacity, Aircraft, Analysis of
MIL-PRF-7032	Inverters, Aircrft, General Specification for
MIL-C-7115	Converters, Aircraft, General Specification for
MIL-PRF-8565	Battery Storage, Aircraft, General Specification for
MIL-PRF-21480	Generator System 400 Hertz, Alternating Current, Aircraft, General Specification for
MIL-PRF-24021	Electric Power Monitors, External, Aircraft
MIL-PRF-29595	Batteries and Cells, Lithium, Rechargeable, Aircraft, General Specifications for
MIL-PRF-81757	Batteries and Cells, Storage, Nickel-Cadmium, Aircraft, General Specification for

MIL-E-85583	Electrical Power Generating Channel, Variable Input Speed, Alternating Current, 400 HZ, Aircraft; General Specification For
AFGS-87249	Mechanical Equipment and Subsystems, Requirements for the Integrity of

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-810	Environmental Engineering Considerations and Laboratory Tests
MIL-STD-882	System Safety
MIL-STD-1553	Digital Time Division Command/ Response Multiplex Data Bus
MIL-STD-1796	Avionics Integrity Program (AVIP)
MIL-STD-1798	Mechanical Equipment and Subsystems Integrity Program
MS17793	Schematic Wiring Diagram (External AC Power Connector, Aircraft)

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-470	Designing and Developint Maintainable Products and Systems, Volume 1
MIL-HDBK-502	Acquisition Logistics
MIL-HDBK-1799	Survivability, Aeronautical Systems (For Combat Mission Effectiveness)
MIL-HDBK-2165	Testability Program for Systems Equiptment

(Copies of these documents are available online at https://assist.dla.mil/quicksearch/or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

A.2.1.1 Other Government documents, drawings, and publications.

AIR FORCE SYSTEMS COMMAND DESIGN HANDBOOKS

DH 1-6	System Safety
DH 2-3	Propulsion and Power

(Copies of Air Force Systems Command Design Handbooks are available from Air Force Life Cycle Management Center, Engineering Standards Office, AFLCMC/ENRS, 2145 Monahan Way, Wright-Patterson AFB, OH 45433-7017 or by email to Engineering.Standards@wpafb.af.mil.)

ROME AIR DEVELOPMENT CENTER

Diagnostic Encyclopedia Series
Government Program Manager's Guide
Contractor Program Manager's Guide
System Designer's Guide

(Copies of the Rome Air Development Center Diagnostic Encyclopedia Series are available from Defense Technical Information Center (DTIC), 8725 John J. Kingman Road, Fort Belvoir, VA 22060-6218. Copy and paste the following web address, http://www.dtic.mil/dtic/.)

A.2.2 Non–Government publications.

SAE INTERNATIONAL

SAE AS1831	Electrical Power, 270 V DC, Aircraft, Characteristics and Utilization of
SAE AS35061	Connector, Receptacle External Electrical Power, Aircraft, 28 Volt DC Operating Power
SAE AIR4845	The FMECA Process in the Concurrent Engineering (CE) Environment
SAE AS50881	Wiring Aerospace Vehicle
SAE AS90362	Connectro, Receptacle, External Electrical Power, Aircraft, 115/200 Volt, 400 Hertz

(Copies of these documents are available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or online at http://www.sae.org.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

IEEE 12207	Systems and Software Engineering – Software Life Cycle Processes

(Copies of these docuemtns are available from IEEE Standards Activities Department, 445 Hoes Lane, Piscataway, NJ 08854 or online at http://www.ieee.org.)

A.3 REQUIREMENTS AND VERIFICATIONS

A.3.1 System description.

The electrical power system (EPS) shall provide for the on–board generation, conversion, storage, distribution, diagnostics, and control of the electric power required for all phases of vehicle operation, including ground maintenance.

REQUIREMENT RATIONALE (A.3.1)

This is an introductory paragraph. Related components and their characteristics will be described in the paragraphs which follow.

REQUIREMENT GUIDANCE (A.3.1)

No tailoring is necessary for this paragraph.

REQUIREMENT LESSONS LEARNED (A.3.1)

A.4.1 General.

The verifications (inspections/analyses/tests) specified herein shall verify the ability of EPS to meet the requirements of section 3 herein. All verifications shall be the responsibility of the contractor; the Government reserves the right to witness or conduct any verification.

VERIFICATION RATIONALE (A.4.1)

VERIFICATION GUIDANCE (A.4.1)

No verification is necessary for this requirement.

VERIFICATION LESSONS LEARNED (A.4.1)

A.3.2 Performance requirements.

REQUIREMENT RATIONALE (A.3.2)

This is an introductory paragraph. Detailed performance requirements are included in paragraphs which follow.

REQUIREMENT GUIDANCE (A.3.2)

No tailoring is necessary for this paragraph.

REQUIREMENT LESSONS LEARNED (A.3.2)

A.4.2 Performance requirements.
Overall performance of the EPS shall be verified by the following tests of the integrated subsystem.

a. Laboratory tests of a subsystem mockup which accurately simulates the aircraft installation. Testing shall include the most adverse electrical loading, environmental, fault, and endurance conditions required of the subsystem.

b. Aircraft ground and flight tests of the installed EPS under the most adverse conditions of electrical loading, cooling, and flight maneuvers. Failure modes which are not hazardous to personnel or the aircraft shall be simulated.

VERIFICATION RATIONALE (A.4.2)

These are general verification requirements for integrated EPS subsystems. Detailed testing should be specified in the Acceptance Test Procedures requested in the Statement of Work and approved by the Government.

VERIFICATION GUIDANCE (A.4.2)

No tailoring is necessary for this paragraph.

VERIFICATION LESSONS LEARNED (A.4.2)

A.3.2.1 Electric power characteristics.
The electrical power system shall provide electric power to the terminals of the power utilization equipment in accordance with the following characteristics: ____________.

REQUIREMENT RATIONALE (A.3.2.1)

To ensure electrical compatibility between the EPS and the equipments using electric power, it is necessary to establish an electric power interface. For manned aircraft, electrical equipment is built to operate from electrical power as defined by MIL-STD-704; thus, MIL-STD-704 defines the electrical power quality for both the EPS and the using equipment (at the input power terminals). The EPS for unmanned aircraft may deviate from this standard. The requirements for power quality were first established by MIL-E-7894 issued 28 April 1952 and subsequently superseded by MIL-STD-704 in October 1959. Present requirements have evolved through several revisions to MIL-STD-704. The interface characteristics controlled include voltage, frequency, distortion, and phase displacement including steady state and transient limits.

REQUIREMENT GUIDANCE (A.3.2.1)

The current issue of MIL-STD-704 should be specified for the electric power interface for new aircraft unless there are overriding considerations which arise. Specify the appropriate limits/interfaces from MIL-STD-704 and/or the peculiar aircraft limit/interface requirements. Commercial specifications such as SAE-AS1831 are very similar to MIL-STD-704 and should be given consideration as an alternative power quality standard if trade studies show a cost or weight savings.

When the EPS of an existing aircraft is modified, the specified power quality must be compatible with the original aircraft requirements. Therefore, the current MIL-STD-704 should be specified only if it ensures power quality equal to or greater than the original requirement. It will be necessary to compare the requirements of the current version of MIL-STD-704 with earlier versions of the specification to make this determination. The utilization equipment must also be compatible with the original power quality.

For unmanned aircraft, special requirements may dictate electrical power with different characteristics than MIL-STD-704. In these cases MIL-STD-704 should be considered a guide when preparing the electrical power characteristics specifications for both EPS and the using equipment.

Although this standard only defines the electrical power quality of the EPS, the system contractor must also assure that all utilization equipments are compatible with the EPS. The contractor must include the power quality specification in each vendor specification and assure that all utilization equipments are tested prior to installation on the vehicle.

REQUIREMENT LESSONS LEARNED (A.3.2.1)

Some aircraft have had problems of incompatibility between aircraft power and using equipment. In some cases, the EPS had to be reworked to accommodate the equipment even though the original power quality requirements were met. Frequently, utilization equipments are not designed or tested to the vehicle power quality standards, resulting in incompatibilities and redesign of the equipments. These problems point out that the power interface requirements must be carefully chosen and consistently applied to both the EPS and the using equipment.

A.4.2.1 Electrical power characteristics.

EPS compliance with the requirements of 3.2.1 shall be verified by analyses and tests as follows: ____________.

VERIFICATION RATIONALE (A.4.2.1)

In order for the EPS to provide power having the required characteristics and quality, the individual subsystem components which contribute to these characteristics must perform as required. Verification of component performance can be obtained by qualification testing. In addition, it may be possible to perform certain analyses to show that the integrated EPS will meet the power quality requirements. The final verification lies in subsystem testing in the laboratory and on the aircraft.

VERIFICATION GUIDANCE (A.4.2.1)

a. Component requirements and test results should be analyzed to ensure that component performance is consistent with overall subsystem requirements.

b. The entire EPS must be tested as a subsystem to verify that the power quality at the inputs to the utilization equipment is within specified limits for all normal and abnormal conditions.

c. Laboratory testing of the EPS in an aircraft configuration is required to demonstrate this requirement. Testing shall include the most adverse electrical loading, fault, and endurance conditions required of the subsystem. The EPS laboratory testing should be in a configuration that includes all components of the subsystem up to the utilization equipment.

VERIFICATION LESSONS LEARNED (A.4.2.1)

Functional subsystem mockups should be retained for the life of the program for analyses of subsystem design and failures.

A.3.2.2 Capacity.
The EPS shall be capable of supplying all electric power requirements for all modes of vehicle operation plus additional capacity to provide for growth loads as follows: ____________.

The buses, conductors, and circuit breakers should be capable of handling the load growth provisions.

REQUIREMENT RATIONALE (A.3.2.2)

The capacity of the EPS is determined by the electric power requirements of the aircraft. All modes of aircraft operation must be considered as well as provisions for load growth and any necessary redundancy.

