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MILITARY STANDARD

TEST REQUIREMENTS
FOR
LAUNCH, UPPER-STAGE, AND SPACE VEHICLES

AMSC **N/A**

FSC 1810

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SECTION 1

SCOPE

1.1 PURPOSE

This Standard establishes the environmental and structural ground testing requirements for launch vehicles, upper-stage vehicles, space vehicles, and for their subsystems and units. In addition, a uniform set of definitions of related terms is established.

1.2 APPLICATION

This Standard is intended for reference in applicable program specifications, or in other documents, to establish general test requirements (10.1). The test requirements focus on design validation and the elimination of latent defects to ensure mission success. The application of these test requirements to a particular program is intended to result in a high confidence for achieving successful space missions.

It is intended that these test requirements be tailored to each specific. program after considering the design complexity, design margins, vulnerabilities, technology state of the art, in-process controls, mission criticality, life cycle cost, number of vehicles involved, prior usage, and acceptable risk (4.1, 10.2).

1.3 TEST CATEGORIES

The tests are categorized as follows:

a. Development tests. Characterization tests and tests to validate qualification and acceptance procedures (Section 5).

b. Qualification tests. Vehicle, subsystem, and unit levels (Section 6).

c. Acceptance tests. Vehicle, subsystem, and unit levels (Section 7).

d. Flightproof and protoqualification tests. Vehicle, subsystem, and unit levels (Section 8).

e. Prelaunch validation tests and follow-on operational tests and evaluations. Integrated system tests, initial operational tests and evaluations, and operational tests (Section 9).

SECTION 2

APPLICABLE DOCUMENTS

2.1 GOVERNMENT DOCUMENTS.

The following standards and specifications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

Military Standards

MIL-STD-810	Environmental Test Methods and Engineering Guidelines.
MIL-STD-1522 (USAF)	Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems.
MIL-STD-1541 (USAF)	Electromagnetic Compatibility Requirements for Space Systems.
MIL-STD-1833 (USAF)	Test Requirements for Ground Equipment and Associated Computer Software Supporting Space Vehicles.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 1911 l-5094.)

2.2 ORDER OF PRECEDENCE.

In the event of 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.

SECTION 3

DEFINITIONS

3.1 ITEM LEVELS

The categories of items in hierarchical order are defined in this section,

3.1.1 Part. A part is a single piece, or two or more joined pieces, which are not normally subject to disassembly without destruction or impairment of the design use. Examples: resistor, integrated circuit, relay, roller bearing.

3.1.2 Subassembly. A subassembly is a unit containing two or more parts which is capable of disassembly or part replacement. Examples: printed circuit board with parts installed, gear train.

3.1.3 Unit. A unit is a functional item that is viewed as a complete and separate entity for purposes of manufacturing, maintenance, or record keeping. Examples: hydraulic actuator, valve, battery, electrical harness, transmitter.

3.1.4 Subsystem. A subsystem is an assembly of functionally related units. It consists of two or more units and may include interconnection items such as cables or tubing, and the supporting structure to which they are mounted. Examples: electrical power, attitude control, telemetry, thermal control, and propulsion subsystems.

3.1.5 Vehicle. Any vehicle defined in this section may be termed expendable or recoverable, as appropriate.

3.1.5.1 Launch Vehicle. A launch vehicle is one or more of the lower stages of a flight vehicle capable of launching upper-stage vehicles and space vehicles, usually into a suborbital trajectory. A fairing to protect the space vehicle, and possibly the upper-stage vehicle, during the boost phase is typically considered to be part of the launch vehicle.

3.1.5.2 Upper-stage Vehicle. An upper-stage vehicle is one or more stages of a flight vehicle capable of injecting a space vehicle or vehicles into orbit from the suborbital trajectory that resulted from operation of a launch vehicle.

3.1.5.3 Space Experiment. A space experiment is usually part of the space vehicle payload and is therefore-considered to be-a lower level assembly of a space vehicle. However, a space experiment may be an integral part of a space vehicle, a payload that performs its mission while attached to a space vehicle, or even a payload that is carried by a host vehicle but performs some of its mission as a free-flyer. Whether complex space equipment is called a space experiment, a space instrument, or a space vehicle is discretionary and the nomenclature used should not affect the classification of the equipment or the requirements.

3.1.5.4 Space Vehicle. A space vehicle is an integrated set of subsystems and units capable of supporting an operational role in space. A space vehicle may be an orbiting vehicle, a major portion of an orbiting vehicle, or a payload which performs its mission while attached to a launch or upper-stage vehicle. The airborne support equipment (3.2.1), which is peculiar to programs utilizing a recoverable launch or upper-stage vehicle, is considered to be a pan of the space vehicle.

3.1.5.5 Flight Vehicle. A flight vehicle is the combination of elements of the launch system that is flown; i.e., the launch vehicle(s), the upper-stage vehicle(s), and the space vehicle(s) to be sent to orbit.

3.1.6 System. A system is a composite of equipment, skills, and techniques capable of performing or supporting an operational role. A system includes all operational equipment, related facilities, material, software, services, and personnel required for its operation. A system is typically defined by the System Program Office or the procurement agency responsible for its acquisition.

3.1.7 Combined Systems. Combined systems are interconnected systems that are required for program level operations or operational tests. The combined systems of interest are typically the launch system and the on-orbit system.

3.1.7.1 bunch System. A launch system is the composite of equipment, skills, and techniques capable of launching and boosting one or more space vehicles into orbit. The launch system includes the flight vehicle and related facilities, ground equipment, material, software, procedures, services, and personnel required for their operation.

3.1.7.2 On-orbit System. An on-orbit system is the composite of equipment, skills, and techniques permitting on-orbit operation of the space vehicle(s). The on-orbit system includes the space vehicle(s), the command and control network, and related facilities, ground equipment, material, software, procedures, services, and personnel required for their operation.

3.2 SPECIAL ITEMS

3.2.1 Air(ASE) Support Equipment . Airborne support equipment is the equipment installed in a flight vehicle to provide support functions and interfaces for the space or upper-stage vehicle during launch and orbital operations of the flight vehicle. This includes the hardware and software that provides the structural, electrical, electronic, and mechanical interfaces with the flight vehicle.

3.2.2 Critical Unit. A critical unit is one whose failure can affect the system operation sufficiently to cause the loss of the stated vehicle objectives, a partial loss of the mission, or is a unit whose proper performance is essential from a range safety standpoint.

3.2.3 Development Test Article. A development test article is a representative vehicle, subsystem, or unit dedicated to provide design and test information. The information may be used to check the validity of analytic techniques and assumed design parameters, to uncover unexpected response characteristics, to evaluate design changes, to determine interface compatibility, to prove qualification and acceptance test procedures and techniques, or to determine if the equipment meets its performance specifications. Development test articles include engineering test models, thermal models, and structural static and dynamic models.

3.2.4 Explosive-ordnance Device. An explosive-ordnance device is a device that contains or is operated by explosives. A cartridge-actuated device, one type of explosive-ordnance device, is a mechanism that employs the energy produced by an explosive charge to perform or initiate a mechanical action.

3.2.5 Moving Mechanical Assembly (MMA). A moving mechanical assembly is a mechanical or electromechanical device that *controls the movement of one mechanical part of a vehicle relative to another part. Examples: gimbals, actuators, despin and separation mechanisms, valves, pumps, motors, latches, clutches, springs, dampers, bearings.

3.2.6 Reusable Item. A reusable item is a unit, subsystem, or vehicle that is to be used for multiple missions. The service life (3.5.6) of reusable hardware includes all planned reuses, refurbishment, and retesting.

3.3 ENVIRONMENTS

The complex flight environment involves a combination of conditions that are usually resolved into individual test environments. Each test environment should be based on actual flight data, scaled if necessary for differences in parameters, or if more reliable, by analytical prediction or a combination of analysis and flight data. The flight data may be from the current flight system, or from other flight systems if configuration variations are accounted for and properly scaled. The individual environments, which may be involved in qualification and acceptance, are described in this section.

3.3.1 Maximum and Minimum Expected Temperatures The maximum and minimum expected temperatures are the highest and lowest* temperatures that an item can experience during its service life (3.5.6), including all operational modes. These temperatures are established from analytically determined extreme temperatures by adding a thermal uncertainty margin, discussed below. The analytically determined extreme temperatures are predicted from thermal models using applicable effects of worst-case combinations of equipment operation, internal heating, vehicle orientation, solar radiation, eclipse conditions, ascent heating, descent heating, and degradation of thermal surfaces during the service life.

For space and upper-stage vehicles, the analytical model is validated using results from a vehicle thermal balance test involving operational modes which include the worst-case hot and cold conditions. The thermal uncertainty margin is applied to the analytically determined extreme temperatures, even after validation by a thermal balance test. The thermal uncertainty margin accounts for uncertainties in parameters such as complicated view factors, surface properties, radiation environment, joint conduction, and unrealistic aspects of ground test simulation. The margins vary depending on whether passive or active thermal control techniques are used. Examples of each type, for purposes of uncenainty margin to be applied, appear in Table I. The margins to be applied are addressed in the following subparagraphs.

3.3.1 .1 Margins for Passive Thermal Control Subsystems. For units that have no thermal control or have only passive thermal control, the recommended minimum thermal uncertainty margin is 17°C prior to achieving a validated analytical model. For space and upper-stage vehicles, the uncertainty margin may be reduced to 11 °C after the analytical model is validated using results from a vehicle thermal balance test. To avoid significant weight and power increases of the power subsystem due to additional hardware or increased heater size, the uncertainty margin of 17°C may be reduced to 11 °C.

For units that have large uncertainties in operational or environmental conditions or that do not require thermal balance testing, the thermal uncertainty margin may be greater than those stated above. Examples of these units for a launch vehicle are a vehicle heat shield, external insulation, and units within the aft skirt.

For passive cryogenic subsystems operating below minus 70°C, the thermal uncenainty margin may be reduced as presented in Table II. In addition, the following thermal-uncertainty heat-load margins are recommended: 50 percent in the conceptual phase, 45 percent for preliminary design, 35 percent for critical design review, and 30 percent for qualification.

3.3.1.2 Margins for Active Thermal Control Subsystems. For thermal designs in which temperatures are actively controlled, a heat-load margin of 25 percent may be used in lieu of the thermal margins specified in 3.3.1 .1 . This margin is applicable at the condition that imposes the maximum and minimum expected temperatures. For example, for heaters regulated by a mechanical thermostat or electronic controller, a 25-percent heater capacity margin may be used in lieu of the thermal margins at the minimum expected temperature and at minimum bus

TABLE I. Categorization of Passive and Active Thermal Control Subsystems.

Passive	Active
Constant-conductance or diode heat pipes.	Variable-conductance heat pipes.
Hardwired heaters (fixed or variable-resistance, such as auto-trace or positive-temperature-coefficient thermistors).	Heat pumps and refrigerators.
Thermal storage devices (phase-change or sensible heat).	Stored-coolant subsystems.
Thermal insulation(multi-layer insulation, foams, or discrete shields).	Resistance heater with commandable or mechanical or electronic controller.
Radiators (fixed, articulated, or deployable) with louvers or pinwheels.	Capillary-pumped loops.
Surface finishes (coatings, paints, treatments, second-surface mirrors).	Pumped fluid loops.
	Thermoelectric cooler.

TABLE II. Thermal Uncertainty Margins For Passive Cryogenic Subsystems.

