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AEROSPACE RECOMMENDED PRACTICE

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ELECTRICAL ACTUATION SYSTEMS FOR AEROSPACE AND OTHER APPLICATIONS

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1. SCOPE:

This Aerospace Recommended Practice (ARP) is intended as a guide in the preparation of Procurement Specifications for electrical actuator systems to be used in aerospace and other applications. Detail requirements, as necessary to completely define a specific actuator, are the responsibility of the procuring agency.

1.1 Definitions:

An electrical actuation systems (EAS) is defined as consisting of all electrical, mechanical, optical, or fluidic components necessary to convert a command signal and electrical power from the vehicle into a controlled linear or rotary force while using an electromagnetic prime mover. For purposes of this document, the following definitions of an EAS apply:

1.1.1 ELECTROMECHANICAL ACTUATOR: An electromechanical actuator is defined as an EAS that utilizes an electric motor mechanically coupled to the load.

1.1.2 ELECTROHYDRAULIC ACTUATOR: An electrohydraulic actuator is defined as a self-contained EAS that utilizes an electric motor driving a hydraulic pump to operate a hydraulic actuation system.

2. REFERENCES:

2.1 Applicable Documents:

The following representative list of documents may in some degree be applicable to the design, material, components, fabrication, testing, etc., of EAS's. Other documents may be applicable in certain actuator systems.

Only those documents included in the requirements should be listed in a procurement specification. The applicable specification revision letter along with the date of the revision should be included in the list.

The following documents indicated form a part of this Aerospace Recommended Practice to the extent specified herein.

Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.

2.1.1 SAE Aerospace Documents:

ARP926	Fault/Failure Analysis Procedure
AIR1799	Missile Flight Control Actuation Terminology
AIR1891	Flight Control Actuator Terminology
AIR1916A	Aerospace Fluid Power and Control/Actuation System Glossary

2.1.2 Military:

MIL-B-5087	Bonding, Electrical and Lightning Protection for Aerospace Systems
MIL-E-5400	Electric Equipment, Airborne, General Specification for
MIL-M-7969	Motors, Alternating Current, 400 Hertz, Specification for
MIL-I-8500	Interchangeability and Replaceability for Component Parts for Aircraft and Missiles
MIL-M-8609	Motors, Direct Current, 28-Volt System, Aircraft, General Specification for
MIL-S-8805	Switches and Switch Assemblies, Sensitive, and Push (Snap Action), General Specification for
MIL-Q-9858	Quality Program Requirements, Military Specification
MIL-C-38999	Connector Electrical Circular, Miniature, High Density Quick Disconnect, Environment Resistant, Removable Crimp & Solder Contacts, General Specification for
MIL-STD-970	Standards and Specifications, Order of Preference for the Selection of
MIL-STD-210	Climate Extremes for Military Equipment
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-461	Electromagnetic Emissions and Susceptibility Requirements
MIL-STD-470	Maintainability Program Requirements (For Systems and Equipment)
MIL-STD-704	Aircraft Electrical Power Characteristics
MIL-STD-810	Environmental Test Methods
MIL-STD-838	Lubrication of Military Equipment
MIL-STD-882	System Safety Program for Systems and Associated Subsystems and Equipment, Requirement for
MIL-STD-889	Military Standard, Dissimilar Materials
MIL-STD-1472	Human Engineering Design Criteria for Military System, Equipment and Facilities
MIL-STD-1523	Age Control of Age-Sensitive Elastomeric Material
MIL-STD-1629	Procedures for Performing a Failure Mode and Effects and Criticality Analysis
MIL-STD-1773	Fiber Optics Mechanization of an Aircraft Internal Time Division Command/Response Multiplex Data Bus

2.1.3 Military Handbooks:

MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-275	Guide for Selection of Lubricant Fluids

2.1.4 Air Force Systems Command Design Handbook:

AFSC DH 1-6	System Safety

2.2 Related Documents:

The following representative list of documents may in some degree be applicable to the design, material, components, fabrication, testing, etc., of EAS's. Other documents may be applicable in certain actuator systems.

Only those documents included in the requirements should be listed in a procurement specification. The applicable specification revision letter along with the date of the revision should be included in the list.