Historically, electric power requirements for most aircraft have increased significantly during their service life as the result of modifications and changing mission. Unless the potential for such growth is recognized and provided for when the EPS is developed, costly retrofit programs may be required in later years to increase EPS capacity. Factors which should be considered are:

a. Transient and steady state load requirements

b. Component power ratings

c. Capacity derating factors such as temperature and altitude

d. Growth requirements

e. Redundancy for flight–critical systems

REQUIREMENT GUIDANCE (A.3.2.2)

a. The procedures of MIL-E-7016 are recommended for the analyses of load requirements and power source capacity.

b. EPS capacity should be at least twice the maximum continuous load of the initial production aircraft to provide for growth, unless other overriding considerations prevent this growth capacity.

c. Short duration load demands must be within the capacity of the EPS.

REQUIREMENT LESSONS LEARNED (A.3.2.2)

a. As a general rule, aircraft electrical loads continue to grow after the initial design. Some aircraft have been forced to eventually change to larger generators or add additional generating capability as the loads increased. Extra capacity is also needed for failure conditions which result in a generator loss, to assure that all systems can still function. Growth capacity also prevents brown–outs from occurring.

b. Some limited application aircraft and most missiles do not require growth capacity. If you feel this is your case, consult with the procuring activity.

c. Some aircraft that are converted over to special mission purposes require an entire new electrical system. Even a 100 percent growth capacity may not be enough. It is not uncommon to see original equipment 40–KVA generators replaced with 120–KVA generators.

A.4.2.2 Capacity.

The ability of the EPS to meet the capacity requirements of 3.2.2 shall be verified by analyses and tests as follows: _____________.

VERIFICATION RATIONALE

Analyses of aircraft requirements are needed to establish the capacity required of the EPS for initial loads, growth and redundancy. Subsequent testing is necessary to confirm actual aircraft requirements and subsystem capacity.

VERIFICATION GUIDANCE (A.4.2.2)

a. Use the procedures of MIL-E-7016 to determine the required capacity of the EPS and its components.

b. Verify actual aircraft loads and installed subsystem performance by aircraft testing.

c. Actual loads will not be available until all vendors have tested their equipments to verify the actual power utilized. The system contractor must work very closely with the vendors early in the program to obtain best estimates on loads so that the EPS can be sized correctly from the start.

VERIFICATION LESSONS LEARNED (A.4.2.2)

In the early stages of design, the electrical power needed is usually underestimated by the vendor; and by the time the first operational aircraft is delivered, the actual loads are above the original estimates. Careful review of vendor estimates of needed power should occur early in the program to assure that the electrical system is sized correctly. Adding 25 percent larger generators halfway through the design can severely impact the total system design.

A.3.2.3 Uninterruptible power.
Fly–by–wire flight controls, and other flight critical subsystems and components which cannot tolerate power interruption, shall be provided with power from full–time redundant power sources. During flight, each redundant power source shall be fully active and shall be either powering the critical loads or capable of assuming such loads without power interruption in the event of failure of other sources.

a. Uninterruptible power __(is) (is not)__ required.

b. A minimum of ____________ failures of sources of uninterruptible power shall be accommodated without interruption or degradation of power to flight–critical loads. This requirement shall be met without crew action or automatic reconfiguration of the power system.

REQUIREMENT RATIONALE (A.3.2.3)

Special consideration must be given to power sources for fly–by–wire flight controls and other flight–critical loads which require continuous power to maintain control of the aircraft. Not only are redundant sources required, but these sources must be capable of instantly assuming the loads without manual or automatic switching which would degrade system integrity. In contrast to the emergency power units for less critical loads, which may operate only when needed, sources of uninterruptible power must be capable of continuous in–flight operation.

REQUIREMENT GUIDANCE (A.3.2.3)

Consult with the cognizant subsystem engineers to determine if flight systems exist, whether uninterruptible power is required, and the degree of redundancy required. On aircraft with flight–critical subsystems requiring electrical power, the EPS also becomes flight–critical.

REQUIREMENT LESSONS LEARNED (A.3.2.3)

a. Experience has shown that an emergency power source intended for operation only after a malfunction has occurred is not a suitable backup for fly–by–wire flight controls. The startup and operating reliability of the emergency power units is deficient for this purpose. It is necessary to have full–time redundant power sources to meet the fly–by–wire requirements.

b. One aircraft started out with a mechanical flight control system with a fly–by–wire system as a backup. Part way through the design, the fly–by–wire became primary with the mechanical system only usable in certain portions of the flight envelope. This late change resulted in significant redesign of the electrical system to meet redundancy and uninterruptible power requirements.

c. Even though reliability analyses have shown aircraft EPS to exceed the requirements for flight–critical systems, total electrical power system failures have occurred on every aircraft. To prevent the loss of an aircraft, it is strongly recommended that a PMG be installed on each engine shaft to provide last–ditch power to keep the aircraft in the air.

A.4.2.3 Uninterruptible power.

Compliance with the requirement for uninterruptible power shall be verified by analyses and tests as follows: ____________.

VERIFICATION RATIONALE (A.4.2.3)

Analyses and tests are the appropriate means of verifying the requirement for uninterruptible power.

VERIFICATION GUIDANCE (A.4.2.3)

a. Circuit analyses, hazard analyses, and failure mode and effect analyses are appropriate.

b. Subsystem tests in the laboratory and on the aircraft should be required.

VERIFICATION LESSONS LEARNED (A.4.2.3)

A.3.2.4 Emergency power.

An independent emergency power source shall be provided to supply all essential loads in the event of failure of the primary power source(s).

a. The power rating and total available energy shall be sufficient to supply all loads identified as essential for control of the vehicle and personnel safety.

b. The transfer of essential loads to and from the emergency power source shall be accomplished without transients of a magnitude hazardous to the vehicle or personnel.

c. A convenient means of verifying the operational readiness of the emergency power source prior to flight shall be provided.

d. The emergency power unit should be flight operable over the entire aircraft flight envelope.

e. The emergency power unit should provide power for at least ____________.

f. Other emergency power requirements are as follows: ____________.

REQUIREMENT RATIONALE (A.3.2.4)

Despite excess capacity, redundancy, and all other measures taken to ensure a reliable subsystem, total failures of the primary power sources do occur. For multi–generator aircraft there is the tendency to assume that the redundancy of main generators will suffice for the emergency requirement. Experience has shown otherwise. Many modern multi–generator aircraft have experienced total failure of the primary power system. An independent emergency power source is needed for this situation. This requirement has been documented by AFSC Design Handbooks DH 1-6 and DH 2-3.

REQUIREMENT GUIDANCE (A.4.2.3)

a. The power rating of the emergency source must be sufficient to supply the emergency loads identified by an electric load analysis in accordance with MIL-E-7016. As a minimum there should be the capability for safe control of the aircraft. When the emergency source is energy–limited as in the case of a battery, for example, the available energy must be sufficient to ensure operation for the required time period.

b. The response time for initially supplying emergency power is also a consideration. This involves factors such as means of sensing power failure, manual or automatic power transfer, and the time required for the emergency unit to come up to speed or otherwise respond. Should normal power subsequently be restored, manual or automatic means for returning loads to the main source are required. Automatic transfer can be detrimental if it surprises the crew with an additional disturbance at a critical time.

c. To maintain confidence in the reliability of the emergency power source it should be given an operational check before each flight if possible. If not, other means of verifying operational readiness should be provided.

d. Thirty minutes is the recommended minimum time for the emergency power unit to provide electrical power. This is generally sufficient for the crew to regain control of the aircraft and make an emergency landing.

REQUIREMENT LESSONS LEARNED (A.4.2.3)

a. Many modern multi–generator aircraft have experienced ultimate failure of the main electrical power system.

b. Serious consideration has been given to eliminating the emergency generator from several programs as a cost and weight savings. However, on several occasions during the flight–test program the emergency generator was required to supply power following multiple failures of the main electrical system.

c. The method of returning emergency loads to the normal power source on one aircraft was changed from automatic to manual following an in–flight incident. A flight control transient resulting from main generator failures had just settled out when normal power was again restored. When the flight controls were then automatically transferred back to main power, the crew was surprised with a second disturbance as severe as that caused by the original failure.

d. Another incident illustrates the criticality of emergency power control logic. A partial failure of the hydraulic system powering the emergency generator caused it to be powered up to speed by an overlooked hydraulic “sneak circuit.” Then when the emergency generator tried to power the essential bus there was insufficient hydraulic power to support it. As a consequence, the essential bus cycled on and off a malfunctioning emergency power unit thereby adding a critical electrical problem to the original hydraulic failure.

A.4.2.4 Emergency power.

a. The capability to supply all essential loads shall be determined by analyses and tests as follows: _____________.

b. Compliance with the load transfer requirements of 3.2.4.b shall be verified by analyses and tests as follows: _____________.

c. Compliance with the operational readiness requirements of 3.2.4.c shall be verified by analyses and tests as follows: _____________.

d. Compliance with other emergency power requirements shall be verified as follows: _____________.

VERIFICATION RATIONALE (A.4.2.4)

Analyses are appropriate for preliminary verification that requirements will be met. Final verification is provided by component qualification tests and tests of subsystems in the laboratory and installed in the aircraft.

VERIFICATION GUIDANCE (A.4.2.4)

a. Electrical load analyses, circuit analyses, component tests, and integrated subsystem testing are appropriate means for verifying emergency power requirements.

b. Electrical load analyses per MIL-E-7016 and component qualification testing are needed to establish that the capacity of the emergency power unit is sufficient for the essential loads.

c. Circuit analyses and subsystem testing are needed to verify proper control logic and compatibility with the rest of the EPS.

d. The performance requirements of the EPS with respect to emergency power can be verified by mockup tests and aircraft tests.

e. Complete verification of emergency power will be required when the system is installed on the aircraft.

VERIFICATION LESSONS LEARNED (A.4.2.4)

Analysis, followed up by system–level testing on the aircraft, is adequate verification. Mockup testing may be used for initial verification, but final verification is required on the aircraft. On–aircraft testing has been shown to produce results that were not predicted or seen in the mockup testing.

A.3.2.5 External ground power.