Predicted Temperature (°C)	Thermal Uncertainty Margin (°C)	
	Pre-validation	Post-validation
Above -70	17	11
-70 to -87	16	10
-88 to -105	15	9
-106 to -123	14	8
-124 to -141	13	7
-142 to -159	11	6
-160 to -177	9	5
-178 to -195	8	4
-196 to -213	6	3
-214 to -232	4	2
Below -232	2	1

voltage, which translates into a duty cycle of no more than 80 percent under these cold conditions. Where an 11 °C addition in the analytically determined extreme temperatures would cause the temperature of any part of the actively-controlled unit to exceed an acceptable temperature limit, a control-authority margin in excess of 25 percent should be demonstrated;

For designs in which the temperatures are actively controlled to below minus 70°C by expendable coolants or refrigerators, the thermal uncertainty heat-load margin of 25 percent should be increased in the early phases of the development. For these cases, the following thermal-uncertainty heat-load margins are recommended: 50 percent in the conceptual phase, 45 percent for preliminary design, 35 percent for the critical design review, and 30 percent for qualification.

3.3.2 Statistical Estimates of Vibration, Acoustic, and Shock Environments. Qualification and acceptance tests for vibration, acoustic, and shock environments are based upon statistically expected spectral levels. The level of the extreme expected environment, used for qualification testing, is that not exceeded on at least 99 percent of flights, estimated with 90-percent confidence (P99/90 level). The level of the maximum expected environment, used for acceptance testing, is that not exceeded on at least 95 percent of flights, estimated with 50-percent confidence (P95/50 level). These statistical estimates are made assuming a lognormal flight-to-flight variability having a standard deviation of 3 dB, unless a different assumption can be justified. As a result, the P95/50 level estimate is 5 dB above the estimated mean (namely, the average of the logarithmic values of the spectral levels of data from all available flights). When data from N flights are used for the estimate, the P99/90 estimate in dB is $2.0 + 3.9/N^{1/2}$ above the P95/50 estimate. When data from only one flight are available, those data are assumed to represent the mean and so the P95/50 is 5 dB higher and the P99/90 level is 11 dB higher.

When ground testing produces the realistic flight environment (for example, engine operation or activation of explosive ordnance), the statistical distribution can be determined using the test data, providing data from a sufficient number of tests are available. The P99/90 and P95/50 levels are then determined from the derived distribution.

Extreme and maximum expected spectra should be specified for zones of the launch, upper-stage, and space vehicles to allow for repositioning of units within their zones without changing the expected environment. Particular spectra can be developed for specific units.

3.3.3 Fatigue Equivalent Duration. For a time-varying flight acoustic or vibration environment, the fatigue equivalent duration is the time duration, at the maximu-n environment achieved during that flight, that would produce the same fatigue damage potential. For a given flight trajectory, the equivalent duration can be assumed to be independent of the maximum environment achieved during any particular flight. The fatigue damage potential is taken to be proportional to the fourth power of amplitude, unless another basis can be justified.

3.3.4 Extreme and Maximum Expected Acoustic Environment. The acoustic environment for an exterior or interior zone of a vehicle results from propulsive and aerodynamic excitations. The acoustic environment is expressed by a 1/3-octave-band pressure spectrum in dB (reference 20 micropascal) for center frequencies spanning a range of at least 31 to 10,000 Hz. For a time-varying environment, the acoustic spectrum used for test purposes is the envelope of the spectra for each of a series of l-second time segments overlapped by at least 50 percent. Longer time segments may be used only if it is shown that significant smoothing of the time-dependent characteristics of the spectra (that is, large bias error) does not occur. The extreme and maximum expected acoustic environments (P99/90 and P95/50 acoustic spectra, respectively, per 3.3.2) are the bases for qualification and acceptance test spectra, respectively, subject to workmanship-based minimum spectra. The associated duration is the fatigue equivalent duration in flight (3.3.3).

3.3.5 Extreme and Maximum Expected Random Vibration Environment. The random vibration environment induced at the structural attachments of units is due to the direct or indirect action of the acoustic and aerodynamic excitations, to roughness in combustion or burning processes, and to machinery induced random disturbances. The random vibration environment is expressed as an acceleration spectral density in g^2/Hz (commonly termed power spectral density or simply PSD) over the frequency range of at least 20 to 2000 Hz. For a time-varying environment, the PSD used for test purposes is the envelope of the spectra for each of a series of l-second time segments overlapped by at least 50 percent. Longer time segments may be used only if it is shown that significant smoothing of the time-dependent characteristics of the spectra (that is, large bias error) does not occur. Also, the resolution bandwidth is to be no greater than 1/6 octave, but need not be less than 5 Hz. The extreme and maximum expected vibration environments (P99/90 and P95/50 PSDs, respectively, per 3.3.2) are the bases for the qualification and acceptance test spectra, respectively, subject to workmanship-based minimum spectra. The associated duration is the fatigue equivalent duration in flight (3.3.3).

3.3.6 Extreme and Maximum Expected Sinusoidal Vibration Environment. The sinusoidal vibration induced at the structural attachments of units may be due to periodic excitations from rotating machinery and from instability involving pogo (interaction of structural and propulsion dynamics), flutter (interaction of structural dynamics and aerodynamics), or combustion. Periodic excitations may also occur during ground transportation. The sinusoidal vibration environment is expressed as an acceleration amplitude in g over the frequency range for which amplitudes are significant. Namely, those whose acceleration amplitude exceeds 0.016 times the frequency in Hz. This is based on a response velocity amplitude of 1.27 meters per second (50 inches per second) when the vibration is applied to a single-degree-of-freedom system having a Q of 50. The resolution bandwidth should be no greater than 10 percent of the lowest frequency sinusoidal component present. The extreme and maximum expected sinusoidal vibration environments (P99/90 and P95/50 amplitude spectra, respectively, per 3.3.2) are the basis for qualification and acceptance spectra, respectively. The associated duration is the fatigue equivalent duration (3.3.3), including flight and transportation.

When combined sinusoidal and random vibration during service life (35.6) can be more severe than sinusoidal and random vibration considered separately, the combined environment is applicable.

3.3.7 Extreme and Maximum Expected Shock Environment n s i e n t s result from the sudden application or release of loads associated'with deployment, separation, impact, and release events. Such events often employ explosive-ordnance devices resulting In generation of a pyroshock environment, characterized by a high-frequency acceleration transient which decays typically within 5 to 15 milliseconds. The shock environment is expressed as the derived shock response spectrum in g, based upon the maximum absolute acceleration or the equivalent static acceleration induced in an ideal, viscously damped, single-degree-of-freedom system. Its natural frequency should span the range from at least 100 Hz to 10,000 Hz for pytoshock or comparable shock disturbances, at intervals of no greater than 1/6 octave, and for a resonant amplification (Q) of 10. The extreme and maximum expected shock environments (P99/90 and P95/50 shock response spectra, respectively, per 3.3.2) are the bases for qualification and acceptance test spectra, respectively.

3.4 STRUCTURAL TERMS

3.4.1 Burst Factor. The burst factor is a multiplying factor applied to the maximum expected operating pressure to obtain the design burst pressure. Burst factor is synonymous with ultimate pressure factor.

3.4.2 Design Burst Pressure. The design burst pressure is a test pressure that pressurized components must withstand without rupture in the applicable operating environments. It is equal to the product of the maximum expected operating pressure and a burst factor.

3.4.3 Design Factor of Safety. The design factor of safety is a multiplying factor used in the design analysis to account for uncertainties such as material properties, design procedures, and manufacturing procedures. The design factor of safety is often called the design safety factor, factor of safety, or, simply, the safety factor. In general, two types of design factors of safety are specified: design yield factor of safety and design ultimate factor of safety.

3.4.4 Design Ultimate Load. The design ultimate load is a load, or combinations of loads, that the structure must withstand without rupture or collapse in the applicable operating environments. It is equal to the product of the limit load and the design ultimate factor of safety.

3.4.5 Design Yield Load. The design yield load is a load, or combinations of loads, that a structure must withstand without experiencing detrimental deformation in the applicable operating environments. It is equal to the product of the limit load and the design yield factor of safety.

3.4.6 Limit Load. A limit load is the highest load, or combinations of loads, that may be applied to a structure during its service life (3.5.6), and acting in association with the applicable operating environments produces a design or extreme loading condition for that structure. When a statistical estimate is applicable, the limit load is that load not expected to be exceeded on at least 99 percent of flights, estimated with 90-percent confidence.

3.4.7 Maximum Fxoected Ooeratina Pressure (MEOP). The MEOP is the highest gage pressure that an item in a pressurized subsystem is required to experience during its service life (3.5.6) and retain its functionality, in association with its applicable operating environments. The MEOP is synonymous with limit pressure or maximum operating pressure (MOP) or maximum working pressure (MWP). included are the effects of maximum ullage pressure, fluid head due to vehicle quasi-steady and dynamic accelerations, waterhammer, slosh, pressure transients and oscillations, temperature, and operating variability of regulators or relief valves.

3.4.8 Maximum Predicted Acceleration. The maximum predicted acceleration (its extreme value), defined for structural loads analysis and test purposes, is the highest acceleration determined from the combined effects of quasi-steady acceleration, the vibroacoustic environment, and the dynamic response to such significant transient flight events as liftoff; engine ignitions and shutdowns; transonic and maximum dynamic pressure traversal; gust; and vehicle separation. The frequency range of concern is usually limited to below 50 Hz for structural loads resulting from the noted transient events, and to below 300 Hz for secondary structural loads resulting from the vibration and acoustic environments. Maximum accelerations are predicted for each of three mutually perpendicular axes in both positive and negative directions. When a statistical estimate is applicable, the maximum predicted acceleration is at least that acceleration not expected to be exceeded on 99 percent of flights, estimated with 90-percent confidence (P99/90).

3.4.9 Operational Deflections. Operational deflections are the deflections imposed on a structure during operation (for example, by engine thrust-vector gimballing, thermal differentials, flight accelerations, and mechanical vibration).

3.4.10 Pressure Component. A pressure component is a unit in a pressurized subsystem, other than a pressure vessel, that is structurally designed largely by the acting pressure. Examples are lines, tubes, fittings, valves, bellows, hoses, regulators, pumps, and accumulators.

3.4.11 Pressure Vessel. A pressure vessel is a structural component whose primary purpose is to store pressurized fluids and one or more of the following apply:

a. Contains stored energy of 19,310 joules (14,240 foot-pounds) or greater based on adiabatic expansionof a perfect 'gas.

b. Contains a gas or liquid that would endanger personnel or equipment or create a mishap (accident) if released.

c. May experience a design limit pressure greater than 690 kilopascals (100 psi).

3.4.12 Pressurized Structure. A pressurized structure is a structure designed to sustain both internal pressure and vehicle structural loads. A main propellent tank of a launch vehicle is a typical example.

3.4.13 Pressurized Subsystem. A pressurized subsystem consists of pressure vessels (3.4.11) or pressurized structures (3.4.12), or both, and pressure components (3.4.10). Excluded are electrical or other control units required for subsystem operation.

3.4.14 Proof Factor. The proof factor is a multiplying factor applied to the limit load, or maximum expected operating pressure, to obtain the proof load or proof pressure for use in a proof test.

3.4.15 Proof Test. A proof test is an acceptance test used to prove the structural integrity of a unit or assembly, or to establish maximum possible flaw sizes for safe-life determination. The proof test gives evidence of satisfactory workmanship and material quality by requiring the absence of failure or detrimental deformation. The proof test load and pressure compensate for the difference in material properties between test and design temperature, if applicable.

3.4.16 Structural Component. A mechanical unit is considered to be a structural component if its primary function is to sustain load or maintain alignment.

3.5 OTHER DEFINITIONS

3.5.1 Ambient Environment The ambient environment for a ground test is defined as normal room condition's with temperature of 23 ± 10°C (73 ± 18°F), atmospheric pressure of 101 + 2/-23 kilopascals (29.9 +0.6/-6.8 in. Hg), and relative humidity of 50 ± 30 percent.