The following documents of the issue indicated form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.

2.2.1 National Bureau of Standards:

Handbook H28 Screw-Thread Standards for Federal Services

2.2.2 Radio Technical Commission for Aeronautics:

DO 160 Environmental Conditions and Test Procedures for Airborne Equipment
DO 178 Software Considerations in Airborne Systems and Equipment Certification

2.2.3 Specifications:

2.2.3.1 Federal:

FF-B-185 Bearings, Roller, Cylindrical, and Bearings Self-Aligning

2.2.3.2 Military:

MIL-B-3990	Bearings, Roller, Needle, Airframe, Antifriction
MIL-S-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems
MIL-W-5088	Wiring Aircraft, Installation of
MIL-B-5628	Bearings, Plain, Airframe
MIL-B-6038	Bearings, Ball, Bellcrank, Antifriction, Airframe
MIL-B-6039	Bearings, Ball Rod End, Antifriction, Self-Aligning
MIL-I-6870	Inspection Requirements, Nondestructive
MIL-B-7949	Bearings, Ball, Airframe, Antifriction
MIL-P-9024	Packaging, Handling and Transportability in System/ Equipment Acquisition
MIL-F-9490	Flight Control System-Design, Installation and Test of Piloted Aircraft, General Specification for
MIL-C-45662	Calibration System Requirements
MIL-H-46855	Human Engineering Requirements for Military Systems, Equipment and Facilities
MIL-A-87221	Aircraft Structure, General Specification for

2.2.3.2 (Continued):

MIL-A-008865 Airplane Strength and Rigidity, Miscellaneous Loads

DOD-D-1000 Drawings, Engineering and Associated Lists

2.2.4 Standards:

2.2.4.1 Military:

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-453	Inspection, Radiographic
MIL-STD-462	Electromagnetic Characteristics, Measurement of
MIL-STD-785	Reliability Program for Systems and Equipment Development and Production
MIL-STD-794	Parts and Equipment, Procedures and Packaging and Packing of
MIL-STD-831	Test Reports, Preparation of
MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-970	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-1553	Aircraft Internal Time Division Command/Response Multiplex Data Bus
MIL-STD-1949	Inspection Process, Magnetic Particle
MIL-STD-2175	Casting, Class and Inspection of
MIL-STD-6866	Inspection, Penetrant Method of
MS33540	Safety Wiring and Cotter Pinning, General Practices for

2.2.5 Publications:

2.2.5.1 Military Handbooks:

MIL-HDBK-217E Reliability Prediction of Electronic Equipment

3. REQUIREMENTS:

3.1 General Performance:

Each actuation system and its components should be designed to operate satisfactorily under all conditions that the aircraft may encounter within the structural limitations of the aircraft including forces or conditions caused by acceleration, deceleration, any flight attitudes, structural deflections or vibrations, or other environmental conditions.

3.1.1 Selection of Specifications and Standards: Selection of specifications and standards for necessary commodities and services not specified herein should be selected in accordance with MIL-STD-143.

3.2 Interface Requirements:

3.2.1 Electrical Power Interface: The electrical input power, both AC and/or DC, to the system should be defined. This definition should include the normal range which the system will see, for the majority of the time, the abnormal or transient range of short time duration and if applicable the emergency input power range. The mechanical and/or control signal output required for each input power range should be specified. If there is a maximum permissible power draw limit for any circuit, it should also be specified.

The input power definition can be specified as MIL-STD-704 or a similar input power specification that has been developed for the industry or for a particular vehicle.

3.2.1.1 Regenerated Power: In some EAS's, significant aiding loads during portions of their operation will over drive the motor into a generating mode. This generated power should be recognized and its method of disposal specified. The probable choices are either to put the power back into the aircraft electrical system capacitive storage or dissipate it across a load resistor.

3.2.2 Control Signal Interface: The control signal interface should be defined as all signals, mechanical, fluidic, electrical or optical but excluding input electrical power, that are either input to or output from the EAS.