The EPS shall accept power from an external source for ground operations as required. The EPS shall be compatible with MIL-STD-704 quality power supplied by the following external electrical power sources: ____________.

a. The EPS shall be capable of handling the maximum external power required for ground operations while maintaining power characteristics in accordance with 3.2.1.

b. The EPS shall provide protection to prevent unsuitable external power from being applied to the aircraft.

c. The EPS shall provide for the power transfer from the external power source to the on–board power source(s) and in the reverse direction in a manner consistent with the transient and power interruption requirements of 3.2.1. Power transfer is required as follows: ____________.

d. Receptacles for 28–volt DC external power shall be in accordance with either SAE-AS35061 or ASIC AIR STD 25/18, and shall be connected in accordance with NATO STANAG 7073. Receptacles for 115 volt, 400 Hz external power shall be in accordance with SAE-AS90362, and shall be connected in accordance with either MS17793 or STANAG 7073. Receptacles shall be isolated from aircraft power circuits when the mating plug is disengaged to ensure that dangerous voltages are not present.

e. External power receptacles shall be accessible from ground level and shall be located to minimize hazards to ground personnel. They shall not be located in or near hazardous areas such as air inlet or exhaust, APU or JFS exhaust, propellers or propeller blasts, or fuel servicing or vent areas.

f. The receptacle should be designed such that should ground maintenance personnel forget to remove the plug, the power cable and plug will pull out of the receptacle when the aircraft moves forward.

g. External power receptacles shall be covered by hinged access doors that will automatically remain closed when the receptacle is not in use. The access door shall be identified in accordance with MIL-STD-2161 and NATO STANAG 3109.

h. Other external ground power requirements are as follows: ____________.

REQUIREMENT RATIONALE (A.3.2.5)

External power is usually required for ground operations such as maintenance, ground alert, aircraft lighting, and/or engine starting. Factors to be considered include the quantity of power required, protection against poor quality power, type and location of external power receptacles, and the means of transferring between aircraft power and external power. AFSC Handbooks DH 1-6 and DH 2-3 document ground power requirements. Damage to aircraft equipment and failure to interface with ground electrical power can result from incompatibility of connector wiring interfaces.

REQUIREMENT GUIDANCE (A.3.2.5)

a. The quantity of ground power that the EPS must handle can be obtained from the electrical load analysis per MIL-E-7016.

b. Protection against poor quality external power is necessary to prevent damage to the EPS and power–using equipments. Specification MIL-PRF-24021 covers external power monitors which provide this protection.

c. Some aircraft require that the transfer from ground power to aircraft power, and the reverse, be made without power interruption because of sensitive on–board equipment. This requirement should be invoked as needed. Peculiar power transfer transients over and above MIL-STD-704 requirements should be specified in the blank.

d. External power receptacles SAE-AS35061 and SAE AS90362 comply with NATO and ASIC standardization agreements to which the U.S. subscribes. Only very unusual circumstances would warrant non–compliance. Pins E and F should not have 115 VAC applied since these should mate to 28 VDC circuits in compliance with international agreements. Older systems may refer to the obsolete MS3506, MS24442, MS90362, NATO STANAGs 3302 and 3303, and ASCC AIR STDs 12/6 and 12/7. These documents have been canceled, and should be used for information purposes only.

e. The safe and convenient location of external power receptacles should be a prime consideration to facilitate servicing and to minimize hazards to the ground crew.

f. It is necessary to protect the external power receptacle from dirt, fluids, and other contaminants when it is not in use. The design of the access door should preclude its being left open inadvertently after the ground servicing operation. Prominent identification of the receptacle is needed to facilitate aircraft servicing by the ground crew. Older systems may reference the canceled MS33739 to identify the access door. This should be used for information purposes only.

g. Consideration should be given to the use of the external power receptacle for connecting load banks to the aircraft for ground check–out of the EPS.

h. When dictated by operational requirements, the external power receptacles shall be installed so that external power will be automatically disengaged upon forward motion of the aircraft.

REQUIREMENT LESSONS LEARNED (A.3.2.5)

Some aircraft use the external power receptacle to connect loads to the aircraft for ground check of the EPS. This has eliminated the need to operate on–board equipment as loads for this purpose. Use of incompatible interfaces has caused damage to aircraft equipment when using the ground power carts provided by some installations.

A.4.2.5 External ground power.

a. The capability of the EPS to accept and distribute the maximum external power requirements while maintaining the required power quality shall be determined by analyses and tests as follows: ____________.

b. Protection of the aircraft against unsuitable external power shall be verified by analyses and tests as follows: ____________.

c. The required power transfer characteristics shall be verified by analyses and tests as follows: ____________.

d. Compliance with the design requirements for external power receptacles and their installation shall be determined by inspection.

e. Compliance with other external ground power requirements shall be as follows: ____________.

VERIFICATION RATIONALE (A.4.2.5)

Analyses of external power requirements are necessary in order to design the EPS interface with external power. Subsequent testing is required to confirm that the external power performance requirements are met. The proper selection and installation of external power receptacles can be verified by inspection.

VERIFICATION GUIDANCE (A.4.2.5)

a. Use the procedures of MIL-E-7016 to analyze the requirements for external power.

b. Proper selection and installation of external power receptacles can be verified by inspection of the applicable drawings and/or by inspection of the aircraft.

c. Performance requirements of the EPS with respect to external power can be verified by mockup tests and aircraft tests.

VERIFICATION LESSONS LEARNED (A.4.2.5)

External power receptacles have been standardized to assure that any aircraft can be provided external power at any location. This eliminates the need for onboard APUs, etc. If the standard power receptacle is not used, then special power carts or adapters will be required at remote locations.

A.3.2.6 Auxiliary power.

The EPS shall be capable of generating, controlling, and distributing power from on–board auxiliary power units for ground or airborne operations as follows: ____________.

REQUIREMENT RATIONALE (A.3.2.6)

Aircraft operational requirements may necessitate an on–board auxiliary power unit (APU) to provide electric power for certain modes of ground or air operation. The EPS must be capable of generating, controlling, and distributing APU electric power in a safe and effective manner. Considerations include the quantity of APU power required, whether both ground and airborne operation are required, whether parallel operation with main generator(s) or ground power is required, and whether no–break power transfer to and from the APU is required. In some installations the APU may be able to serve as the emergency power source.

REQUIREMENT GUIDANCE (A.3.2.6)

If specific auxiliary power requirements are known, they should be specified accordingly. Otherwise performance should be as necessary to meet aircraft operational requirements. Auxiliary power requirements for ground maintenance, system checkout, manned alert, lighting, cargo loading, starting, emergency power, etc., should be specified as determined from analysis of aircraft operational requirements.

REQUIREMENT LESSONS LEARNED (A.3.2.6)

APUs have proven to be beneficial to most aircraft. They eliminate the need to connect external electrical power for any maintenance, checkouts, etc. They can also provide electrical power for alert situations, emergency power, and hot turns.

A.4.2.6 Auxiliary power.

Compliance with the requirements of 3.2.6 for EPS operation with on–board auxiliary power shall be verified by analyses and tests as follows: ____________.

VERIFICATION RATIONALE (A.4.2.6)

The performance of the EPS with respect to auxiliary power requires verification by analyses and test.

VERIFICATION GUIDANCE (A.4.2.6)

a. Use electrical load analyses in accordance with MIL-E-7016 to aid in determining the quantity of auxiliary power required for various modes of operation.

b. Verify performance of the EPS by testing in the laboratory and on the aircraft.

VERIFICATION LESSONS LEARNED (A.4.2.6)

Testing is the only viable means to demonstrate that the auxiliary power unit comes on as designed and picks up the electrical loads. Laboratory testing followed by on–aircraft testing is required, to demonstrate the entire system function.

A.3.2.7 Power distribution.

Electric power shall be distributed from the various power sources to the aircraft loads in a safe and effective manner.

a. The buses and distribution circuits shall be configured so that normal EPS operation loads receive power from the aircraft primary power source(s), ground power, or an auxiliary power source as applicable.

b. In the event of an EPS failure that reduces the amount of available power below total aircraft requirements, non–flight critical and/or preselected loads shall be automatically disconnected as required.

c. Flight critical loads shall have first priority to primary power and shall be supplied from the emergency power source when primary power is not available.

d. The power quality requirements of 3.2.1 shall be maintained.

e. Convenient means shall be provided for disconnecting ground power from equipment not requiring power during ground operation.

f. Other requirements for electric power distribution are as follows: ____________.

REQUIREMENT RATIONALE (A.3.2.7)

An effective distribution system is needed to transmit electric power to the using equipment in a safe and reliable manner. Factors to be considered include power quality, load priorities, reliability, vulnerability, and safety. AFSC Design Handbooks DH 1-6 and DH 2-3 have requirements for power distribution design and performance.

REQUIREMENT GUIDANCE (A.3.2.7)

The requirements of paragraph 3.2.7 are applicable to all aircraft. Additional requirements for a particular application should be added as needed.

REQUIREMENT LESSONS LEARNED (A.3.2.7)

Automatic load shedding is required in the event of a partial loss of the electrical system. This assures that the entire system is not lost due to one item failing. The crew cannot be expected to shut down equipment in time to prevent a total electrical system failure. Some aircraft without load shedding have lost total electrical power due to one small failure that could have been automatically detected and isolated.

A.4.2.7 Power distribution.

Compliance with the power distribution requirements of 3.2.7 shall be verified by analyses and tests as follows: ____________.

VERIFICATION RATIONALE (A.4.2.7)

Analyses and tests are the appropriate means of verifying compliance with this requirement.

VERIFICATION GUIDANCE (A.4.2.7)

a. Analyses appropriate for this requirement include electrical load analyses per MIL-E-7016, hazard analyses, failure mode and effect analyses, and circuit analyses.

b. Testing should be applied to verify distribution system performance in the laboratory and on the vehicle. The laboratory testing should duplicate actual electrical loads and simulate normal and fault conditions.

VERIFICATION LESSONS LEARNED (A.4.2.7)

The power distribution system on some aircraft has malfunctioned or been improperly designed, with the result that a failure in the distribution system resulted in partial or total loss of all electrical power. The distribution system needs the same careful design and analysis effort as the main electrical system itself.

A.3.2.8 Control and protection.