3.5.2 Contamination Tolerance Level The contamination tolerance level is the value of contaminant particle size, or level of contamination, at which a specified performance, reliability, or life expectancy of the item is adversely affected.

3.5.3 Operational Modes. The operational modes for a unit, assembly, subsystem, or system include all combinations of operational configurations or conditions that can occur during its service life (3.5.6). Examples: power condition, command mode, readout mode, attitude control mode, redundancy management mode, safe mode, and spinning or despun condition.

3.5.4 Other Test. An "other" test is a test that may be required subject to an evaluation of its benefit on a case-by-case basis. Special requirements of usage and peculiarities of the particular test item should be taken into account. If the evaluation shows that an 'other' test is effective, it becomes a "required" test for that case (10.2.1.3). In general, "other" tests are unique tests and therefore have a low probability of being required.

3.5.5 Qualification Margin. An environmental qualification margin is the increase in an environmental condition, over that expected during service life (3.5.6), including acceptance testing, to demonstrate that adequate ruggedness exists in the design and in its implementation. A margin may include an increase in level or range, an increase in duration or cycles of exposure, as well as any other appropriate increase in severity. Environmental qualification margins are intended to demonstrate the ability to satisfy all of the following on a single qualification item:

a. Be tolerant of differences in ruggedness and functionality of flight items relative to the qualification item, due to reasonable variations in parts, material properties, dimensions, processes, and manufacturing.

b. Be immune to excessive degradation (such as fatigue, wear, loss of material properties or functionality) after enduring a specified maximum of acceptance testing prior to operational use of a flight item.

c. Meet requirements under extreme conditions of flight, which when expressed statistically are the P99/90 estimates (3.3.2, 3.4.8).

3.5.6 Service Life. The service life of an item starts at the completion of fabrication and continues through all acceptance testing, handling, storage, transponation, prelaunch testing, all phases of launch, orbital operations, disposal, reentry or recovery from orbit, refurbishment, retesting, and reuse that may be required or specified.

3.5.7 Temperature Stabilization. For thermal cycle and thermal vacuum testing, temperature stabilization for a unit is achieved when the unit baseplate is within the allowed test tolerance on the specified test temperature (4.6), and the rate of change of temperature has been less than 3°C per hour for 30 minutes. For steady-state thermal balance testing; temperature stabilization is achieved when the unit having the largest thermal time constant is within 3°C of its steady state value, as determined by numerical extrapolation of test temperatures, and the rate of change is less than 1°C per hour.

3.5.8 Test Discrepancy. A test discrepancy is a functional or structural anomaly that occurs during testing, which may reveal itself as a deviation from specification requirements for the test item. A test discrepancy may be a momentary, unrepeatable anomaly; or it may be a permanent failure to respond in the predicted manner to a specified combination of test environment and functional test stimuli. Test discrepancies include those associated with functional performance, premature operation, failure to operate or cease operation at the prescribed time, and others that are unique to the item.

A test discrepancy may be due to a failure of the test item, or may be due to some unintended cause such as from the test setup, test instrumentation, supplied power, test procedures, or computer software used.

3.5.9 Test Item Failure. A failure of a test item is defined as a test discrepancy that is due to a design, workmanship, or quality deficiency in the item being tested. Any test discrepancy is considered to be a failure of the test item unless it can be determined to have been due to some unintended cause (3.5.8).

3.5.10 Thermal Soak Duration. The thermal soak duration of a unit at the hot or cold extreme of a thermal cycle is the time that the unit is operating and its baseplate is continuously maintained within the allowed tolerance of the specified test temperature.

SECTION 4

GENERAL REQUIREMENTS

This section addresses general requirements applicable to all test categories. Included are tailoring of requirements, testing philosophy, propulsion equipment tests, firmware tests, inspections, test condition tolerances, test plans and procedures, retest, and documentation.

4.1 TAILORING OF REQUIREMENTS

This Standard establishes a baseline of requirements which should be tailored up or down to meet the needs of a particular program (10.2). The programmatic implications of imposing each requirement should be evaluated. This includes not only the direct costs versus the benefits, but also the risks and potential costs of not imposing requirements. If extensive tailoring of the testing requirements is appropriate for a particular program, the procuring agency may provide a summary of the applicability of the various paragraphs. Tables in 10.2.2 provide Requirements Applicability Matrices, in general and detailed forms, to be used by the procuring agency for stating changes to the stringency or applicability of the requirements appearing in the various sections and for the various tests of this Standard, If the applicable requirements in this Standard are not tailored by the contract, they stand as written.

4.2 TESTING PHILOSOPHY

The complete test program for launch vehicles, upper-stage vehicles, and space vehicles encompasses development, qualification, acceptance, prelaunch validation, and follow-on operational tests and evaluations. Test methods, environments, and measured parameters shall be selected to permit the collection of empirical design parameters and the correlation of data throughout the complete test program. A satisfactory test program requires the completion of specific test objectives prior to the accomplishment of others. The test program encompasses the testing of progressively more complex assemblies of hardware and computer software. Design suitability should be demonstrated in the earlier development tests prior to testing the next more complex assemblies or combinations in the progression and prior to the start of formal qualification testing. All qualification testing for an item should be completed, and consequential design improvements Incorporated, prior to the initiation of flight hardware acceptance testing for that item. In general, hardware items subjected to qualification tests are themselves not eligible for flight, since there has been no demonstration of remaining life from fatigue and wear standpoints. Section 8 describes higher risk, alternative strategies which may be used to tailor a qualification test program. The integrated system prelaunch validation tests, described in Section 9, are intended to be combined with or incorporated with the MIL-STD-1833 Step 3 integrated system tests, and the Step 4 and 5 operational tests that include the applicable ground equipment and associated computer software.

Environments other than those specified in this Standard can be sufficiently stressful as to warrant additional qualification and possibly acceptance testing. These include environments such as nuclear and electromagnetic radiation, as well as climatic conditions not specified such as lightning.

The environmental tests specified are intended to be imposed sequentially, rather than in combination. Nevertheless, features of the hardware design or of the service environments may warrant the imposition of combined environments in some tests. Examples: combined temperature, acceleration, and vibration when testing units employing elastomeric isolators in their design; and combined shock, vibration, and pressure when testing pressurized components. In formulating the test requirements in these situations, a logical combination of environmental factors should be imposed to enhance test effectiveness.

4.3 PROPULSION EQUIPMENT TESTS

In general, tests of solid rocket motors and tests of liquid rocket engines are not addressed in this Standard. However, units which comprise a vehicle propulsion subsystem, including units which are integral to or mounted on a motor or engine, are covered by this Standard in that they shall be qualified and acceptance tested to the applicable unit requirements specified herein. Testing of a unit on an engine during the engine acceptance test firing may be substituted for part of the unit level acceptance test if it can be established that the environments and duration meet the intent of the individual acceptance test criteria, or if such units are not amenable to testing individually. Environmental testing of thrusters (such as staging rockets, retro-motors, and attitude control thrusters) shall meet the applicable unit requirements of this Standard.

4.3.1 Engine Line Replaceable Unit (LRU) Acceptance Testing An engine LRU is an engine unit which may be removed from an engine and replaced by a new unit without requiring m-acceptance test firing of the engine with the new unit. If the unit being replaced was included in an engine acceptance test firing as part of its acceptance test, then the replacement unit shall either be subjected to such a test on an engine, or shall undergo equivalent unit level acceptance testing. Equivalent testing shalt consider-all. appropriate environments such as temperature;' vibration, pressure, vacuum, and chemical. Testing shall demonstrate functionality of the unit under conditions similar to those achieved in the engine acceptance test firing and flight.

4.3.2 Engine Line Replaceable Unit (LRU) Qualification Testing. All engine LRUs shall be qualified at a unit level to the requirements of this Standard.

4.4 FIRMWARE TESTS

Firmware is the combination of a hardware device and computer instructions or computer data that reside as read-only software on the hardware device. The software cannot be readily modified under program control. Firmware that falls under the intent and purpose of a Commercial Off the Shelf item (COTS) should be tested as COTS. Firmware that is not COTS should be tested as a development item subject to the test requirements of this document. The software element of firmware should be tested as software, and the hardware element of firmware should be tested as hardware.

4.5 INSPECTIONS

All units and higher levels of assembly should be inspected to identify discrepancies before and after testing, including tests performed at the launch site, The inspections of flight hardware shall not entail the removal of unit covers nor any disassembly, unless specifically called out in the test procedures. Included should be applicable checks of finish, identification markings, and cleanliness. Weight, dimensions, fastener tightness torques and breakaway forces and torques should be measured, as applicable, to determine compliance with specifications.

4.6 TEST CONDITION TOLERANCES,

Unless stated otherwise, the specified test parameters should be assumed to include the maximum allowable test tolerances listed in Table III. For conditions outside the ranges specified, the tolerances should be appropriate for the purpose. of the test.

4.7 TEST PLANS AND PROCEDURES

The test plans and procedures shall be documented in sufficient detail to provide the framework for identifying and interrelating all of the individual tests and test procedures needed.

4.7.1 Test Plans. The test plans should provide a general description of each test planned and the conditions of the tests. The test plans should be based upon a function-by-function mission -analysis and any specified testing requirements; To the degree practicable, tests should be planned and executed to fulfill test objectives from development through operations. Test objectives should be planned to verify compliance with the design and specified requirements of the

TABLE III. Maximum Allowable Test Tolerances.

Test Parameters			Test Tolerance
Temperature -54°C to + 100°C			± 3°C
Relative Humidity			± 5 percent
Acceleration			+ 1 0/-0 percent
Static Load and Pressure			+ 5/-0 percent
Atmospheric Pressure			
Above 133 pascals	(> 1 Torr)		± 10 percent
133 to 0.133 pascals	(1 Torr to 0.001 Torr)		± 25 percent
Below 0.133 pascal	(< 0.001 Torr)		± 80 percent
Test Time Duration			+ 1 0/-0 percent
Vibration Frequency			± 2 percent
Sinusoidal Vibration Amplitude			± 10 percent
Random Vibration Power Spectral Density			
Frequency Range	Maximum Control Bandwidth		
20 to 100 Hz	10 Hz		± 1.5 dB
100 to 1000 Hz	10 percent of midband frequency		± 1.5 dB
1000 to 2000 Hz	100 Hz		± 3.0 dB
Overall			± 1.0 dB
Note: Control bandwidths may be combined for tolerance evaluation purposes. The statistical degrees of freedom shall be at least 100.			
Sound Pressure Levels			
1/3-Octave Midband Frequencies			
31.5 to 40 Hz			± 5.0 dB
50 to 2000 Hz			± 3.0 dB
2500 to 10000 Hz			± 5.0 dB
Overall			± 1.5 dB
Note: The statistical degrees of freedom shall be at least 100.			
Shock Response Spectrum (Peak Absolute Acceleration, Q = 10)			
Natural Frequencies Spaced at 1/6-Octave Intervals			
At or below 3000 Hz			± 6.0 dB
Above 3000 Hz			+ 9.0/-6.0 dB
Note: At least 50 percent of the spectrum values shall be greater than the nominal test specification.			

items involved, including interfaces. The test plans should incorporate by reference, or directly document, the following:

a. A brief background of the applicable project and descriptions of the test items covered (such as the systems, vehicles, and subtier equipment).

b. The overall test philosophy, testing approach, and test objective for each item, including any special tailoring or interpretation of design and testing requirements.

c. The allocation of requirements to appropriate testable levels of assembly. Usually this is a reference to a requirements traceability matrix listing all design requirements and indicating a *cross* reference to a verification method and to the applicable assembly level.

d. The identification of separate environmental test zones (such as the engine, fairing, or payload).

e. The identification of separate states or modes where the configuration or environmental levels may. be different (such as during testing, launch, upper-stage transfer, on-orbit, eclipse, or reentry).

f. The environmental specifications or life-cycle environmental profiles for each of the environmental test zones.

g. Required special test equipment, facilities, interfaces, and downtime requirements.

h. Required test tools and test beds including the qualification testing planned for the test tools and test beds to demonstrate that they represent an operational system environment and verify that simulated interfaces are correct.

i. Standards to be used for the recording of test data on computer compatible electronic media, such as disks or magnetic tape, to facilitate automated accumulation and sorting of data.

j. The review and approval process to be followed for test plans and procedures, and for making changes to approved test plans and procedures.

k. Overall schedule of tests showing conformance with the program schedules including the scheduled availability of test articles, test facilities, special test equipment, and procedures.