The definition of this interface shall include but not be limited to:

a. Number and types of interfaces
b. Data or control content of each interface
c. Ranges, scales, resolutions, frequencies
d. Voltages, impedances, currents, bit rate
e. Applicable specifications, such as MIL-STD-1553, MIL-STD-1773

3.2.3 Mechanical Interface: The mounting configuration for the EAS should be specified. This should include airframe attachment points, output motion attachment definition, and desired location of electrical connections. If the EAS center of gravity is required, it can be shown as a to be determined requirement of this paragraph.

The information for this paragraph is best provided with a written requirement paragraph referring to a figure elsewhere in the specification or to a specification drawing.

3.2.4 Envelope: The maximum envelope available for the EAS should be shown as a figure in the specification or on a separate specification drawing. If there is a separate location for mounting a controller, this should also be shown along with the distance between the two components.

The envelope may be specified as follows:

a. The EAS shall be as small as practical using good design practices and shall be within the envelope(s) shown in Figure 1.

NOTE: It may be practical to provide "mechanical interface" and "envelope" information in one figure or specification drawing.

3.2.5 Thermal Interface: An EAS contains electrical and electronic components that generate heat and the performance, reliability, and life of these components depend on dissipating this heat and maintaining critical components within their operating temperature range. The vehicle thermal interface greatly affects the process of removing this heat and, therefore; it is necessary to describe the thermal environment (conductive, convective, radiant) as it pertains to the EAS.

This description should include the following minimum information.

a. The ambient temperature range at EAS location for operating and nonoperating conditions.

b. The ambient temperature of surrounding structure including maximum temperature limits and, if applicable, mass and thermal conductivity of material.

c. A description of any air or other gas available for cooling including temperature range, mass flow rate, and thermal characteristics.

d. A description of any fluid available for cooling, including temperature range, flow and pressure available, and thermal characteristics.

3.2.6 Operator Interface: The interface between an operator and the EAS should be considered in order to allow for manual operation of switches and levers, installation of hardware, visual observance of critical parameters, and normal maintenance or ground operations.

3.3 Performance:

This section should contain all the dynamic and static output performance requirements for the actuator system. For definition of the terminology used, refer to the following SAE documents providing industry accepted definitions:

a. AIR1799
b. [1]AIR1891
c. [2]AIR1916

If relevant definitions are not found in these documents, the terminology should be explained in the procurement document.

In many cases, the load and travel profiles are described in a lead paragraph and shown graphically in a figure or table.

[1] These documents have not been released as of the date of issue of this document.
[2] See Footnote 1.

3.3 (Continued):

Only the requirements pertaining to a particular application should be included in the specification.

When appropriate, performance under any mounting orientation and for appropriate g-loads, including negative and zero g should be specified.

The performance section should also contain a statement specifying input power conditions normal and abnormal (AC and/or DC) at which full and/or degraded output performance requirement of the EAS must be met.

3.3.1 Dynamic Loads: These are the operating loads external to the actuator that either oppose or aid the actuator output motion. If any of these loads exist simultaneously in any combination, it should be specified.

3.3.1.1 Friction: Friction associated with the load may vary with changes in load and velocity.

3.3.1.2 Inertia: The load inertia and the movement requirement should be specified.

3.3.1.3 Preload: This should be specified as a torque or axial load.

3.3.1.4 Rated Load: Rated load can be specified either as a steady state load or a cyclic load for the purpose of measuring input and/or output parameters of the EAS. This load can be chosen as any point in the performance range and is used as part of a nondestructive test to establish the acceptability of production EAS's.

3.3.1.5 Side Load: If there is a side load perpendicular to the output of the EAS due to either intentional or possible accidental misalignment of the actuator and the load, it should be specified.

3.3.1.6 Spring Load: Any spring load and its rate of change with position should be specified. If any random spring loads due to random effects of aerodynamics or environmental conditions are possible, they should also be specified along with any allowable degradation in performance.

3.3.2 Static Loads: There are two categories of static loads to be considered. One category deals with the output capabilities of the EAS while the other category dictates its structural characteristics. By definition, these loads are specified singularly and not in any combination.

3.3.2.1 Holding Load: This load can be specified at any or all points in the operating range. The holding can be accomplished with some form of brake, no back device, or prime mover. If any specific type is desired, it should be specified.

3.3.2.2 Limit Load: Limit load defined as the maximum static load applied to the actuator output that will not cause permanent deformation of the EAS should be specified. The application of this load should not cause a subsequent degradation in performance.