The electric power subsystem shall include all control and protective functions necessary for safe and effective operation.

a. Routine operations of the EPS such as normal start–up, shut–down, paralleling, and voltage and frequency regulation which require no crew decisions shall be performed automatically.

b. The crew shall be provided with the instruments and manual controls necessary for effective control of the EPS for normal and abnormal operation. This shall include indications of all system faults and malfunctions which affect flight safety or mission effectiveness.

c. Automatic protective functions shall be provided for abnormal conditions of the electric power subsystem which require a prompt predetermined response and for which no crew decisions are needed. Faults and malfunctions shall be detected, isolated, and de–energized in a manner which eliminates the hazardous condition with minimum effect on the safety and performance of the aircraft.

d. All distribution circuits including generator feeders, bus ties, and load circuits shall be protected against short circuits and overloads throughout their total length. Each load circuit shall be individually protected to prevent a single fault from affecting more than one critical function.

e. Multiple–wire feeder circuits shall be used as necessary to meet reliability and vulnerability requirements.

f. Redundant power circuits and components shall be routed/located separately to minimize vulnerability. Means shall be provided for detecting the failure of each redundant component.

g. Distribution buses shall be enclosed within junction boxes to reduce vulnerability. The junction boxes shall be located to take maximum advantage of the protection offered by aircraft structure.

h. Circuit breakers which are essential for flight safety shall be easily resettable by the crew.

i. Other requirements for control and protection are as follows: ____________.

REQUIREMENT RATIONALE (A.3.2.8)

Appropriate means of control and protection are necessary for the safe and effective operation of the EPS. Factors to be considered include crew instrumentation and controls, failure modes and effects, automatic control and protection, reliability, vulnerability, and safety. AFSC Design Handbooks DH 1-6 and DH 2-3 and JSSG 2009 have previously stated subsystem requirements.

REQUIREMENT GUIDANCE (A.3.2.8)

a. Means of controlling the EPS should be provided such that mission and safety requirements are met without unnecessarily burdening the crew. On the other hand, the crew should be involved in non-routine situations in which crew action can improve mission effectiveness or control abnormal or hazardous conditions. Interface with crew station/human factors engineers when establishing instrument and manual control requirements.

b. Coordinate warning/caution/advisory requirements related to this specification with crew station/human factors engineers. Refer to JSSG-2010 and MIL-STD-1800 for further guidance on the location and actuation of the instruments and manual controls, and further guidance on indicator system requirements. Older systems may refereance the canceled, MIL-STD-1776 and MIL-STD-1800. They should only be used for information.

c. The multiplexing of control signals for the EPS and for the monitoring and control of individual load circuits is a possible option to reduce the amount of wiring required. MIL-STD-1553 gives requirements for multiplexed data buses.

d. All component failure modes should be identified and means to accommodate them provided. No segment of the EPS from prime mover output to the load equipment terminals should be unprotected.

e. The advantages of redundant components are realized only if the components are sufficiently isolated electrically and physically so that multiple failures are improbable. Furthermore, if there is no way to detect the failure of a redundant component, the value of redundancy is lost.

f. Requirements for electrical power generation system control and protection are provided by MIL-E-85583.

g. Solid state power controllers should be used whenever possible. They provide faster switching times, which are effective at preventing arc-tracking.

REQUIREMENT LESSONS LEARNED (A.3.2.8)

a. One electrical power generation subsystem was designed to parallel the main generators through bus tie contractors (BTC). As originally designed, the BTCs would open to provide isolated generator operation only for certain fault conditions. Opening was automatic—no crew control was provided. During flight testing it was discovered that faults on the paralleled system could produce excessive voltage transients on all buses before the BTCs could open. This was corrected by automatic control.

b. Switching of one essential bus from the emergency generator back to the main generator was changed from automatic to manual to give the crew better control of an abnormal situation.

c. The use of a multiplexed data bus for load control signals and related data proved to be a successful approach on the B-1 aircraft. A significant reduction of wiring weight and volume was achieved.

d. Multiple wire feeders for the essential bus of one aircraft have been instrumental in maintaining electrical power under emergency conditions. Attempts to remove this capability during modification programs were met with great resistance from the user community.

A.4.2.8 Control and protection.

Compliance with the EPS control and protection requirements of 3.2.8 shall be verified as follows: ____________.

VERIFICATION RATIONALE (A.4.2.8)

Analyses and tests are the appropriate means of verifying compliance with this requirement.

VERIFICATION GUIDANCE

a. Initial verification of control and protection requirements can be accomplished by circuit analyses, including analyses of failure modes and effects.

b. Qualification testing will verify that the control and protection requirements of individual components are met.

c. Performance of the complete subsystem can be verified by laboratory and vehicle testing.

VERIFICATION LESSONS LEARNED (A.4.2.8)

Verification of the control and protection system to isolate and remove faults is essential. This will result in the system still being able to provide power to the non–affected areas. One system failed to detect a small fault that eventually grew until the entire electrical system shut down. Adequate fault detection and isolation would have prevented this.

A.3.2.9 Major components.
Criteria shall be established for major components of the EPS as necessary to enable the requirements of the integrated subsystem to be met.

A.3.2.9.1 Aircraft wiring.
The design and installation of wiring associated with the electric power subsystem shall be as follows: ____________.

REQUIREMENT RATIONALE (A.3.2.9.1)

EPS performance and reliability is dependent to a large extent on the integrity of the wiring which interconnects the subsystem. Wiring components must be suitable for the application with particular attention given to the environment. Considerations for wiring installation should include maximum reliability, minimum interference and coupling between subsystems, accessibility for inspection and maintenance, and protection against damage. Since the wiring is normally expected to last for the entire service life of the aircraft, special care is required in its design and installation. SAE-AS50881, DH 1-6, and DH 2-3 provide guidance based on years of experience with aircraft wiring installations and on the capabilities of wiring components.

REQUIREMENT GUIDANCE (A.3.2.9.1)

Use SAE-AS50881 for wiring requirements. Older systems may reference the inactive standard, MIL-W-5088.

REQUIREMENT LESSONS LEARNED (A.3.2.9.1)

a. Most problems with aircraft wiring have involved deterioration caused by the environment, aging, improper application of materials and components, and abuse of various kinds. Moisture, heat, vibration and rough handling are common hazards which should be recognized and guarded against during subsystem design.

b. In Vietnam, aircraft experienced a major problem when the potting compound in the electrical connectors reverted to a sticky, gummy mass because of heat and humidity. This cost millions of dollars and extensive downtime to repair. Environmentally–sealed connectors which do not require potting are now preferred for most applications. Where potting is required, use should be restricted to those materials which have been qualified to the service environment.

c. Short, easy replaceable harnesses to go between the equipment and aircraft wiring should be considered for use with equipment that is frequently removed (such as liquid oxygen converters). As the equipment is removed and replaced, the connectors become worn and have to be replaced. After a few replacements, the wires are no longer long enough and an entire harness must be replaced.

d. Aluminum wire is used on some aircraft to feed power to the load centers from the engine pylons, and from the load centers to points throughout the aircraft. Loose connections, electrolysis, and galvanic reactions have led to corrosion and arcing at the terminal boards. Fires and loss of electrical power have resulted. Therefore, aluminum wire should not be approved for use unless solutions to termination problems have been proven.

A.4.2.9 Major components.

A.4.2.9.1 Aircraft wiring.

Compliance with the requirements of 3.2.9.1 for the design and installation of wiring shall be verified by inspection.

VERIFICATION RATIONALE (A.4.2.9.1)

Verification of proper component selection requires analyses of the operational environment and performance requirements and analyses of the characteristics of the selected component. Visual inspections of wiring mockups and the first aircraft are necessary to verify proper installation. Performance is verified by aircraft continuity and dielectric checks and by operational tests of the aircraft subsystems.

VERIFICATION GUIDANCE (A.4.2.9.1)

a. Ensure that there are sufficient analyses and inspections of the aircraft wiring components and their installation to verify compliance with this requirement.

b. A physical mockup of the wiring installation should be required.

VERIFICATION LESSONS LEARNED (A.4.2.9.1)

One aircraft development program included no formal physical mockup of electrical wiring and equipment installations. Consequently, verification of physical installation requirements was delayed until the first aircraft was available for inspection. The inspection revealed numerous wiring discrepancies such as inadequate clearances, inadequate support, and improper wire lengths. Since the inspection occurred only a few days prior to first flight when several aircraft were in final assembly, corrective actions were costly and were only partially implemented. On other programs a mockup of the wiring installation has served as a useful design tool and has allowed verification of installation requirements much earlier in the program. The mockup can then be used for future aircraft modifications.

A.3.2.9.2 Batteries.

Batteries, components of the vehicle electric system, shall be capable of providing specified battery power under environmental and operational conditions.

a. Battery design and performance shall be in accordance with: ____________.

b. A battery relay shall be installed in each battery circuit to enable the flight crew to isolate the battery from the rest of the electric subsystem. The battery relay shall be controlled by a crew station battery switch. Any circuits which must remain connected to the battery with the battery switch OFF shall be connected directly to the battery through suitable fuses or circuit breakers.

c. On–board charging of batteries shall be controlled to enable the battery to become fully charged without excessive gassing or heating throughout the entire range of specified battery temperatures. The charging rate shall be sufficient to maintain the battery in a state of charge which will meet the battery power demands of normal ground and airborne operation of the aircraft. Battery charging shall be provided as follows: ____________.

d. Each battery shall be located and installed so it can be readily inspected and easily removed from the aircraft through an access panel or door and without removing other components.

e. The location and design of the battery installation shall be such that the release of heat, smoke, gases, electrolyte or other products of a severe battery failure will not damage adjacent components or structure, endanger personnel, or adversely affect crew performance.

f. The battery and/or battery compartment shall be ventilated to prevent the accumulation of explosive mixtures of gases. All vent tubes leading to the exterior of the aircraft shall be designed to preclude the collection of rainwater and other liquids for all ground and flight environments.

g. The installation shall provide for maintaining battery temperature within the limits specified for battery operation. Any heater or thermal insulation required for low temperature operation shall be provided as part of the aircraft's battery compartment and not as an integral part of the battery.

h. Other battery requirements are as follows: ____________.

REQUIREMENT RATIONALE (A.3.2.9.2)

Because they are a convenient source of stored energy, batteries are widely used in aircraft for emergency power, standby and fill–in power, engine and APU starting, and for limited energy requirements when no other source is available. On the other hand, batteries have limitations which have to be recognized and accounted for in order to have a reliable installation. Since chemical reactions are involved in the charging and discharging processes, battery performance is very sensitive to temperature. Other factors affecting performance and life include depth of discharge, method of charge, quality of maintenance, and type of construction. Present requirements for aircraft secondary batteries have evolved over the years as the result of experience and new technology. Prior to the issuance of specifications MIL-PRF-81757, MIL-PRF-8565, and MIL-PRF-29595, each military service had its own procurement specifications. These separate requirements are now combined into the three coordinated specifications for nickel–cadmium, maintenance-free, and lithium batteries. Battery installation requirements were previously in DH 1-6 and DH 2-3.