4.7.2 Test Procedures. Tests shall be conducted using documented test procedures, prepared for performing all of the required tests in accordance with the test objectives in the approved test plans. The test objectives, testing criteria, and pass-fail criteria shall be stated clearly in the test procedures. The test procedures shall cover all operations in enough detail so that there is no doubt as to the execution of any step. Test objectives and criteria should be stated clearly to relate to design or operations specifications. Where appropriate, minimum requirements for valid data and pass-fail criteria should be provided at the procedure step level. Traceability should be provided from the specifications or requirements to the test procedures. Where practicable, the individual procedure step that satisfies the requirement should be identified. The test procedure for each item shall include, as a minimum, descriptions of the following:

a. Criteria, objectives, assumptions, and constraints.

b. Test setup.

c. Initialization requirements.

d. Input data.

e. Test instrumentation.

f. Expected intermediate test results.

g. Requirements for recording output data.

h. Expected output data.

i. Minimum requirements for valid data to consider the test successful,

j. Pass-fail criteria for evaluating results.

k. Safety considerations and hazardous conditions.

4.8 RETEST

Whenever the design of hardware is changed, the hardware involved should be retested, as necessary, and all documentation pertinent to the changes shall be revised. When retesting a redesigned item, limited testing may be satisfactory as long as it is adequate to verify the redesign, to confirm that the redesign did not negate prior testing, and to show that no new problems have been introduced. However, care must be exercised with this limited retesting concept since even small changes can potentially affect the item in unexpected ways.

Retesting may also be necessary if a test discrepancy (3.5.8) occurs while performing any of the required testing steps. In that case, conducting a proper faiiure analysis plays an important part in determining the type and degree of retesting. The failure analysis should include the determination of whether a failure occurred, the cause of the failure, the symptoms of the failure, and isolation of the failure to the smallest replaceable item.

4.8.1 Retest Durina Qualification or Acceptance. if a test discrepancy occurs during qualification or acceptance testing, the test may be continued without corrective action.if the discrepant item or software coding does. not affect the validity of test data obtained by the continuation of testing. Otherwise the test shall be interrupted and the discrepancy verified. To the extent practicable, the test configuration should not be modified until the cause of the discrepancy has been isolated and verified. if the discrepancy is caused by the test setup, test software, or a failure in the test equipment, the test being conducted at the time of the discrepancy may be continued after the cause is removed and repairs are completed, as long as the discrepancy did not overstress the item under test. If the discrepancy is caused by a failure of the item under test, the preliminary failure analysis and appropriate corrective action should normally be completed and properly documented before testing is resumed. 'Retesting may be required to establish a basis for determining compliance of a test item to a specification or requirement, and may be required to assess the readiness of test items for integrated system testing.

4.8.2 Retest Durina Prelaunch Validation. If a discrepancy occurs during prelaunch validation testing (integrated system testing), it shall be documented for later evaluation. The test director is responsible for assessing the effect of the discrepancy to determine whether the discrepancy has jeopardized the probable success of the remainder of the test. The test director may decide to continue or halt the test. if continued, the test starts at the test procedure step designated by the test director. The integrated system testing should be continued, where practicable, to conserve time-critical operational resources. When the discrepancy has been corrected or explained, retesting may be required.

4.8.3 Retest During Ooerational Tests and Evaluations. if a discrepancy occurs during operational tests and evaluations, it shall be documented for later evaluation. The operating agency is responsible for assessing the effect of the discrepancy to determine whether the discrepancy has jeopardized the probable success of the remainder of the test. The operating agency is also responsible for determining the degree of retesting required.

4.9 DOCUMENTATION

See Subsection 10.5 for additional information.

4.9.1 Test Documentation Files. The test plans and procedures (4.7), including a list of test equipment, calibration dates and accuracy, computer software, test data, test log, test results and conclusions, problems or deficiencies, pertinent analyses, and resolutions shall be documented and maintained. The test documentation files shall be maintained by the applicable contractors for the duration of their contracts.

4.9.2 Test Data. Pertinent test data'shall be maintained in a quantitative form to permit the evaluation of performance under the various specified test conditions; pass or fail statements alone may be insufficient. The test data should also be compared across major test sequences for trends or evidence of anomalous behavior. To the extent practicable, all relevant test measurements and the environmental conditions imposed on the units should be recorded on computer compatible electronic media, such as disks, magnetic tape, or by other suitable means to facilitate automated accumulation and sorting of data for the critical test parameters. These records are intended to be an accumulation of trend data and critical test parameters that should be examined for out of tolerance values and for characteristic signatures during transient and mode switching. For development and qualification tests, a summary of the test results should be documented in test reports. The test report should detail the degree of success'in meeting the test objectives of the approved test plans and should document the test results, deficiencies, problems encountered, and problem resolutions.

4.9.3 Test Log. Formal test conduct shall be documented in a test log. The test log shall identify the personnel involved and be time-tagged to permit a reconstruction of test events such as start time, stop time, anomalies, and any periods of interruption.

SECTION 5

DEVELOPMENT TESTS

5.1 GENERAL

Development tests, or engineering tests, shall be conducted as required to:

a. Validate new design concepts or the application of proven concepts and techniques to a new configuration.

b. Assist in the evolution of designs from the conceptual phase to the operational phase.

c. Reduce the risk involved in committing designs to the fabrication of qualification and flight hardware.

d. Validate qualification and acceptance test procedures.

e. Investigate problems or concerns that arise after successful qualification.

Requirements for development testing therefore depend upon the maturity of the subsystems and units used and upon the operational requirements of the specific program. An objective of development testing is to identify problems early in their design evolution so that any required corrective actions can be taken prior to starting formal qualification testing. Development tests should be used to confirm structural and performance margins, manufacturability, testability, maintainability, reliability, life expectancy, and compatibility with system safety. Where practicable, development tests should be conducted over a range of operating conditions that exceeds the design limits to identify marginal capabilities and marginal design features. Comprehensive development testing is an especially important ingredient to mission success in programs that plan to use qualification items for flight, including those that allow a reduction in the qualification test levels and durations. Development tests may be conducted on breadboard equipment, prototype hardware, or the development test vehicle equipment.

Development tests may be conducted at in-plant test facilities, which may include subcontractor's facilities; at a governmentapproved-test bed, or at any other appropriate test facility. However, when performed at a government facility, that facility may require approval of the test plans and procedures. Internal contractor documentation of development test plans, test procedures, and test results are normally used unless stated otherwise by contract.

The development test requirements are necessarily unique to each new launch vehicle, upper-stage vehicle, and space vehicle. The following provide guidelines for conducting appropriate development tests when their need has been established.

5.2 ART. MATER AL. AND PROCESS DEVELOPMENT TESTS
A N D

Part, material, and process development tests and evaluations are conducted to demonstrate the feasibility of using certain items or processes in the implementation of a design. These development tests and evaluations may be conducted to assess design alternatives, manufacturing alternatives, and to evaluate tradeoffs to best achieve the development objectives. Development tests and evaluations are required for new types of parts, materials, and processes; to assure proper application of parts, materials, and processes in the design.; and to develop acceptance criteria for these items to avoid assembling defective units.

Material characterization testing under simulated environmental conditions is normally conducted for composite laminate, insulations, seals, fluid lines, and items, not well characterized for their intended use.

5.3 SUBASSEMBLY DEVELOPMENT TESTS, IN-PROCESS TESTS AND INSPECTIONS

Subassemblies are subjected to development tests and evaluations as required to minimize design risk, to demonstrate manufacturing feasibility, and to assess the design and manufacturing alternatives and trade-offs required to best achieve the development objectives. Tests are conducted as required to develop in-process manufacturing tests, inspections, and acceptance criteria for the items to avoid assembling defective hardware items.

5.4 UNIT DEVELOPMENT TESTS

Units are subjected to development tests and evaluations as may be required to minimize design risk, to demonstrate manufacturing feasibility, to establish packaging designs, to demonstrate electrical and mechanical performance, and to demonstrate the capability to withstand environmental stress including storage, transportation, extreme combined environments, and launch base operations. Temperature cycling and random vibration testing at levels beyond the qualification requirements should be conducted to further increase confidence in-the designand identify the weakest elements. New designs should be characterized across worst-case voltage, frequency, and temperature variations at the breadboard level. Functional tests of prototype units in thermal and vibration environments are normally conducted. Development tests of deployables, of thrust vector controls, and of the attitude control subsystem are normally conducted. Life tests of critical items that may have a wearout failure mode, such as moving mechanical assemblies, should also be conducted. Vibration resonance searches of a unit should be conducted to correlate with a mathematical model and to support design margin or failure evaluations. Development tests and evaluations of vibration and shock test fixtures should be conducted prior to first use to prevent inadvertent overtesting or under-testing, including avoidance of excessive cross-axis responses. These development tests of fixtures should result in the design of shock and vibration test fixtures that can be used during unit qualification and acceptance tests. When it is not practicable to use fixtures of the same design for unit qualification and acceptance tests, evaluation surveys should be performed on each fixture design to assure that the unit responses are within allowable margins.

5.4.1 Structural Comoosite Develooment Tests. Development tests shall be conducted on structural components made of advanced composites or bonded materials, such as payload adapters, payload fairings, motor cases, and composite-overwrapped pressure vessels.

If appropriate, testing should include:

a. ‘Static load or burst testing to validate the ultimate structural capabilities.

b. Damage tolerance testing to define acceptance criteria.

c. Acoustic transmission loss test for composite fairings.

5.4.2 Thermal Develooment Tests. For critical electrical and electronic units designed to operate in a vacuum environment less than 0.133 pascal (0.001 Torr), thermal mapping for known boundary conditions should be performed in the vacuum environment to verify the internal unit thermal analysis, and to provide data for thermal mathematical model correlation. Once correlated, the thermal model. is used to demonstrate that critical pan temperature limits, consistent with reliability requirements and performance, are not exceeded. When electrical and electronic packaging is not accomplished in accordance with known and accepted techniques relative to the interconnect subsystem, parts mounting, board sizes and thickness, number of layers, thermal coefficients of expansion, or installation method, development tests should be performed. The tests should establish confidence in the design and manufacturing processes used. Heat transport capacity tests may be required for constant and variable conductance heat pipes at the unit level to demonstrate compliance with 3.3.1. Thermal,-conductance tests may be performed to verify conductivity across items such as vibration isolators, thermal isolators, cabling, and any other potentially significant heat conduction path.