3.3.2.3 Stall Load: The minimum load at which the EAS will not cause motion to occur should be specified. The input power condition controller parameters and environmental conditions applicable should also be specified.

3.3.2.4 Ultimate Load: The ultimate load as applied to the output shall be specified. This load shall not cause any structural failures, however, yielding of the components is allowable. Operation after the ultimate load is not usually required.

3.3.3 Output Travel: The actuator stroke or travel should be specified in the text, and if practical, should also be shown as a figure in the specification or on the specification control drawing. As applicable, the travel between normal limits and travel between emergency or extreme limits should be specified.

3.3.3.1 Stops: Nonjamming mechanical stops are normally required on EAS's. These stops may be located external to the EAS, or they may be specified as being an integral part of the EAS. The load and number of impacts requirement should be specified.

3.3.4 Rated Velocity: The required EAS output velocity or rate, with the specified input power applied and the specified rated load applied at the actuation output attach point should be specified.

3.3.5 Limit Velocity: The maximum rate or velocity at which the load can be moved should be specified. The reason for the specified limit should be given to aid in determining methods of limiting the maximum velocity if necessary.

3.3.6 Slew Rate: The steady state output velocity requirements for the actuator system in response to a step input command should be specified. This velocity is usually measured as the average velocity between the 10 and 90% points of the step command in order to eliminate the effect of acceleration and deceleration.

3.3.7 Dynamic Response Requirements: Some EAS's systems have cyclic loads with rapid response requirements. For these the motion definition and requirements are more complicated and involve dynamic characteristics of the entire EAS and load including the prime mover, controller, actuator and feedback sensors. Some of the more prominent requirements to be specified are frequency response, bandwidth, step response, overshoot, and dynamic stiffness.

3.3.8 Position Accuracy: The salient requirements that define the accuracy of an EAS should be specified as applicable along with an explanation of how this feature is to be demonstrated.

Some of the requirements that affect accuracy are STIFFNESS, including the attachment points, BACKLASH, LINEARITY (conformity of the EAS output to the input command), THRESHOLD (amount of input change required to produce an EAS output change), RESOLUTION, and HYSTERISIS.

3.3.9 Duty Cycle: A description of the loads and their duration should be specified so that the heat-sensitive EAS components can be sized to handle the resulting thermal loads. This duty cycle specification is particularly important for EAS components since the losses from the electronic power converter and motor are not carried away by the working fluid, as in the case of their hydromechanical counterparts.

It is recommended that the duty cycle be specified for a typical mission in terms of consecutive time intervals for identifiable mission segments such as takeoff, cruise, special maneuvers (if applicable), and landing. The time duration of each segment should be specifically indicated. If the typical mission is likely to be repeated according to a predictable schedule (such as for commercial aircraft), the ground time between mission cycles should be included in the duty cycle specifications.

Loading during each mission segment should preferably be specified in two parts corresponding to: (1) a steady state aerodynamic loading, and (2) a dynamic inertial loading. The steady state loading should be specified as an average force (torque) which the EAS must supply during the particular mission segment. The dynamic component of the loading should preferably be specified as a single dominant sinusoidal motion about the steady state operating point, characterized by both the amplitude and the frequency of the motion. Unless specifically indicated, it will be assumed that the amplitude of the dynamic motion is sufficiently small so that the aerodynamic loading can be considered constant over the range of the dynamic motion. If it is impossible to specify the loading as a single dominant frequency component, it is necessary to provide sufficient information so that the amplitudes of motion associated with each frequency component can be identified.

In addition to the information regarding loading during typical mission profiles, it is very important that details of the worst-case duty cycle requirements be specified as well. For example, worst-case dynamic loading might occur during intervals of heavy turbulence, or enemy engagement conditions for military aircraft. If loading changes significantly during abnormal flight conditions (such as steady state loading on a flight surface following loss of one engine in a multiengine aircraft), the duration and magnitude of this loading should be specified. In addition, it is very important to specify worst-case thermal environments (both hot and cold) for the EAS components during the individual mission segments, such as very high ambient temperatures during ground time segments in hot climates.