REQUIREMENT GUIDANCE (A.3.2.9.2)

a. Lead–acid, nickel–cadmium, and lithium are the three types of secondary batteries most used in aircraft. Lead–acid batteries are less costly, easier to maintain, and can be effectively charged from a simple constant–potential source. Nickel–cadmium batteries, however, provide much better high–rate performance, especially at low temperature. The disadvantages of nickel–cadmium include higher cost, special maintenance procedures, and more closely controlled charging for safe and reliable performance.

b. MIL-PRF-81757, MIL-PRF-8565, and MIL-PRF-29595 are tri–service specifications for nickel–cadmium, maintenance-free, and lithium batteries respectively. These standard batteries, which are the product of considerable tri–service experience and research, should be used where suitable. They are procured competitively and in quantities which result in lower cost. Sealed–cell lead–acid batteries have been qualified to MIL-PRF-8565. This type should be preferred over lead-acid batteries that were qualified to the canceled MIL-B-83769.

c. Both MIL-PRF-81757 and MIL-PRF-29595 specifie individual cells as well as complete batteries. Therefore, if none of the MIL-PRF-81757 or MIL-PRF-29595 standard batteries are suitable, the next best choice for a nickel–cadmium or lithium battery would be a non–standard battery made up of either MIL-PRF-81757 or MIL-PRF-29595 standard cells.

d. In selecting a battery to meet a required ampere–hour capacity and other performance requirements, the effects of temperature, charging efficiency, aging, and other de-rating factors should be considered.

e. The crew should be provided with means to disconnect the battery so it can be electrically isolated in the event of battery failure. This provision also helps to prevent excessive and inadvertent discharge of the battery on the ground. It may be necessary, however, for some circuits to remain connected to the battery at all times.

f. Effective on–board charging is usually required to keep secondary batteries adequately charged. For lead–acid batteries this can be accomplished simply by "floating" the battery on a constant–potential DC bus. This not only provides for continuous maintenance of charge, but also allows the battery to supply power instantly to the bus when required. Charging of nickel–cadmium batteries is not so simple since they are very sensitive to applied voltage. If the voltage is too low the battery will not become fully charged. If it is too high, the battery will become overcharged with excessive heating and loss of electrolyte. Furthermore, the optimum charging voltage varies inversely with temperature. This can lead to a catastrophic failure (thermal runaway) when a battery overheats and then draws ever–increasing current as its terminal voltage decreases further. Consequently, it is not good practice to float a nickel–cadmium battery directly on a high current DC bus. Better control of the charging current is needed.

g. A generally accepted procedure for charging nickel–cadmium batteries is to supply a constant–current charge until a predetermined, temperature–compensated battery voltage is reached. At that point charging is terminated or reduced to a small trickle–charge rate. The "constant" current may be a continuous direct current or a series of pulses of a controlled average value. In addition, charging is terminated when battery temperature becomes excessive. This method of charge control requires sensing of battery temperature which is not provided by MIL-PRF-81757. Therefore, temperature sensors must be added to the standard nickel–cadmium battery for this purpose.

   The following factors require careful consideration in designing the battery installation:

   1) Because of the requirement for frequent maintenance, the battery should be readily accessible for inspection and removal.

   2) The potential hazard of a battery failure should be recognized and provided for. Failure effects can range from excessive gassing to complete thermal destruction.

   3) The possibility of hydrogen gas evolution requires adequate ventilation of the battery to prevent explosive concentrations from developing.

   4) The sensitivity of batteries to temperature and other environmental factors should be considered.

h. Indication of battery system malfunctions such as over-temperature, battery discharging, and low battery voltage should be provided to the crew as necessary to meet subsystem safety and reliability requirements.

REQUIREMENT LESSONS LEARNED (A.3.2.9.2)

The horror stories of aircraft battery failures are well known and too numerous to relate individually. Catastrophic failures and loss of power have resulted in the loss of both aircraft and personnel. Countless instances of less severe problems have caused personnel injury, aircraft damage, mission aborts, poor maintainability and reliability, and high replacement costs. The lessons learned from these experiences are reflected in the guidance provided by AFSC Design Handbooks DH 1-6 and DH 2-3.

Some specific lessons learned are:

a. One aircraft required a non–standard battery because of available space and the need for thermal insulation. Several deficiencies were later discovered in the design and installation of the unit.

    1) A non–standard cell which was much more costly than an equivalent standard cell was originally selected for the battery. It was later found that the standard cell could be substituted without loss of performance.

    2) The thermal insulation was designed as an integral part of the battery case. This not only increased the initial and replacement costs, but also downgraded battery reliability because of susceptibility to cracking and contamination by the electrolyte. Making the insulation (or other thermal conditioning) a part of the aircraft battery compartment rather than a part of the battery would have been a better approach.

    3) The original configuration of the battery vent tube allowed rain water to enter the battery and contribute to corrosion of thermal switches. A redesign of the vent was required to correct this problem.

    4) Access to the battery required the removal of a structural fuselage panel secured by approximately 50 stubborn screws. This is unsatisfactory for an item which requires frequent maintenance.

b. There have been numerous instances of thermal runaway of nickel–cadmium batteries directly connected to high current DC generators. The loss of one aircraft and one of its crew members was attributed to this cause. Safe limitations on charging current are needed for nickel–cadmium batteries.

c. As a result of its location in the cockpit, one aircraft battery not only required seat removal for battery maintenance, but also subjected the crew to smoke and fumes in the event of a major battery failure. The cockpit is a poor location for the aircraft main battery.

d. Silver–zinc secondary batteries were used in one aircraft because of their very high energy density. However, these batteries have a very limited cycle life and are extremely susceptible to internal shorting. Because of the numerous catastrophic failures which were experienced, this type of secondary battery is not recommended for aircraft.

e. Because of the weight and space penalties involved, inadequate batteries are often selected for the required performance. Insufficient de-rating for temperature, aging, on–board charge efficiency, and high discharge rates are common pitfalls.

f. One aircraft's batteries are installed in fiberglass boxes with attached circuit breakers. The entire assembly (box, battery, circuit breaker, wiring, and connector) must be removed each time the battery is removed for maintenance. Due to the close proximity of components, electrical shorting is reported to be a frequent problem during such maintenance.

g. Sealed lead–acid batteries are now gaining support due to their reduced maintenance factors and cost. Adequate charging systems are required and heaters may be needed for cold–temperature use.

A.4.2.9.2 Batteries.
Compliance with the battery requirements of 3.2.9.2 shall be verified by analyses, tests, and inspection as follows: ____________.

VERIFICATION RATIONALE (A.4.2.9.2)

Analyses, tests, and inspection are the appropriate means of verifying conformance with the battery requirements.

VERIFICATION GUIDANCE (A.4.2.9.2)

a. The battery, battery charger, and any other functional components of the battery system require qualifications to their own procurement specifications. Furthermore, if a previously qualified standard battery is selected, additional battery testing may be needed if requirements of the application exceed those of the previous qualification testing.

b. If a battery charger or a battery monitor is part of the system, extensive laboratory testing of the integrated battery system is needed to ensure compatibility.

c. The ability to keep the battery charged without excessive heating or overcharging should be demonstrated for the required operational profiles and environmental conditions.

d. The battery system should also be included in the laboratory and aircraft testing of the complete EPS.

VERIFICATION LESSONS LEARNED (A.4.2.9.2)

Battery systems which incorporate a charger have experienced operational problems as a result of inadequate laboratory testing of the integrated system. The battery and charger are often procured from different vendors with little or no system testing before their installation in the aircraft. Costly incompatibilities have arisen which could have been precluded by more complete laboratory testing.

A.3.2.9.3 Generators.

Generator systems shall be in accordance with ____________.

REQUIREMENT RATIONALE (A.3.2.9.3)

The design and performance of the generator system are essential contributors to the overall performance of the EPS. The fundamental subsystem power parameters of voltage, frequency, and capacity are established primarily by the main generators and associated components.

REQUIREMENT GUIDANCE (A.3.2.9.3)

a. Constant frequency 400 Hz power can be obtained from a constant speed generator driven directly from a prime mover when the prime mover operates at fixed speed. Generator systems of this type should be in accordance with MIL-PRF-21480B with changes as necessary for the specific application.

b. When the prime mover operates at varying speeds, either of two types of generator systems can be used for producing constant frequency power. One approach is to use a constant speed drive between the prime mover and the generator. The airframe contractror or drive manufatur should define the performance and quality assurance requirements. Older systems may reference the canceled MIL-D-83029. The second approach is to drive the generator directly from the prime mover at varying speed and convert the variable frequency produced by the generator to constant frequency by means of an electronic converter. MIL-E-85583 should be specified for systems of this type. Older systems may reference the canceled specification MIL-E-23001.

c. Generators in accordance with MIL-DTL-6162 are suitable for 28 volt DC systems.

d. Generator system capacity is often limited by the amount of cooling available. Therefore particular attention should be given to this aspect of the installation.

e. Other guidance concerning the design and installation of generator systems is provided by AFSC Design Handbook DH 2-3.

REQUIREMENT LESSONS LEARNED (A.3.2.9.3)

a. Oil–cooled, oil–lubricated generators have proven to be smaller, lighter and more reliable than their air–cooled, grease–lubricated predecessors.

b. Constant speed drive oil level has been critical to satisfactory operation on various aircraft. Furthermore, filling to the proper level has been adversely affected by temperature, aircraft attitude and inadequate oil level indication. New designs should be less critical with respect to oil level and should provide for simple and accurate filling and inspection procedures. The drive must be capable of operation under all specified "g" conditions over the entire range of specified oil levels.

c. When an external oil cooler is used in a generating system, it should be protected against contamination from the generating system by an outlet or scavenge filter. On one aircraft, when an Integrated Drive Generator (IDG) had a hardware failure, metal could and did contaminate the oil cooler, which meant the cooler had to be replaced. An Engineering Change Proposal (ECP)for a scavenge filter was later approved and added to the system.

A.4.2.9.3 Generators.
Compliance with the requirements of 3.2.9.3 shall be verified by analyses, tests, and inspection as follows: ____________.