5.4.3 Shock and Vibration Isolator Development Tests When a unit is to be mounted on shock or vibration isolators whose performance' is not well known., development testing should be conducted to verify their suitability. The isolators should be exposed to the various induced environments (for example, temperature and chemical environments) to verify retention of isolator performance (especially resonant frequencies and amplifications) and to verify that the isolators have adequate service life (3.5.6). The unit or a rigid simulator with proper mass properties (mass, center of gravity, mass moments of inertia), should be tested on its isolators in each of three orthogonal axes, and, if necessary, in each of three rotational axes. Responses at all corners of the unit should be determined to evaluate isolator effectiveness and, when applicable, to establish the criteria for unit acceptance testing without isolators (7.4.4). When multiple units are supported by a vibration isolated panel, responses at all units should be measured to account for the contribution of panel vibration modes.

5.5 VEHICLE AND SUBSYSTEM DEVELOPMENT TESTS

Vehicles and subsystems are subjected to development tests and evaluations using structural and thermal development models as may be required to confirm dynamic and thermal environmental criteria for design of subsystems, to verify mechanical interfaces, and to assess functional performance of deployment mechanisms and thermal control subsystems. Vehicle level development testing also provides an opportunity to develop handling and operating procedures as well as to characterize interfaces and interactions.

5.5.1 Mechanical Fit Development Tests. For launch, upper-stage, and space vehicles, a mechanical fit, assembly, and operational interface test with the facilities at the launch or test site is recommended. Flight-weight hardware should be used if practicable; however, a facsimile or portions thereof may be used to conduct the development tests at an early point in the schedule in order to reduce the impact of hardware design changes that may be necessary.

5.5.2 Mode Survey Development Tests. In advance of the qualification mode survey test (6.2.10), a development mode survey test (or modal survey) should be conducted at the vehicle or subsystem level when uncertainty in analytically predicted structural dynamic characteristics is judged to be excessive for purposes of structural or control subsystem design, and an early identification of problem areas is desired. The test article may be full-scale or subscale; for a large vehicle, such as a launch vehicle, a subscale model is often used. Such a development test does not replace a modal survey required for vehicle qualification, unless the test also meets the requirements in 6.2.10.

5.5.3 Structural Development Tests. For structures having redundant load paths, structural tests may be required to verify the stiffness properties and to measure member loads, stress distributions, and deflections. The stiffness data are of particular interest where nonlinear structural behavior exists that is not fully exercised in a mode survey test (5.5.2, 6.2.10). This may include nonlinear bearings, elastic buckling of panels, gapping at preloaded interfaces, and slipping at friction joints. The member load and stress distribution data may be used to experimentally verify the loads transformation matrix. Deflection data may be also used to experimentally verify the appropriate deflection transformation matrix. These matrices may be used, in conjunction with the dynamic model, to calculate loads such as axial forces, bending moments, shears, and torsional moments, and various stresses and deflections, which can be converted into design load and clearance margins for the vehicle. This development test does not replace the structural static load test that is required for subsystem qualification (6.3.1); however, the two tests may be incorporated into a single test sequence that encompasses the requirements of both tests, provided that the test article is flight-like, the manufacturing log is up-to-date, and the test plan is prepared according to the qualification requirements.

5.5.4 Acoustic and Shock Development Tests. Since high-frequency vibration and shock responses are difficult to predict by analytical techniques, acoustic and shock development testing of the launch, upper-stage, and space vehicles may be necessary to verify the adequacy of the dynamic design criteria for units. Vehicle units that are not installed at the time of the test should be dynamically simulated with respect to mass, center of gravity, moments of inertia, interface stiffness, and geometric characteristics. For the acoustic test, the vehicle is normally exposed to the qualification acoustic levels in an acoustic chamber. For the shock test, all explosive-ordnance devices and other mechanisms capable of imparting a significant shock to the vehicle should be operated. Where practicable, the shock test should involve physical separation of elements being deployed or released. When a significant shock is expected from subsystems not on board the vehicle under test (such as when a fairing separation causes shock responses on an upper stage under test), the adaptor subsystem or suitable simulation shall be attached and appropriate explosive-ordnance devices or other means used to simulate the shock imposed. The pyroshock environment may vary significantly between ordnance activations. Therefore, the statistical basis given in 3.3.2 shall be used for estimating maximum expected and extreme spectra. Multiple activations of ordnance devices may be used to provide data for better-substantiated estimates.

5.5.5 Thermal Balance Development Tests. A thermal balance development test may be necessary to verify the analytical modeling of launch, upper-stage, or space vehicles, and to verify the unit thermal design criteria. For vehicles in which thermally induced structural distortions are critical to mission success, the thermal balance test also evaluates alignment concerns. The test vehicle should consist of a thermally equivalent structure with addition of equipment panels, thermal control insulation, finishes, and thermally equivalent models of electrical, electronic, pneumatic, and mechanical units. Testing should be conducted in a space simulation test chamber capable of simulating the ascent, transfer orbit, and orbital thermal-vacuum conditions as may be appropriate.

5.5.6 Transportation and Handling Development Tests The handling and transport of launch, upper-stage, and space vehicles, or their subtier elements, is normally conducted so as to result in dynamic environments well below those expected for launch and flight. However, since these environments are difficult to predict, it is often necessary to conduct a development test of potentially significant handling and transportation configurations to determine worst-case dynamic inputs. Such a test should use a development model of the item or a simulator which has at least the proper mass properties, instrumented to measure responses of the item. In particular, a drop test representative of a maximum credible operational occurrence should be conducted to demonstrate protection of the item in the handling apparatus and shipping container. The data should be sufficient to determine whether the environments are benign relative to the design requirements, or to provide a basis for an analysis to demonstrate lack of damage, or to augment qualification and acceptance testing, if necessary.

5.5.7 Wind-tunnel Development Tests. Flight vehicle aerodynamic and aerothermal data are needed to establish that the vehicles survive flight, and function properly under the imposed loads. For flight vehicles with a new or significantly changed aerodynamic design, the following wind-tunnel tests shall be conducted:

a. Force and Moment Tests. These tests provide the resultant aerodynamic forces and moments acting on the vehicle during the high-dynamic-pressure region of flight. Data from these tests are used in both structural and control subsystem design and in trajectory analysis.

b. Steady-State Pressure Tests. These tests determine the spatial distribution of the steady-state component of the pressures imposed on the vehicle's external surfaces during the high-dynamic-pressure region of flight. These data are used to obtain the axial airload distributions which are used to evaluate the static-elastic characteristics of the vehicle. These data are also used in compartment venting analyses to determine burst and collapse pressures imposed on the vehicle structure. The design and testing of the payload fairing structure are particularly dependent-upon high-quality definition of these pressures.

c. **Aerodynamic Heatina Tests**. These tests determine the heating effects due to fin and fuselage junctures, drag (friction), angle of attack, flow transition, shock wave impingement, proximity effects for multibody vehicles, and surface discontinuities.

d. **Base Heatina Tests**. These tests determine the heating effects due to thermal radiation, multiplume recirculation convection, plume-induced flow separation on the vehicle body, and the base flow field.

e. **Jhruster Plume-impingement Heatina Tests**. These tests determine the heating effects due to impingement of the thruster plumes.

f. **Jransonic and Supersonic Buffet and Aerodynamic Noise Tests**. These tests define the spatial distribution of the unsteady or fluctuating component of the pressures imposed on the vehicle external surfaces during the high-dynamic-pressure region of flight. -These data are used to obtain the dynamic airloads acting to excite the various structural modes of the vehicle and are used in aeroelastic, flutter, and vibroacoustic analyses.

g. **Ground-wind-induced Oscillation Tests**. These tests define the resultant forces and moments acting on the vehicle prior to launch when it is exposed to the ground-wind environment. Flexible models or elastically-mounted rigid models are used to simulate at least the first cantilever bending mode of the vehicle. Nearby structures or terrain, which may influence the flow around the vehicle, shall also be simulated.

SECTION 6

QUALIFICATION TESTS

6.1 GENERAL QUALIFICATION TEST REQUIREMENTS

Qualification tests shall be conducted to demonstrate that the design, manufacturing process, and acceptance program produce mission items that meet specification requirements. In addition, the qualification tests shall validate the planned acceptance program including test techniques, procedures, equipment, instrumentation, and software. The qualification test baseline shall be tailored for each program. Each type of flight item that is to be acceptance tested shall undergo a corresponding qualification test, except for certain structural items as identified herein.

In general, a single qualification test specimen of a given design shall be exposed to all applicable environmental tests. The use of multiple qualification test specimens may be required for one-time-use devices (such as explosive ordnance or solid-propellant rocket motors). Aside from such cases, multiple qualification specimens of a given design may be used to enhance confidence in the qualification process, but are not required by this Standard.

6.1.1 Qualification Hardware. The hardware subjected to qualification testing shall be produced from the same drawings, using the same materials, tooling, manufacturing process, and level of personnel competency as used for flight hardware. Ideally, a qualification item would be randomly selected from a group of production items. A vehicle or subsystem qualification test article should be fabricated using qualification units to the maximum extent practicable. Modifications are permitted if required to accommodate benign changes that may be necessary to conduct the test. These changes include adding instrumentation to record functional parameters, test control limits, or design parameters for engineering evaluation. When structural items are rebuilt or reinforced to meet specific strength or rigidity requirements, all modifications shall be structurally identical to the changes incorporated in flight articles. The only testing required prior to the start of qualification testing of an item is the wear-in (7.4.10) to achieve a smooth, consistent, and controlled operation of the item (such as for moving mechanical assemblies, Valves, and thrusters).

6.1.2 Qualification Test Levels and Durations. To demonstratemargin; the qualification environmental conditions shall stress the qualification hardware to more severe conditions than the maximum conditions that might occur during service life (3.5.6), including not only flight, but also a maximum time or number of cycles that can be accumulated in acceptance testing and retesting. Qualification testing, however, should not create conditions that exceed applicable design safety margins or cause unrealistic modes of failure. If the equipment is to be used by more than one program, or in different vehicle locations, the qualification test conditions should envelope those of the various programs or vehicle locations involved. Typical qualification margins on the flight and acceptance test levels and durations are summarized in Table IV.

TABLE IV. Typical Qualification Test Level Margins and Durations.

Test	Units	Vehicle
Shock	6 dB above maximum expected environment, 3 times in both directions of 3 axes	1 activation of all shock-producing events; 2 additional activations of controlling events (6.2.3.3)
Acoustic*	6 dB above acceptance for 3 minutes	6 dB above acceptance for 2 minutes
Vibration*	6 dB above acceptance for 3 minutes, each of 3 axes	6 dB above acceptance for 2 minutes, each of 3 axes
Thermal Vacuum (Tables V, VI)	10°C beyond acceptance temperatures for 6 cycles	10°C beyond acceptance temperatures for 13 cycles
Combined Thermal Vacuum and Thermal Cycle (Tables V, VI)	10°C beyond acceptance temperatures for 25 thermal vacuum cycles and 53½ thermal cycles	10°C beyond acceptance temperatures for 3 thermal vacuum cycles and 10 thermal cycles
Static Load	1.25 times the limit load for unmanned flight or 1.4 times the limit load for manned flight, for a duration close to actual flight loading times	Same as for unit, but only tested at subsystem level

- Accelerated testing per 6.1.4.2 is assumed. Also, durations generally are longer for environments dominated by liquid engine or solid motor operation.

6.1.3 Thermal Vacuum and Thermal Cycle Tests. The required number of qualification thermal cycles is intended to demonstrate a capability for 4 times the thermal fatigue potentially expended in service life (3.5.6). The requirements stated assume that such fatigue is dominated by acceptance testing, and that the flight and other aspects (such as transportation) do not impose significant additional fatigue. It is further assumed that units, due to acceptance retesting, may be subjected to as many as 2 times the number of thermal cycles specified for a basic test. If 8 different hit on number of cycles is used, the required number of qualification cycles shall be changed per note 5 of Table VI. No allowance is made for acceptance retest of vehicles. For both thermal cycle and thermal vacuum tests, the temperature ranges in Table V are the basis for the number of cycles in Table VI for qualification and acceptance testing.