In some cases, the worst-case EAS loading occurs on the ground during training or maintenance exercises during which the amplitude of the steady state and/or dynamic loading can be set artificially high compared to in-flight values. If such conditions are expected, the nature and duration of such ground-based loading should be specified.

3.3.10 Life: The required life of the system shall be specified. Life is defined as that period during which the system shall meet a given set of specified parameters.

It is important that only those parameters that are truly salient to the life of the system be included. In addition, any specified parameter must be measurable, preferably while installed.

The units of life may be expressed in terms of aircraft flight hours, system operational hours, system operational cycles, or others. Whichever units are chosen, it is important that full account of the specified duty cycle is taken in order that the units used during qualification testing and verification of life are commensurate with those units used by the system's end user.

3.4 Design and Construction:

3.4.1 General: The EAS shall be the optimum design and construction to meet the proposed use in the detail specification. The following should be used as a guide in specifying requirements for the design and construction of an EAS:

3.4.1.1 Electrical and Electronic Components: Electrical and electronic components should be designed to meet the applicable sections of MIL-E-5400 and MIL-STD-454.

3.4.1.2 Lubrication: Unless otherwise specified, all lubricants for the EAS should be in accordance with MIL-STD-838 and/or MIL-HDBK-275. If there is a specific requirement for or against a specific lubricant, it should be so stated in the procurement specification.

3.4.1.3 Bearings: Bearings should be selected as necessary to meet the life and performance requirements of the procurement specification. Self-contained lubricant bearings with adequate sealing for their application are preferred. Bearings located such that the environmental conditions may affect their life or performance shall be adequately protected with either integral or external seals. Unless otherwise specified, bearings shall be selected in accordance with the applicable military specifications.

3.4.1.4 Reliability: The mean time between failure (MTBF) for the EAS when operating within the loading, environmental, input power levels, and command signal levels specified should be defined in the procurement specification. The analysis using a mathematical model should be performed in accordance with MIL-STD-785 and MIL-STD-1629. The failure mode and effect analysis should be in accordance with ARP926.

3.4.1.4.1 Redundancy: Some actuation systems require full or partial redundancy in order to improve mission reliability. The degree of redundancy required should be specified as well as the philosophy of redundancy for the vehicle.

3.4.1.4.2 Single Point Failure: The procurement specification should define the required capabilities in the event of a single point failure.

3.4.2 Workmanship: Workmanship standards for the EAS and components should be in compliance with requirement 9 of MIL-STD-454.

3.4.2.1 Quality: The procurement specification should require that a quality control system per MIL-Q-9858 or equivalent be in place to insure the continuing quality of the EAS.

3.4.2.2 Interchangeability: Interchangeability of the EAS or its components should be in accordance with requirement 7 of MIL-STD-454 and/or MIL-I-8500.

3.4.3 Weight: Design and materials used in the EAS should be chosen to minimize weight while still meeting all the requirements of the procurement specification.

3.4.4 Materials and Processes: The material and processes used in the EAS and its components should be suitable for the service and purpose intended and should meet the applicable government specification. If no applicable government specification exists, the material or process should be given prior approval for use by the procuring agency.

3.4.4.1 Dissimilar Metals: The use of dissimilar metals, as defined in MIL-STD-889, in direct contact is prohibited unless the mating surfaces are adequately protected.

3.4.4.2 Nonmetallic Components: Nonmetallic seals, gaskets, grommets, and similar items used in the EAS or components shall be compatible with the environmental conditions specified in the procurement specification. Age sensitive elastomers shall be controlled in accordance with MIL-STD-1523.

3.4.4.3 Protective Treatment: When materials are used in the construction of the actuator that are subject to deterioration when exposed to climatic and environmental conditions likely to occur during service usage, they shall be protected against such deterioration in a manner that will in no way prevent compliance with the procurement specification. The use of any protective coating that will crack, chip, or scale with age or extreme of climatic and environmental conditions shall be avoided.

3.4.4.4 Material Properties: Material properties should be obtained from MIL-HDBK-5 when possible. When materials are specified whose properties are not contained in MIL-HDBK-5, the appropriate references should be identified and if necessary made available. Any materials disallowed should be identified in the specification.