VERIFICATION RATIONALE (A.4.2.9.3)

Experience has shown that system analyses, component qualification tests, and integrated EPS subsystem tests and inspections are required to verify performance of the generator system.

VERIFICATION GUIDANCE (A.4.2.9.3)

a. Analyses appropriate for the generator system include electrical load analyses, functional analyses, failure mode and effect analyses, hazard analyses and reliability analyses.

b. Individual components should be qualification tested and inspected to their particular specification requirements.

c. The generator system should be tested as a component of the EPS in mockup testing and tested and inspected after installation in the vehicle.

VERIFICATION LESSONS LEARNED (A.4.2.9.3)

A generator must be tested to demonstrate compliance with all of its performance requirements. This assures that the generator will operate in its actual environment. Every qualification test program results in some design changes that provide a better system in the field.

A.3.2.9.4 Converters.

a. DC to AC converters (inverters) shall be in accordance with: ____________.

b. When equipment that is essential for safe flight derives power from an inverter, a spare inverter shall be provided. Changeover from the main inverter to the spare shall be automatic in the event of main inverter failure. Spare inverters may be used as operative units to supply power to nonessential loads, but these loads shall be dropped in the event of main inverter failures.

c. AC to DC converters shall be in accordance with: ____________. When the outputs of two or more AC to DC converters are parallel to supply a common DC bus, no single unit shall be loaded beyond its rating for the worst–case load unbalance or failure mode which can occur.

REQUIREMENT RATIONALE (A.3.2.9.4)

The EPS is often required to supply power of a type different from that provided by the primary source. In this event a means of power conversion is needed. Typically, the conversion is from 115–volt, 400 Hz power to 28 volts DC (rectification) or from 28–volt DC to 115–volt, 400 Hz, 3-phase or single–phase (inversion).

REQUIREMENT GUIDANCE

a. Requirements for DC to AC converters (inverters) should be based on MIL-PRF-7032. This specification covers both rotary and solid–state types.

b. Requirements for AC to 28 Volt Unregulated DC should be based upon MIL-C-7115. Older systems may refer to the inactive MIL-DTL-26517. This specification should only be used for AC to DC converter (transformer-rectifier) replacepent, and not new designs.

REQUIREMENT LESSONS LEARNED (A.3.2.9.4)

Converters are frequently used in the system to provide voltages other than the ones provided by the main generators. This results in an electrical system that is more efficient overall. Many aircraft use off–the–shelf equipment which do not operate on normal aircraft power, and converters are the best way to provide the electrical power these equipments need.

A.4.2.9.4 Converters.
Compliance with the requirements of 3.2.9.4 shall be verified by analyses and tests as follows: ____________.

VERIFICATION RATIONALE (A.4.2.9.4)

System analyses, component qualification tests, and integrated EPS subsystem tests have proven to be required to verify converter performance.

VERIFICATION GUIDANCE (A.4.2.9.4)

a. Analyses appropriate for the converter installation include electrical load analyses, failure mode and effect analyses, hazard analyses, and reliability analyses.

b. Each converter should be qualification tested to its specification requirements.

c. The converters should be tested as components of the integrated EPS in mockup testing and after installation in the vehicle.

VERIFICATION LESSONS LEARNED (A.4.2.9.4)

Converters must be tested to demonstrate compliance with all of their performance requirements. This assures that the converters will operate in their actual environment. Every qualification test program results in some design changes that provide a better system in the field.

A.3.2.9.5 Other.
Requirements for other major components are as follows: ____________.

REQUIREMENT RATIONALE (A.3.2.9.5)

Advanced EPS may include major components other than those described previously based on uniqueness of aircraft configuration. Requirements should be specified accordingly.

REQUIREMENT GUIDANCE (A.3.2.9.5)

Any unique requirement—such as permanent magnet generators (PMG)—should be specified here.

REQUIREMENT LESSONS LEARNED (A.3.2.9.5)

Most systems are unique and may require additional components. If they are needed, then adequate requirements must be specified to assure system operational compatibility.

A.4.2.9.5 Other.
The compliance of other components with the requirements of 3.2.9.5 shall be verified by _____________.

VERIFICATION RATIONALE (A.4.2.9.5)

System analyses, component qualification tests and integrated EPS tests have proven to be required on other major components and should be considered for verification of other major components.

VERIFICATION GUIDANCE (A.4.2.9.5)

a. Analyses appropriate to the major component installation include electrical load analyses, failure mode and effect analyses, hazard analyses and reliability analyses.

b. Each major component should be tested to its specification requirements.

c. The major component should be tested in an integrated EPS mockup and after installation in the vehicle.

VERIFICATION LESSONS LEARNED (A.4.2.9.5)

All unique components must be qualified to their individual performance specifications to assure compatibility on the aircraft.

A.3.2.10 Environmental conditions.
The EPS and its components shall be capable of withstanding and operating under the following environmental conditions to which they are subjected during all phases of aircraft operation: _____________. Performance shall be as follows: _____________.

Environment	Requirement	Performance
Low Pressure		
High Temperature		
Low Temperature		
Temperature Shock		
Temperature/Altitude		
Humidity Fungus		
Vibration		
Dust		
Salt Fog		

Environment	Requirement	Performance
Sand and Dust		
Rain		
Acoustic Noise		
Explosive Atmosphere		
Shock		
Gunfire		
Temperature, Humidity, Vibration, Altitude		
Acceleration		
Vibro–Acoustic, Temperature		
Nuclear Exposure		

REQUIREMENT RATIONALE (A.3.2.10)

The components of the EPS are normally dispersed throughout the aircraft and are subjected to a wide variety of environments. Therefore, environmental requirements have to be determined for each component individually.

REQUIREMENT GUIDANCE (A.3.2.10)

The intent of this requirement is to provide a suitable definition of environmental conditions under which the ____________ must operate periodically and continuously. Environmental requirements are usually included in the host aircraft specifications. However, changes in the air vehicle since its initial configuration have to be considered. With the environment defined, the various tests needed during the development cycle can be tailored to meet the application. The risk is the ability to accurately assess the true environment.

MIL-STD-810 requirements can be specified for various environmental tests if it is determined that they are applicable to the particular weapon system. It is generally accepted that the performance of various equipment is degraded at environmental extremes such as high and low temperature. It will be necessary to determine the weapons systems performance requirements at these extremes and specify the performance of the equipment accordingly. Use care to avoid unnecessary requirements or requirements the equipment is not susceptible, such as noise on heavy equipment or solar radiation on equipment in bays.

REQUIREMENT LESSONS LEARNED (A.3.2.10)

Typically, the most critical environmental factors for electrical power systems are temperature and vibration. Other factors such as humidity and salt fog affect some components, depending upon their design. Vibration levels are very dependent upon the location in the aircraft and must be adequately specified.

A.4.2.10 Environmental conditions.
The capability of the EPS and its components to perform as required under all specified environmental conditions shall be verified by analyses and tests as follows: ____________.

VERIFICATION RATIONALE (A.4.2.10)

Analyses are required to determine the aircraft environment for most EPS components. Component environmental tests are needed to verify component compatibility with the environment. The laboratory is the only place where all environmental conditions can be simulated using various chambers for temperature, altitude and humidity along with other test equipment such as vibration machines.

VERIFICATION GUIDANCE (A.4.2.10)

a. Ensure that the storage and operational environments for each component are determined prior to component development or selection.

b. Depending on the equipment, the environmental tests should be tailored to evaluate its critical characteristics. The classical methods of environmental testing are presented in MIL-STD-810. These should be used whenever they can be determined to be applicable or where they simulate operational conditions.

Some environmental tests are long and costly. Only those tests required to ensure compliance with the requirements should be specified. Certain tests such as fungus can be eliminated if the contractor provides certification that no material which supports fungal growth has been used. When equipment is hermetically sealed, salt spray, rain, humidity, dust and fungus tests may be conducted on empty equipment cans only to test paint connectors, external hardware, etc. This usually results in a savings of time and money.

VERIFICATION LESSONS LEARNED (A.4.2.10)

Several lessons have been learned during environmental verification testing. Most of the lessons have been included in MIL-STD-810 test procedures. Mounting of equipment during vibration testing has been found to be critical. It is important that the mounting fixture not amplify or reduce the vibration which the equipment experiences.

A.3.3 Electromagnetic interference (EMI).
The electromagnetic interference requirements for the EPS shall be as follows: ____________.

REQUIREMENT RATIONALE (A.3.3)

EMI requirements for the electric power subsystem must be established which are consistent with, and in support of, the EMI requirements for the total aircraft system.

REQUIREMENT GUIDANCE (A.3.3)

Specify the applicable requirements of MIL-STD-461 for the EPS and its components. EMI engineers within AFLCMC can provide guidance for a particular application. Tailoring of the conducted emission requirements of MIL-STD-461 to be compatible with the harmonic distortion requirements will be required.

REQUIREMENT LESSONS LEARNED (A.3.3)

EMI–related problems have resulted from high–voltage, short–duration spikes on power lines. These spikes are usually load–induced and are most often caused by the switching of inductive loads. Spikes are a concern of the EPS because they can be transmitted to susceptible equipment via the EPS distribution circuits. Spike compatibility can be ensured by limiting spike levels in accordance with MIL-STD-464 and by requiring equipment to meet the spike susceptibility requirements of MIL-STD-461. Inductive coils should have diode suppression to minimize EMI effects.

A.4.3 Electromagnetic interference.
Compliance with the electromagnetic interference requirements of 3.3 shall be verified by tests as follows: ____________.

VERIFICATION RATIONALE (A.4.3)

Appropriate testing of the EPS components and the installed subsystem is the only means of ensuring that EMI requirements are met.

VERIFICATION GUIDANCE (A.4.3)

Specify the applicable test requirements of MIL-STD-461 for the EPS and its components. Ensure that the EMI test program for the total aircraft adequately covers the requirements for the installed electric power subsystem. Consult with EMI engineers within AFLCMC for additional guidance.

VERIFICATION LESSONS LEARNED (A.4.3)

Modification of MIL-STD-461 limits will be needed to prevent over–design of the generator output filtering. Generally, the output harmonic distortion requirements of MIL-STD-704 are adequate.