In instances where these baseline requirements are not appropriate due to the temperature range, acceptance retest allowance, or significance of the mission or other service, the qualification number of cycles shall be modified per note 5 of Table VI. Also, the maximum allowable number of acceptance thermal cycles can be extended after the original qualification by performing the required additional testing on the qualification test item necessary to meet the requirement in note 5 of Table VI.

Electrical and electronic units, or units Containing electrical and electronic elements, are subjected to multiple thermal vacuum cycles and thermal cycles for the purpose of uncovering workmanship deficiencies by a process known as "environmental stress screening.' Such screening is intended to identify defects that may result in early failures. Therefore the number of cycles imposed is generally unrelated to mission thermal cycles. For units not containing electrical or electronic elements, only thermal vacuum testing is required and the number of thermal cycles are considerably reduced (Table VI, 6.4.3.4, and 7.4.3.3).

6.1.4 Acoustic and Vibration Qualification. For the acoustic and vibration environments, the qualification tests are designed to demonstrate the ability of the test item to endure both of the following:

a. The acceptance test spectrum (7.1.2 or 7.1.3) for 4 times the maximum allowable duration of acceptance testing of flight items, including any retesting.

b. The extreme expected spectrum (6 dB higher than acceptance, unless a lesser margin can be justified per 3.3.2) for a duration of 4 times the fatigue equivalent duration in flight (3.3.3), but for not less than 1 minute.

The maximum allowable duration of acceptance testing can be extended after the original qualification by performing additional testing on the qualification test item. If one or more electrical or electronic units are involved, this additional acoustic or vibration testing shall be followed by at least 1.5 thermal cycles or 1.5 thermal vacuum cycles.

Either the approach described in 6.1.4.1 or 6.1.4.2 may be selected for conduct of the qualification testing.

TABLE V. Temperature Ranges for Thermal Cycle (TC) and Thermal Vacuum (TV) Tests.

Required Testing	Unit	Vehicle	
	TC & TV	TC	TV
Acceptance (ΔT_A)	105°C[1]	≥50°C	note 3
Qualification (ΔT_Q)	125°C[2]	≥70°C[2]	note 4

Notes: 1 Recommended, but reduced if impracticable or increased if necessary to encompass operational temperatures (7.1.1).
2 AT , = AT, + 20°C.
3 Governed by the unit that first reaches its hot or cold acceptance temperature limit.
4 Like note 3, but for qualification temperature limit.

Symbols: AT, = Acceptance temperature range.
AT, = Qualification temperature range.

TABLE VI. Numbers of Cycles[1] for Thermal Cycle (TC) and Thermal Vacuum (TV) Tests.

Required Testing	Unit			Vehicle	
	Acceptance (Table XIII)		Qualification (Table X)	Acceptance (Table XII)	Qualification (Table VIII)
	N_A[3]	N_{AMAX}[4]	N_Q[5]	N_A	N_Q[5,6]
Both: TC[2]	8.5	17	53.5	4	10
TV	4	8	25	1	3
Only TV	1	2	6	4	13
Only TC	12.5	25	78.5		

Notes: 1 Numbers of cycles correspond to temperature ranges in Table V.
2 Tests may be conducted in vacuum to be integrated with TV.
3 For tailoring: $N_A = 10(125/\Delta T_A)^{1.4}$ for TC only and for the sum of TC and TV when both conducted.
4 $N_{AMAX} = 2N_A$, but can be changed to allow for more or less retesting.
5 $N_Q = 4N_{AMAX}(\Delta T_A/\Delta T_Q)^{1.4}$, assuming temperature cycling during mission or other service is insignificant; if significant, additional cycling shall be required using the same fatigue equivalence basis.
6 $N_{AMAX} = N_A$, assuming that vehicle-level acceptance retesting will not be conducted.

Symbols: N_A = Required number of acceptance cycles.
N_{AMAX} = Maximum allowable number of acceptance cycles, including retesting.
N_Q = Required number of qualification cycles.

6.1.4.1 Two-condition Testing. The two-condition approach to acoustic or vibration qualification testing applies the acceptance test condition first (6.1.4a). For example, if the maximum allowable duration of acceptance vibration testing per axis is 6 minutes for any flight item, then 24 minutes of acceptance level vibration per axis would be required to satisfy the acceptance condition part of qualification, This would be followed by a test at the extreme expected spectrum, typically 6 dB higher for 1 minute per axis (6.1.4b)

6.1.4.2 Accelerated Testing. All or any portion of the testing at the acceptance level may be accelerated by replacing it with a reduced duration of testing at the qualification level. Table VII shows time reduction factors, rounded to the nearest integer, for selected combinations of margin and maximum test tolerance on the spectrum at any frequency. For example, when the qualification margin M is 6 dB and the test tolerance on the spectrum T is as high as 3 dB at some frequency, the time reduction factor is 1'2. Then 24 minutes of acceptance level testing could be accelerated to 2 minutes of testing at the qualification level. With a typical 1 minute test duration required for flight, the qualification test for this example would apply the extreme expected level for a total of 3 minutes per axis.

TABLE VII. Time Reduction Factors, Acoustic and Random Vibration Tests.

Margin M (dB)	Maximum Test Tolerance on Spectrum, T (dB)	Time Reduction Factor
6.0	±1.5	15
6.0	±3.0	12
4.5	±1.5	7
4.5	±3.0	4
3.0	±1.5	3
3.0	±3.0	1

Note: In general, the time reduction factor is $10^{M/5}[1+(4/3)\sinh^2(T/M)]^{-1}$, where T is sum of the absolute value of the negative tolerance for the qualification test and the positive tolerance for the acceptance test.

6.2 VEHICLE QUALIFICATION TESTS

The vehicle-level qualification test baseline shall include all the required tests specified in Table VIII. The "other" tests (3.5.4) deemed applicable, and additional special tests that are conducted as acceptance tests for the vehicle element (such as alignments, instrument calibrations, antenna patterns, and mass properties), shall also be conducted as part of qualification testing. Vehicle elements controlled by on-board data processing shall have the flight version of the computer software resident in the on-board computer. Verification of the operational requirements shall be demonstrated to the maximum extent practicable.

TABLE VIII. Vehicle Qualification Test Baseline.

Test	Reference Paragraph	Suggested Sequence	Launch Vehicle	Upper-stage Vehicle	Space Vehicle
Inspection[1]	4.4	1	R	R	R
Functional[1]	6.2.1	2'	R	R	R
Pressure/leakage	6.2.6	3,7,11	R	R	R
EMC	6.2.2	4	R	R	R
Shock	6.2.3	5	R	R	R
Acoustic or Vibration[2]	6.2.4 or 6.2.5	6	0	R	R
Thermal Cycle[3]	6.2.7	8'	0	O	O
Thermal Balance'	6.2.8	9	—	R	R
Thermal Vacuum	6.2.9	10	O	R	R
Modal Survey	6.2.10	any	R	R	R

All vehicle qualification requirements to be specified by the procuring agency (4.1). Symbols (10.2.1.3) indicate the following:

R = baseline requirement (high probability of being required)

0 = "other' (low probability of being required; 3.5.4)

— = not required (negligible probability of being required).

Notes:
1 Required before and after each test as appropriate. Include special tests as applicable (6.2).
2 Vibration conducted in place of acoustic test for a compact vehicle typically with mass less than 180 kg (400 lb).
3 Required if thermal cycling acceptance test (7.2.7) conducted.
4 May be combined with thermal vacuum test.

6.21 Functional Test. Vehicle Qualification

6.2.1.1 Purpose. The functional test verifies that the mechanical and electrical performance of the vehicle meet the specification requirements, including compatibility with ground support equipment, and validates all test techniques and software algorithms used in computer-assisted commanding and data processing. Proper operation of all redundant units or mechanisms should be demonstrated to the maximum extent practicable.

6.2.1.2 Mechanical Functional Test. Mechanical devices, valves, deployables, and separation subsystems shall be functionally tested at the vehicle level in the launch, orbital, or recovery configuration appropriate to the function. Alignment checks shall be made where appropriate. Fit checks shall be made of the vehicle physical interfaces using master gages or interface assemblies. The test should validate that the vehicle performs within maximum and minimum limits under worst-case conditions including environments, time, and other applicable requirements. Tests shall demonstrate positive margins of strength, torque, and related kinematics and clearances. Where operation in earth gravity or in an operational temperature environment cannot be performed, a suitable ground test fixture may be used to permit operation and performance evaluation. The pass-fail criteria shall be adjusted as appropriate to account for worst-case maximum and minimum limits that have been modified to adjust for ground test conditions.

6.2.1.3 Electrical and Fiber-optic Circuit Functional Test. The vehicle should be in its flight configuration with all units and subsystems connected, except explosive-ordnance elements. The test shall verify the integrity of electrical and fiber-optic circuits, including functions, redundancies, end-to-end paths, and at least nominal performance, including radio-frequency and other sensor inputs. End-to-end sensor testing may be accomplished with a self-test or coupled inputs.

The test shall be designed to operate all units, primary and redundant, and to exercise all commands and operational modes to the extent practicable. The operation of all thermally controlled units, such as heaters and thermostats, shall be verified by test. Where control of such units is implemented by sensors, electrical or electronic devices, coded algorithms, or a computer, end-to-end performance testing should be conducted. The test shall demonstrate that all commands having precondition requirements (such as enable, disable, a specific equipment configuration, and a specific command sequence), cannot be executed unless the preconditions are satisfied. Whenever practicable, equipment performance parameters that might affect end-to-end performance (such as power, voltage, gain, frequency, command and data rates) shall be varied over specification ranges to demonstrate the performance. Autonomous functions shall be verified to occur when the conditions exist for which they are designed. Continuous monitoring of several perceptive parameters, including input and output parameters, and the vehicle main bus by a power transient monitoring device, shall be provided to detect intermittent failures.

For at least one functional test in the qualification sequence, the vehicle shall be operated through a mission profile with all events occurring in actual flight sequence to the extent practicable. This sequence shall include the final countdown, launch, ascent, separation, upper-stage operation, orbital operation, and return from orbit as appropriate. All explosive-ordnance firing circuits shall be energized and monitored during these events to verify that the proper energy density is delivered to each device and in the proper sequence. All measurements that are telemetered shall also be monitored during appropriate portions of these events to verify proper operations.

6.2.1.4 Supplementary Requirements. Functional tests shall be conducted before and after each of the vehicle tests to detect equipment anomalies and to assure that performance meets specification requirements. These tests do not require the mission profile sequence. Sufficient data shall be analyzed to verify the adequacy of the testing and the validity of the data before any change is made to an environmental test configuration, so that any required retesting can be readily accomplished. During these tests, the maximum use of telemetry shall be employed for data acquisition, problem identification, and problem isolation. Functional tests required during individual vehicle tests are specified in connection with each test.

6.2.2 Electromagnetic Compatibility Test. Vehicle Qualification

6.2.2.1 Purpose. The electromagnetic compatibility test demonstrates electromagnetic compatibility of the vehicle and ensures that adequate margins exist in a simulated launch, orbital, disposal, and return-from-orbit electromagnetic environment.