3.4.5 Electrical Requirements: All assembly or processes involving electrical or electronic components and/or assemblies should be controlled by Government specifications or other applicable industry specifications unless otherwise specifically authorized by the procuring activity.

3.4.5.1 Connectors: Unless otherwise specified in the procurement specification, connectors should be chosen per MIL-C-38999, Series III. Consideration shall be given to separating power leads from signal leads to avoid interference.

3.4.5.2 Electric Motors: Electric motors for the EAS should be designed to meet the load requirements of the actuator system with input power per MIL-STD-704 or other applicable industry specifications while operating in all the natural or unnatural combinations of climatic and environmental conditions listed in the procurement specification. A preference for a specific motor type is normally given in the procurement specification; however, the bidder should be invited to propose any alternate motor which can be shown capable of the required performance with distinct advantages to the EAS. Technical requirements for the motor such as redundancy, thermal protection, thermal interface, etc., should be specified. Motor specifications MIL-M-7969 (Alternating Current Motors) and MIL-M-8609 (Direct Current Motors) may be used as a guide for certain requirements. Unless otherwise specified, the electric motor shall meet the performance, climatic, and environmental requirements of the procurement specification while assembled as an integral part of the EAS.

3.4.5.3 Limit Switches: Limit switches may be integral with the actuator and accessibility and adjustment requirement should be defined.

3.4.5.4 Electromagnetic Interference and Compatibility: Unless otherwise specified in the procurement specification, the generation and susceptibility to EMI for all electrical and electronic equipment should be controlled in accordance with MIL-STD-461 or similar industry standard.

3.4.5.5 Bonding and Grounding: Bonding of electrical and electronic components should be in accordance with MIL-B-5087. Each electrical or electronic assembly other than sensors should have a ground return isolated from the power return lead or connector pin.

3.4.5.6 Dielectric Strength: Each electrical or electronic assembly should have a dielectric strength requirement between its electrical circuit and the ground point of the system.

3.4.5.7 Controller: The electronic controller acts as an interface between the command input signal and the electrical power output to the electric motor driving a particular actuation system load. Many of the interface, performance, and environmental requirements for the controller are discussed in other sections and need not be repeated here. If there are specific interface, performance or environmental requirements applicable to the controller only, they should be specified in this section.

These specific requirements may include:

a. Alternate location and space available for part or all of the controller.

b. Special cooling available for the controller.

c. Preferred parts list for controller components.

d. Electronic language to be used for interfacing with aircraft electronics.

3.4.5.8 (Continued):

e. Electronic component derating required for reliability.

The electronic controller may be subdivided by its two distinguishing electronic power levels: (1) control and signal electronics and (2) power electronics.

The control and signal electronics are those functions in the controller which are associated with both vehicle and power stage interfaces, loop closures, sensor signals and excitations, and motor commutation, if applicable. The control and signal electronics may be located with or separately from the power electronics, packaged with the actuator or become integrated separately with the vehicle application controller electronics.

The power electronics are the power stages that interface with the electrical power bus, the control and signal electronics, and the electric motor driven actuator. The power stage also provides input and output switching for the motor during the motoring and regeneration phases of operation. The power stage may be part of the electronic controller, packaged with the actuator or in a separate remote location depending upon the particular application. The power stage is usually actively cooled to insure high reliability; however, cooling depends on the particular application being considered.

3.4.6 Marking: Requirements for nameplates and other marking provisions shall be defined in the procurring specification.

3.4.7 Exterior Finish: Requirements for exterior finish shall be defined in the procurement specification.

3.5 Environmental Requirements:

The EAS should be capable of meeting the requirements of the procurement specification when subjected to an environmental condition or any natural or unnatural combination of environmental conditions listed in the procurement specification.

Unless otherwise specified, EAS components should use the specified environmental requirements as a design guide but they must meet the environmental requirements specified when they are assembled as a part of the EAS.

The following is a list of environmental requirements normally specified in aerospace systems. Specifications may be added or subtracted from this list depending on the application. The specific requirements and test methods should be per MIL-STD-210 and/or MIL-STD-810 or an approved industry standard.

a. Low temperature
b. High temperature
c. Temperature cycling
d. High altitude
e. Vibration