A.3.4 Integrity.
The integrity program requirements shall be in accordance with MIL-STD-1796 for electronics and MIL-STD-1798 for mechanical equipment and subsystems.

REQUIREMENT RATIONALE (A.3.4)

The integrity of the EPS is one of the factors which contribute to the overall integrity of the total aircraft system. The EPS integrity requirement is established by analyses which allocate the overall aircraft requirement among the various subsystems. The EPS requirement is then allocated among its component parts.

REQUIREMENT GUIDANCE (A.3.4)

Ensure that the integrity requirements for the EPS and its components are compatible with the requirement for the total aircraft. For details of the integrity program see MIL-STD-1796, AFGS-87249, and MIL-STD-1798.

REQUIREMENT LESSONS LEARNED (A.3.4)

Some aircraft had problems with failures of relays used in controlling subsystems' equipment. When investigated, these Military Secification (MS) relays were found to be all in the normal reliability classes of their specifications. However, for a small increase in purchase price, Established Reliability (ER) class relays could have been used. The ER relays with their adequate life requirements would pay for their higher price in savings of troubleshooting and maintenance time and less aircraft down time.

A.4.4 Integrity.
Compliance with the integrity requirements of 3.4 shall be verified by analyses and tests as follows: ____________.

VERIFICATION RATIONALE (A.4.4)

Subsystem and component analyses and tests are the appropriate means for verifying subsystem integrity.

VERIFICATION GUIDANCE (A.4.4)

Specify the analyses, component tests, laboratory subsystem tests, and installed subsystem tests which are necessary to verify that the integrity requirements are met. See MIL-STD-1796, AFGS-87249, and MIL-STD-1798 for further guidance.

VERIFICATION LESSONS LEARNED (A.4.4)

Integrity must be demonstrated on an early production unit to assure that any design changes can be incorporated early in the program.

A.3.5 Maintainability.
The EPS maintainability requirements shall be as follows: ____________.

REQUIREMENT RATIONALE (A.3.5)

The maintainability of the electric power subsystem is one of the factors contributing to the overall maintainability of the total aircraft system. Therefore, limits on maintenance tasks and associated times to accomplish them should be established for the EPS and its components.

REQUIREMENT GUIDANCE (A.3.5)

Consult the overall system Maintainability Monitor for assistance in establishing maintainability requirements. Refer to MIL-HDBK-470 for maintainability program guidance.

REQUIREMENT LESSONS LEARNED (A.3.5)

Easy access to EPS components is an essential factor for effective maintenance. Problems with maintaining proper oil level in the one aircraft integrated drive generators were attributed in part to the poor accessibility of the installation. Careful attention must be given to this area.

A.4.5 Maintainability.
Compliance with the maintainability requirements of 3.5 shall be verified by analyses and demonstrations as follows: ____________.

VERIFICATION RATIONALE (A.4.5)

Subsystem and component analyses and demonstrations are the appropriate means for verifying subsystem maintainability.

VERIFICATION GUIDANCE (A.4.5)

Specify the maintainability analyses and demonstrations which are necessary to ensure that maintainability requirements are met. Consult the system Maintainability Monitor for additional guidance. Refer to MIL-HDBK-470 for maintainability demonstration procedures and methods.

VERIFICATION LESSONS LEARNED (A.4.5)

Early maintainability demonstrations of the oil quantity gage on one aircraft would have shown that it was impossible for ground maintenance to obtain accurate readings due to the gage's poor location. Bad readings resulted in many generator failures before the quantity gage was finally relocated.

A.3.6 System safety.

The system safety requirements for the EPS shall be as follows: ____________.

REQUIREMENT RATIONALE (A.3.6)

Safety requirements and features are needed to protect personnel and equipment.

REQUIREMENT GUIDANCE (A.3.6)

The safety requirements of MIL-STD-882 are often applied.

REQUIREMENT LESSONS LEARNED (A.3.6)

Since electrical power is now flight critical on most aircraft, a safety analysis will demonstrate that all possible failure modes are identified and appropriate design measures incorporated.

A.4.6 System safety.

Compliance with the system safety requirements of 3.6 shall be verified by analyses and tests as follows: ____________.

VERIFICATION RATIONALE (A.4.6)

Safety assessment of the electric power subsystem is an integral part of the system safety program for the total aircraft. Safety is generally verified by analytical methods which include preliminary hazard analyses, subsystem hazard analyses, and operating hazard analyses.

VERIFICATION GUIDANCE (A.4.6)

See that the appropriate safety analyses of the electric power subsystem are included in program requirements. Ensure that the requirements for the subsystem and components include appropriate tests to verify safe operation for all failure modes.

VERIFICATION LESSONS LEARNED (A.4.6)

Early safety analysis on one program discovered a major deficiency which, if not corrected, would have caused the entire electrical system to shut down in the event of two highly probable failures on one flight.

A.3.7 Interface requirements.

The EPS and its components shall interface with other aircraft subsystems as necessary to provide the performance specified herein. In addition, the following detailed interface characteristics are required: ____________.

REQUIREMENT RATIONALE (A.3.7)

The EPS normally interfaces with many aircraft subsystems including propulsion, for prime motive power; airframe, for mechanical support; and environmental control, for cooling and pressurization. The EPS, in turn, furnishes electric power to these and most other subsystems. General requirements for interfaces with load equipment, ground power, and auxiliary power are called out in the appropriate sections of the basic specification. Definition of the detailed interface requirements necessary to integrate the EPS and its components into the aircraft is usually the responsibility of the airframe prime contractor. However, a particular program may require that additional interface requirements be levied by the Air Force.

REQUIREMENT GUIDANCE (A.3.7)

Specify any additional interface requirements necessary for the particular application.

REQUIREMENT LESSONS LEARNED (A.3.7)

Inadequate cooling of the integrated drive generator has been a major interface problem in many aircraft. Close attention must be given to this area.

A.4.7 Interface requirements.

Compliance with the EPS interface requirements of 3.7 shall be verified as follows: ____________.

VERIFICATION RATIONALE (A.4.7)

All interface requirements will require appropriate means of verification. Inspection, analyses, and tests can be used for this purpose.

VERIFICATION GUIDANCE (A.4.7)

Specify appropriate means of verification for each interface requirement.

VERIFICATION LESSONS LEARNED (A.4.7)

Verification of all interfaces assures that the system will work as advertised when installed.

A.3.8 Supportability.

A.3.8.1 Integrated diagnostics and testability.

The EPS shall be designed and constructed to permit system status and unambiguous location of faults to be reported within ____________ and ____________, respectively. Diagnostics/testability design and fault isolation times shall be constrained by operational and safety requirements, including maintenance system operational requirements, and life cycle cost.

REQUIREMENT RATIONALE (A.3.8.1)

Status information is required by the air crew to permit safe and effective operation and control of the EPS. The system maintainer must also be provided the capability to determine the status and the unambiguous location of all faults in a timely and cost–effective manner.

REQUIREMENT GUIDANCE (A.3.8.1)

This requirement needs to be tailored to reflect requirements during air vehicle missions and during ground maintenance. Determination of status refers not only to determination of operating parameters and to detection of faults, but also to servicing and replenishment needs for consumables. The term "faults" refers not only to faults which are observable no matter when the faulty equipment is operated or tested, but also to performance–eroding faults which manifest symptoms only in particular situations. Note that for this latter type of intermittent fault, the diagnostic system must be capable of documenting the fault indications and interpreting these indications in order to recognize any significant patterns. To provide for effective implementation of this requirement, the Statement of Work should require that an Integrated Diagnostics Program Plan (IDPP) be developed and incorporated in the Systems Engineering Master Plan (SEMP) and that appropriate Integrated Diagnostics milestones be incorporated in the Systems Engineering Master Schedule (SEMS). Additional requirements addressing testability and the compatibility of testing between the factory and the various repair levels need to be developed and inserted as subparagraphs within this paragraph. The specific requirements can be guided by the IDPP. Guidance on preparation of the IDPP can be found in MIL-HDBK-1814.

REQUIREMENT LESSONS LEARNED (A.3.8.1)

A.4.8 Supportability.

A.4.8.1 Integrated diagnostics and testability verification.

In–process verification that the EPS satisfies the diagnostics and testability requirements and constraints shall be accomplished by ____________. Final verification shall be accomplished by ____________.

VERIFICATION RATIONALE (A.4.8.1)

As the process of allocating the diagnostics and testability requirements is accomplished, it is necessary to synthesize the operation of the EPS's diagnostic system to establish that the diagnostics and testability requirements are satisfied. At completion of development, final verification is necessary to assure that contractual requirements have been met.

VERIFICATION GUIDANCE (A.4.8.1)

Select appropriate verification methods from the following verification methods to fill in the blanks.

VERIFICATION METHODS

It is necessary to verify that all required EPS diagnostic and testability capabilities function as intended. Each of the following activities can be utilized to assist with the verification of these capabilities.

1. In–process verification should be accomplished by conducting a comprehensive comparative analysis of status monitoring, diagnostic, maintenance, and servicing functions required for the EPS, its subsystems, equipment, components, and parts versus the embedded capabilities and support resources identified. The results of the analysis and any modeling (for example, the Logistics Composite Model (LCOM) should, at a minimum, be presented and critically reviewed at system PDR and CDR. Data for comparison should be drawn from the results and records of the following:

a. Logistic Support Analysis (LSA)— MIL-HDBK-502, tasks 201, 202, 203, 204, 205, 301, 302, 303, 401, and 402 to the extent that these tasks have been iterated.

b. Maintainability— MIL-HDBK-470, task 201, Failure Modes and Effects Analysis (SAE AIR4845).

c. Avionics Integrity Program (AVIP)—MIL-STD-1796, Durability/Economic Life Plan.

d. Mechanical Equipment and Subsystems Integrity Program (MECSIP)—MIL-STD-1798, Task V, Integrity Management Data Package.

e. Older systems may reference the canceled, Software Development Integrity Program (SDIP)—MIL-STD-1803, Software Integrity Maintenance Approach. Use IEEE 12207 – Sysetems and Software Engineering – Software Life Cycle Process. A Computer Systems and Software Integrity Program (CSSIP) is in development. Refer to CSSIP guidance upon publication.

f. Systems and Software Engineering – Software Life Cycle Process – IEEE 12207. Older systems may reference the canceled, Defense System Software Development—DOD-STD-2167A, Computer Resource Integrated Support Document (CRISD), software operational/support plans.

g. Aeronautical Systems Survivability (For Combat Mission Effectiveness)—MIL-HDBK-1799, task 104, Survivability Maintenance/Surveillance Plan and the maintenance/surveillance programs developed thereunder.