6.2.2.2 Test De- The operation of the vehicle and selection of instrumentation shall be suitable for determining the margin against malfunctions and unacceptable or undesired responses due to electromagnetic incompatibilities. The test shall demonstrate satisfactory electrical and electronic equipment operation in conjunction with the expected electromagnetic radiation from other subsystems or equipment, such as from other vehicle elements and ground support equipment. The vehicle shall be subjected to the required tests while in the launch, orbital, and return-from-orbit configurations and in all possible operational modes, as applicable. Special attention shall-be given to areas indicated to be marginal by analysis. Potential electromagnetic interference from the test vehicle to other subsystems shall be measured. The tests shall be conducted according to the requirements of MIL-STD-1541. The tests shall include but not be limited to three main segments:

a. Radiated emissions susceptibility.

b. intersystem radiated susceptibility.

c. External radio frequency interference susceptibility.

Explosive-ordnance devices having bridge wires, but otherwise inert, shall be installed in the vehicle and monitored during all tests.

6.2.3 Shock Test. Vehicle &all-

&2.3:1 Purpose. The shock test demonstrates the capability of the vehicle to withstand or, if appropriate, to operate in the induced shock environments. The shock test also yields the data to validate the extreme and maximum expected unit shock requirement (3.3.7).

6.2.3.2 Jest Description The vehicle shall be supported and configured to allow flight-like dynamic response of the vehicle with respect to amplitude, frequency content, and paths of transmission. Support of the vehicle may vary during the course of a series of shock tests in order to reflect the configuration at the time of each shock event. Test setups shall avoid undue influence of test fixtures, and prevent recontact of separated portions.

In the shock test or series of shock tests, the vehicle shall be subjected to shock transients that simulate the extreme expected shock environment (3.3.7) to the extent practicable. Shock events to be considered include separations and deployments initiated by explosive ordnance or other devices, as well as impacts and suddenly applied or released loads that may be significant for unit dynamic response (such as due to an engine transient, parachute deployment, and vehicle landing). All devices on the vehicle capable of imparting significant shock excitation to vehicle units shall be activated. Those potentially significant shock sources not on the vehicle under test, such as on an adjoining payload fairing or a nearby staging joint, shall also be actuated or simulated and applied through appropriate interfacing structures. Dynamic instrumentation shall be installed to. measure shock responses in 3 orthogonal directions at attachments of selected units.

6.2.3.3 Test Activations. All explosive-ordnance devices and other potentially significant shock-producing devices or events, including those from sources not installed on the vehicle under test, shall be activated at least one time or simulated as appropriate. Significant shocksources are those that induce a shock-response . spectrum (3.3.7) at any unit location that is within 6 dB of the envelope of the shock response spectra from all shock sources. The significant sources shall be activated 2 additional times to provide for variability in the vehicle test and to provide data for prediction of maximum and extreme expected shock environments for units (3.3.2). Activation of both primary and redundant devices shall be carried out in the same sequence as they are intended to operate in service.

6.2.3.4 Supplementary Requirements. Electrical and electronic units shall be operating and monitored to the maximum extent practicable. Continuous monitoring of several perceptive parameters, including input and output parameters, and the vehicle main bus by a power transient monitoring device, shall be provided to detect intermittent failures.

6.2.4 Acoustic Test, Vehicle Qualification

6.2.4.1 Purpose. The acoustic test demonstrates the ability of the vehicle to endure acoustic acceptance testing and meet requirements during and after exposure to the extreme expected acoustic environment in flight (3.3.4). Except for items whose environment is dominated by structure-borne vibration, the acoustic test also verifies the adequacy of unit vibration qualification levels and serves as a qualification test for items not tested at a lower level of assembly.

6.2.4.2 Test Description. The vehicle in its ascent configuration shall be installed in an acoustic test facility capable of generating sound fields or fluctuating surface pressures that induce vehicle vibration environments sufficient for vehicle qualification. The vehicle shall be mounted on 8 flight-type support structure or reasonable simulation thereof. Significant fluid and pressure conditions shall be replicated to the extent practicable. Appropriate dynamic instrumentation shall be installed to measure vibration responses at attachment points of critical and representative units. Control microphones shall be placed at a minimum of 4 well-separated locations, preferably at one half the distance from the test article to the nearest chamber wall, but no closer than 0.5 meter (20 inches) to both the test article surface and the chamber wall. When test article size exceeds facility capability, the vehicle may be appropriately subdivided and acoustically tested as one or more subsystems or assemblies.

6.2.4.3 Test Level and Duration. The test shall be conducted per 6.1.4. The typical version of the test involves accelerated acceptance-level testing per 6.1.4.2 and applies the qualification-level spectrum for a total of 2 minutes. This is based on a qualification margin of 6 dB, a maximum of 3 minutes of accumulated acceptance testing on a flight vehicle, and a fatigue equivalent duration of not greater than 15 seconds. Operating time should be divided approximately equally between redundant functions. Where insufficient test time is available to test redundant units;-functions;-and modes-that are operating duringthe launch, ascent, or reentry phase, extended testing shall be performed at a level no lower than 6 dB below the qualification level.

6.2.4.4 Supplementary Requirements. During the test, all electrical and electronic units, even if not operating during launch, shall be electrically energized and sequenced through operational modes to the maximum extent practicable, with the exception of units that may sustain damage if energized. Continuous monitoring of several perceptive parameters, including input and output parameters, and the vehicle main bus by a power transient monitoring device, shall be provided to detect intermittent failures.

6.2.5 Vibration Test, Vehicle Qualification. The vibration test may be conducted instead of an acoustic, test. (6.2.4) for small, compact vehicles which can be excited more effectively via interface vibration than by an acoustic field. Such vehicles typically have a mass under 180 kilograms (400 pounds).

6.2.5.1 Purpose. The vibration test demonstrates the ability of the vehicle to endure vibration acceptance testing and meet requirements during and after exposure to the extreme expected environment in flight (3.3.5). Except for items whose response is dominated by acoustic excitation, the vibration test also verifies the adequacy of unit vibration qualification levels and serves as a qualification test for items that have not been tested at a lower level of assembly.

6.2.5.2 Test Description. The vehicle and a flight-type adapter, in the ascent configuration, shall be vibrated using one or more shakers through appropriate vibration fixtures. Vibration shall be applied in each of 3 orthogonal axes, one direction being parallel to the vehicle thrust axis. Instrumentation shall be installed to measure, in those same 3 axes, the vibration inputs and the vibration responses at attachment points of critical and representative units.

6.2.5.3 Test Levels and Duration. The test shall be conducted per 6.1.4 to produce the required spectrum at the input to the vehicle or at attachment points of critical or representative units, as specified. When necessary to prevent unrealistic input forces or unit responses, the spectrum at the vehicle input may be limited or notched, but not below the minimum spectrum for a vehicle (7.1.3). The typical version of the test for each axis involves accelerated acceptance-level testing per 6.1.4.2 and applies the qualification spectrum for 2 minutes (same basis as in 6.2.4.3). Operating time should be divided approximately equally between redundant functions. Where insufficient test time is available to test redundant units, functions, and modes that are operating during the launch, ascent, or reentry phase, extended testing shall be performed at a level no lower than 6 dB below the qualification level.

6.2.5.4 Supplementary Requirements. Same as 6.2.4.4, except that the structural response shall also be monitored to ensure that no unrealistic test conditions occur.

6.2.6 Pressure and Leakage Tests. Vehicle Qualification

6.2.6.1 Purpose. These tests demonstrate the capability of pressurized subsystems to meet the specified flow, pressure, and leakage rate requirements.

6.2.6.2 Test Description. The vehicle shall be placed in a facility that provides the services and safety conditions required to protect personnel and equipment during the testing of high-pressure subsystems and in the handling of dangerous fluids. Preliminary tests shall be performed, as necessary, to verify compatibility with the test setup and to ensure proper control of the equipment and test functions. The requirements of the subsystem including flow, leakage, and regulation shall be measured while operating applicable valves, pumps, and motors. The flow checks shall verify that the plumbing configurations are adequate. Checks for subsystem cleanliness, moisture levels, and pH levels shall also be made. Where pressurized subsystems are assembled with other than brazed or welded connections, the specified torque values for these connections shall be verified prior to the initial qualification leak check.

In addition to the high-pressure test, propellant tanks and thruster valves shall be tested for leakage under propellant servicing conditions. The subsystem shall be evacuated to the internal pressure normally used for propellant loading and the pressure monitored for decay as an indication of leakage.

6.2.6.3 Test Levels and Durations.

a. For launch and upper-stage vehicles which contain pressurized structures, the pressurized subsystem shall be pressurized to a proof pressure which is 1.1 times the maximum expected operating pressure (MEOP) and held constant for a short dwell time, sufficient to assure that the proper pressure was achieved within the allowed test tolerance. The test pressure shall then be reduced to the MEOP for leakage inspection.

b. For space vehicles, unless specified otherwise, the pressurized subsystems shall be pressurized to a proof pressure which is 1.25 times the MEOP and held for 5 minutes and then the pressure shall be reduced to the MEOP. This sequence shall be conducted 3 times, followed by inspection for leakage at the MEOP. The duration of the evacuated propulsion subsystem leakage test shall not exceed the time that this condition is normally, experienced during propellant loading.

6.2.6.4 Supplementary Requirements. Applicable safety standards shall be followed in conducting all tests. Tests for detecting external leakage shall be performed at such locations as joints, fittings, plugs, and lines. The acceptable leakage rate to meet mission requirements shall be based upon an appropriate analysis. In addition, the measurement technique shall account for leakage rate variations with pressure and temperature and have the required threshold, resolution, and accuracy to detect any leakage equal to or greater than the acceptable leak rate. If appropriate, the leakage rate measurement shall be performed at the MEOP and at operational temperature, with the representative fluid commodity, to account for dimensional and viscosity changes. Times to achieve thermal and pressure equilibrium, test duration, and temperature sensitivity shall be determined by an appropriate combination of analysis and development test, and the results documented. Leakage detection and measurement procedures may require vacuum chambers, bagging of the entire vehicle or localized areas, or other special techniques to achieve the required accuracies.

6.2.7 Thermal Cycle Test, Vehicle Qualification

6.2.7.1 Purpose. The thermal cycle test demonstrates the ability of the vehicle to withstand the stressing associated with flight vehicle thermal cycle acceptance testing, with a qualification margin on temperature range and maximum number of cycles. The thermal cycle test, in combination with a reduced-cycle thermal vacuum test, can be selected as an alternate to the thermal vacuum test (6.2.9 and Table VI).

6.2.7.2 Test Description. The vehicle shall be placed in a thermal chamber at ambient pressure, and a functional test shall be performed to assure readiness for the test, The vehicle shall be operated and monitored during the entire test, except that vehicle power may be turned off if necessary to reach stabilization at the cold temperature. Vehicle operation shall be asynchronous with the temperature cycling, and redundant units shall be operated for approximately equal times.

When the relative humidity of the inside spaces of the vehicle is below the value at which the cold test temperature would cause condensation, the temperature cycling shall begin. One complete thermal cycle is a period beginning at ambient temperature, then cycling to one temperature extreme and stabilizing (3.5.7), then to the other temperature extreme and stabilizing, and then returning to ambient temperature. Strategically placed temperature monitors installed on units shall assure attainment and stabilization of the expected temperature extremes for several units. Auxiliary heating and cooling may be employed for selected temperature-sensitive- units (e.g., batteries). If it is necessary in order to achieve the required temperature rate of change, parts of the vehicle such as solar arrays and passive thermal equipment may be removed for the test. The last thermal cycle shall contain cold and hot soaks during which the vehicle shall undergo a functional test, including testing of redundant units.

6.2.7.3 Test level and Duration. The minimum vehicle temperature range shall be 70°C from the hot to the cold condition (Table V). With the 70°C qualification temperature range, the required number of cycles shall be 10. For other ranges, see Table VI. The average rate of change of temperature shall be as rapid as practicable.