2. Functional verification/qualification of the diagnostic and testability requirements should be accomplished incrementally during EPS development, test and evaluation (DT&E), and operational test and evaluation (OT&E) by using a combination of tests and demonstrations which include those listed below.

a. Tests of built–in diagnostic capability during component, subassembly, assembly, and integrated aircraft system testing.

b. Use of embedded diagnostic capability to support final assembly checkout and flight test activities combined with comprehensive maintenance data collection and analysis.

c. Use of common tools and support equipment identified for operational use to support manufacturing, checkout, and flight test activities combined with comprehensive maintenance data collection and analysis (including collection and analysis of analogous data from the manufacturing and checkout operations). Qualification tests and demonstrations of the EPS should include tests and/or demonstrations to verify the adequacy of all support resources (for example, tools, support equipment, and technical data) to perform all required maintenance functions. Note that this requirement is not intended to preclude the use of laboratory and other special test equipment for engineering development test activity support during flight test but is intended to encourage contractor reliance on identified operational maintenance system capabilities and equipment for all maintenance activities which could be anticipated to occur in weapon system operational use.

d. Use of development program manuals (DPMs) which are procedurally and physically as close to the planned technical orders (T.O.s) as possible to support flight test operational and maintenance activities.

e. Use of a maintenance data collection and analysis system for flight test support which is (1) designed to interface with and support the contractor's Reliability and Maintainability data collection and analysis system and (2) designed to be transitioned to the maintenance data collection and analysis system planned for Air Force operational use.

f. Conduct maintainability demonstrations using preliminary T.O.s (or the DPMs) during the flight test program to demonstrate those functions of the maintenance system which have not been demonstrated during other flight test activities. If possible, conduct these demonstrations using appropriately trained Air Force personnel. MIL-HDBK-470 provides guidance on ensuring that the system meets the required level of maintainability.

g. Use of the technical order (T.O.) validation (by the contractor) and verification (by the Government) process to verify that manual diagnostic techniques are complete and perform as intended.

h. Conduct operational test and evaluation (OTE) to assure the embedded and support resource capabilities are satisfactory and support proceeding with deployment.

VERIFICATION LESSONS LEARNED (A.4.8.1)

A.3.8.1.1 Fault detection/isolation.
The EPS design shall facilitate complete and efficient fault detection and isolation at all levels of maintenance. The system design requirement is 100 percent for fault detection and isolation to an appropriate replaceable, adjustable, or repairable assembly or part. This shall be accomplished using an optimized combination of any or all of the fault detection/isolation methods listed herein. The fault detection/isolation capability shall consist of ____________.

REQUIREMENT RATIONALE (A.3.8.1.1)

The reason for this requirement is to assure that the EPS and its subsystems and equipment designs facilitate the detection and isolation of all faults to the individual item so that the EPS can be more rapidly restored to its full capability.

REQUIREMENT GUIDANCE (A.3.8.1.1)

This requirement addresses the overall fault detection/isolation capability for the EPS system. Implementation of this requirement must be based on a viable requirements allocation process and appropriate trade studies, cost benefit analyses, and maintenance timeline analyses to be effective. Hence, contractual imposition of this requirement must be accompanied by statement of work (SOW) tasking for appropriate trade studies and analyses. The fault detection/isolation functions may be accomplished by using the following methods. The blank should contain a description of the method(s) to be used to satisfy the requirements.

a. Built–in–test (BIT), built–in–test–equipment (BITE).

b. Automatic testing.

c. Troubleshooting via computer–assisted procedures.

d. Troubleshooting via ancillary tools and test equipment.

e. Troubleshooting via specific T.O. procedures.

f. Troubleshooting via manual techniques compatible with application and appropriate technical skill level.

REQUIREMENT LESSONS LEARNED (A.3.8.1.1)

A.4.8.1.1 Verification of fault detection/isolation.
In–process verification that the EPS, its subsystems and equipment satisfy the fault detection/isolation requirements shall be accomplished by ____________. Final verification shall be accomplished by ____________.

VERIFICATION RATIONALE (A.4.8.1.1)

Verification of fault detection/isolation is needed to assure that appropriate actions have been taken at each step in the integrated diagnostics design process to incorporate fault detection/isolation capability, to establish that these measures prove effective, and to provide an initial mechanism for identifying and accomplishing corrective actions when needed.

VERIFICATION GUIDANCE (A.4.8.1.1)

Specific fault detection/fault isolation (FD/FI) capability requirements for subsystems and equipment are determined by a requirements allocation process beginning at the system level and allocating requirements downward to individual subsystems and equipment using appropriate trade studies, cost benefit analyses, and maintenance timeline analyses to achieve an optimum solution. FD/FI capability implementation begins with the design phase of single repairable items and continues as these items are integrated into equipments, subsystems, and systems. In–process verification of FD/FI capability should begin with review of allocation process studies and analyses and correlation of their results with functionally based FMEA/FMECA failure detection method entries. In–process verification of BIT capability should begin with review of testability analyses and continue with review of test requirements documents and developmental and integration testing of equipment items, subsystems, and systems. Review and correlation of FMEA/FMECA results, especially failure detection method entries, in conjunction with testability analyses should be used to help assure adequacy of FD/FI. Prime mission subsystem and equipment development (including qualification) and integration tests, test program set development tests, and support equipment and maintenance system tests provide additional opportunities to verify test compatibility and to identify and accomplish corrective actions as needed. Final verification of fault detection/isolation capability can be accomplished using the maintainability verification/demonstration/evaluation procedure of MIL-HDBK-470.

VERIFICATION LESSONS LEARNED (A.4.8.1.1)

A.3.8.2 Packaging, handling, storage, and transportation (PHST).
The EPS, its subsystems and components shall be designed with PHST characteristics that allow it to be readily transported in the logistics environment at the lowest life cycle cost. The PHST characteristics that will be established as requirements include ____________.

REQUIREMENT RATIONALE (A.3.8.2)

Designing systems and equipment with optimum PHST characteristics contributes to operationally effective and supportable systems and equipment, at the lowest life cycle cost.

REQUIREMENT GUIDANCE (A.3.8.2)

The PHST characteristics to be required should be derived based on the constraints imposed by the distribution environment defined in the integrated support plan. MIL-STD-1367 and the documents referenced therein may provide guidance to tailor the PHST characteristics into requirements to be satisfied by the EPS and its subsystems and components.

REQUIREMENT LESSONS LEARNED (A.3.8.2)

A.4.8.2 Packaging, handling, storage, and transportation.
The PHST requirements shall be verified by ____________.

VERIFICATION RATIONALE (A.4.8.2)

Thorough verification is necessary to insure that the EPS and its components have been designed so they can be efficiently moved within the distribution environment.

VERIFICATION GUIDANCE (A.4.8.2)

Verification of PHST characteristics should be accomplished through a combination of inspection, analysis, and test. The specific parameters should be established in accordance with the distribution environment defined in the integrated support plan. Testing should be performed whenever possible to get the most reliable verification results. Actual distribution environment tests are prescribed in MIL-STD-810, Federal Test Method Standard 101, and various ASTM Test Method Standards.

VERIFICATION LESSONS LEARNED (A.4.8.2)

A.3.8.3 Tools.
Tools required to perform on aircraft organizational level maintenance functions shall be limited to those on the STAM2 list. Tools required to perform intermediate level functions shall consist of ____________.

REQUIREMENT RATIONALE (A.3.8.3)

This requirement is to minimize the number of tools and tool types required in the aircraft's maintenance system, to effect standardization of those tools, and to impose these requirements on the design of subsystems and equipment for the weapon system. The intent of this requirement is to place the focus of maintenance tool acquisition in the systems engineering process so that it receives appropriate attention during the system development process. It is also the intent of the requirement to keep the size of the maintainer's tool kits to a minimum.

REQUIREMENT GUIDANCE (A.3.8.3)

The blank should be filled in after reviewing the specific tools included on the STAM and STAM2 lists. STAM is the list of desired common hand tools for organizational and intermediate level maintenance of aircraft, aircraft engines, and related support equipment. The STAM list includes STAM2 tools and the additional common hand tools for disassembly, reassembly, and adjustment of units, assemblies, and subassemblies. The STAM list does not include tools which may be required for fabrication, rework, or battle damage repair. The STAM list will be used during the acquisition process to measure the contractor's ability and willingness to develop systems maintainable primarily with those common hand tools desired by the Air Force. STAM2 is the list of common hand tools for on–equipment maintenance of aircraft, aircraft engines, and related support equipment. It contains all of the tools for removal, replacement, adjustment, and servicing of installed units, assemblies, and subassemblies during organizational and intermediate level maintenance. Use of STAM2, in whole or in part, is mandatory. System design and on–equipment maintenance concepts must be consistent with the STAM2 list.

REQUIREMENT LESSONS LEARNED (A.3.8.3)

Failure to give appropriate focus and attention to maintenance tool requirements leads to excessive numbers and types of tools and to cases of "10,000.00 Allen wrenches."

A.4.8.3 Tools verification.
In–process verification of tool requirement and selection shall be accomplished by review of the tool lists, drawings, and justifications for modified and special tools. Final verification of the adequacy and completeness of tools shall be accomplished by ____________.

VERIFICATION RATIONALE (A.4.8.3)

Incorporation of tool verification as a required step in the supported subsystem/equipment qualification process further implements the focus of the tools acquisition process on systems engineering where it properly belongs. Qualification of supported subsystems and equipment is not complete without verification of tools.

VERIFICATION GUIDANCE (A.4.8.3)

The final verification should consist of specific demonstrations and tests during qualification of the subsystem or equipment being supported. Maintainability verifications/demonstrations to be conducted in accordance with MIL-HDBK-470 or comparable verifications can serve a dual purpose if they are also used to verify compliance with tool requirements.

VERIFICATION LESSONS LEARNED (A.4.8.3)

CONCLUDING MATERIAL

Custodian:
Air Force – 11

Preparing Activity:
Air Force – 11

(Project 61GP-2011-001)

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