6.2.7.4 Supplementary Requirements. Continuous monitoring of several perceptive parameters, including input and output parameters and the vehicle main bus by a power transient monitoring device, shall be provided to detect intermittent failures. Moisture condensation inside of electrical and electronic units shall be prevented. Combinations of temperature and humidity which allow moisture deposition either on the exterior surfaces of the vehicle or inside spaces where the humidity is slow to diffuse (for example, multilayer insulation) shall be avoided.

6.2.8 Thermal Balance Test, Vehicle Qualification

6.2.8.1 Purpose. The thermal balance test provides the data necessary to verify the analytical thermal model and demonstrates the ability of the vehicle thermal control subsystem to maintain the specified operational temperature limits of the units and throughout the entire vehicle. The thermal balance test also verifies the adequacy of unit thermal design criteria. The thermal balance test can be combined with the thermal vacuum test (6.2.9).

6.2.8.2 Test Description. The qualification vehicle shall be tested to simulate the thermal environment experienced by the vehicle during its mission. Tests shall be capable of validating the thermal model over the full mission range of seasons, equipment duty cycles, ascent conditions, solar angles, maximum and minimum unit thermal dissipations including effects of bus voltage variations, and eclipse combinations so as to include the worst-case hot and cold temperatures for all vehicle units. As a minimum, two test conditions shall be imposed: a worst hot case and a worst cold case. If practicable, 2 additional cases should be imposed: a transient for correlation with the model and a case chosen to check the validity of the correlated model. Special emphasis shall be placed on defining the test conditions expected to produce the maximum and minimum temperatures of sensitive units such as batteries. Sufficient measurements shall be made on the vehicle internal and external units to verify the vehicle thermal design and analyses, The power requirements of ail thermostatically or electronically controlled heaters and coolers shall be verified during the test, and appropriate control authority demonstrated.

The test chamber, with the test item installed, shall provide a pressure of no higher than 13.3 millipascal (10^{-4} Torr) for space and upper-stage vehicles, or a pressure commensurate with service altitude for launch vehicles. Where appropriate, provisions should be made to prevent the test item from "viewing" warm chamber walls, by using black-coated cryogenic shrouds of sufficient area and shape that are capable of approximating liquid nitrogen temperatures. The vehicle thermal environment may be supplied by one of the following methods:

a. Absorbed Flux. The absorbed solar, albedo, and planetary irradiation is simulated using heater panels or infrared (IR) lamps with their spectrum adjusted for the external thermal coating properties, or using electrical resistance heaters attached to vehicle surfaces.

b. Incident Flux. The intensity, spectral content, and angular distribution of the incident solar, albedo, and planetary irradiation are simulated.

c. Equivalent Radiation Sink Temperature. The equivalent radiation sink temperature is simulated using infrared lamps and calorimeters with optical properties identical to those of the vehicle surface.

d. Combination. The thermal environment is supplied by a combination of the above methods.

The selection of the method and fidelity of the simulation depends upon details of the vehicle thermal design such as vehicle geometry, the size of internally produced heat loads compared with those supplied by the external environment, and the thermal characteristics of the external surfaces. Instrumentation shall be incorporated down to the unit level to evaluate total vehicle performance within operational limits as well as to identify unit problems. The vehicle shall be operated and monitored throughout the test. Dynamic flight simulation of the vehicle thermal environment should be provided unless the external vehicle temperature does not vary significantly with time. (See 10.3 regarding formation of a Test Evaluation Team.)

6.2.8.3 Test Levels and Duration. Test conditions and durations for the thermal balance test are dependent upon the vehicle configuration, design, and mission details. Normally, boundary conditions for evaluating thermal design shall Include both of the following:

a. Maximum external absorbed flux plus maximum internal power dissipation.

b. Minimum external absorbed flux plus minimum internal power dissipation..

The thermal time constant of the subsystems and mission profile both influence the time required for the vehicle to achieve thermal equilibrium and hence the test duration.

performed including the operating and monitoring of redundant units and paths. Vehicle electrical equipment shall be operating and monitored throughout the test. Temperature monitors shall assure attainment of temperature limits. Strategically placed witness plates, quartz crystal microbalances, or other instrumentation shall be installed in the test chamber to measure the outgassing from the vehicle and test equipment.

6.2.9.3 Test Levels and Duration. Temperatures in various equipment areas shall be controlled by the external test environment and internal heating resulting from equipment operation.. During the hot and cold half cycles, the temperature limit is reached as soon as one unit in each equipment area is at the hot or cold temperature reached during its qualification thermal testing. Unit temperatures shall not be allowed to go outside their qualification range at any time during the test. The pressure shall be maintained at no higher than 13.3 millipascal (10^{-4} Torr) for space and upper-stage vehicles and, for launch vehicles, at no higher than the pressure commensurate with the highest possible service altitude. When the alternate thermal cycle test (6.2.7) is not performed, the thermal vacuum qualification test shall include at least 13 complete hot-cold cycles (Table VI). When thermal cycling is performed, the thermal vacuum qualification test shall include at least 3 complete hot-cold cycles (Table VI).

The rate of temperature change shall equal or exceed the maximum predicted mission rate of change. The temperature soak (3.5.10) shall be at least 8 hours at each temperature extreme during the first and last cycles. For intermediate cycles, the soak duration shall be at least 4 hours. Operating time should be divided approximately equally between redundant units.

6.2.9.4 Supplementary Requirements. Continuous monitoring of several perceptive parameters, including input and output parameters, and the vehicle main bus by a power transient monitoring device, shall be provided to detect intermittent failures. It may be necessary to achieve temperature limits at certain locations by altering thermal boundary conditions locally or by altering the operational sequence to provide additional heating or cooling. Adjacent equipments may be turned on or off; however, any special conditioning within the vehicle shall generally be avoided. External baffling, shadowing, or heating shall be utilized to the extent feasible. The vehicle shall be operated over the qualification temperature range, although performance within specification is not required outside of 10°C beyond the maximum and minimum expected temperatures.

6.2.10 Mode Survey Test, Vehicle Qualification.

6.2.10.1 Purpose. The mode survey test (or modal survey) is conducted to experimentally derive a structural dynamic model of a vehicle or to provide a basis for test-verification of an analytical model. After upgrading analytically to the flight

6.2.8.4 Supplementary Requirements. Success criteria depend not only on survival and operation of each item within specified temperature limits, but also on correlation of the test data with theoretical thermal models. As a goal, correlation of test results to the thermal model predictions should be within ± 3°C. Lack of correlation with the theoretical models may indicate either a deficiency in the model, test setup, or vehicle hardware. The correlated thermal math model shall be used to make the final temperature predictions for the various mission phases (such as prelaunch, ascent, on-orbit, and disposal orbit).

6.2.9 Thermal V:Qualification Vehicle

6.2.9.1 Purpose. The thermal vacuum test demonstrates the ability of the vehicle to meet qualification requirements under vacuum conditions and temperature extremes which simulate those predicted for flight plus a design margin, and to withstand the thermal stressing environment of the vehicle thermal vacuum acceptance test plus a qualification margin on temperature range and number of cycles.

6.2.9.2 Jest D'e's -. The vehicle shall be placed in a thermal vacuum chamber and a functional test performed to assure readiness for chamber closure. The vehicle shall be divided into separate equipment zones, based on the limits of the temperature-sensitive units and similar unit qualification temperatures within each zone. Units that operate during ascent shall be operating and monitored for corona and muitipacting, as applicable, as the pressure is reduced to the lowest specified level. The rate of chamber pressure reduction shall be no greater than during ascent, and may have to be slower to allow sufficient time to monitor for corona and multipacting. Equipment that does not operate during launch shall have electrical power applied after the lowest specified pressure level has been reached. A thermal cycle begins with the vehicle at ambient temperature. The temperature is raised to the specified high level and stabilized (3.5.7). Following the high-temperature soak, the temperature shall be reduced to the lowest specified level and stabilized. Following the low-temperature soak, the vehicle shall be returned to ambient temperature to complete one thermal cycle. Functional tests shall be conducted during the first and last thermal cycle at both the high- and low-temperature limits with functional operation and monitoring of perceptive parameters during ail other cycles. If simulation of the ascent environment is desirable at the beginning of the test, the first cycle may begin with a transition to cold thermal environment, rather than a hot thermal environment.

In addition to the thermal cycles for an upper-stage or space vehicle, the chamber may be programmed to simulate various orbital flight operations. Execution of operational sequences shall be coordinated with expected environmental conditions, and a complete cycling of all equipment shall be configuration (such as different propellant loading and minor differences between flight and test unit mass properties); this model is used in analytical simulations of flight loading events to define the verification-cycle structural loads environment. These loads are used to determine structural margins and adequacy of the structural static test loading conditions (6.3.1). They are therefore critical for verification of vehicle structural integrity and qualification of the structural subsystem as flight-ready. Where practicable, a modal survey is also performed to define or verify models used in the final preflight evaluation of structural dynamic effects on control subsystem precision and stability.

6.2.10.2 Test Description The test article shall consist of flight-quality structure with assembled units: payloads, and other major subsystems, and shall contain actual or simulated liquids at specified fill-levels. For large vehicles, complexity and testing practicability may dictate that tests be performed on separate sections of the vehicle. For large launch vehicles in particular, practicality may also dictate use of an integrated program of ground and flight tests, involving substantial flight data acquisition and analysis, to acquire the necessary data for model verification. Wire harnesses may be installed for the mode survey test, but are not required. Mass simulators may be used to represent a flight item when its attachment-fixed resonances have been demonstrated by test to occur above the frequency range of interest established for the modal survey. Dynamic simulators may be used for items that have resonances within the frequency range of interest if they are accurate dynamic representations of the flight item. Alternatively, mass simulators may be used if flight-quality items are subjected separately to a modal survey meeting qualification requirements. All mass simulators are to include realistic simulation of interface attach structure and artificial stiffening of the test structure shall be avoided.

The data obtained in the modal survey shall be adequate to define the resonant frequencies and associated mode shapes and damping values, for all modes that occur in the frequency range of interest, generally up to at least 50 Hz. In addition, the primary mode shall be acquired in each coordinate direction, even if its frequency lies outside the specified test range. The test modes are considered to have acceptable quality when they are orthogonal, with respect to the analytical mass matrix, to within 10 percent. (See 10.3 regarding formation of a Test Evaluation Team to facilitate deviations from these requirements.)

6.2.10.3 Jest Levels. The test is generally conducted at response levels that are low compared to the expected flight levels. Limited testing shall be conducted to evaluate nonlinear. behavior, with a minimum of -3 levels used. when significant nonlinearity is identified.

6.2.10.4 Supplementary Requirements.

6.2.10.4.1 Correlation Requirements. When the modal survey data are used to test-verify an analytical dynamic model for the verification-cycle loads analyses, rather than to define the model directly, adequate model-to-test correlation shall be demonstrated quantitatively as follows:

a. Using a cross-orthogonality matrix formed from the analytical mass matrix and the analytical and test modes, corresponding modes are to exhibit at least %-percent correlation and dissimilar modes are to be orthogonal to within 10 percent.

b. Analytical model frequencies are to be within 3 percent of test frequencies.

With adequate justification, limited exceptions to this standard of correlation are acceptable for problem modes; also, alternative quantitative techniques can be used if their criteria for acceptability are comparable.

6.2.10.4.2 pretest Requirements. Because of their criticality to achieving a successful test, appropriate pretest analyses and experimentation shall be performed to:

a. Establish adequacy of the test instrumentation.

b . Evaluate the test stand and fixturing to preclude any boundary condition uncertainties that could compromise test objectives.

c. Verify that mass simulators have no resonances within the frequency range of interest.

6.3 SUBSYSTEM QUALIFICATION TESTS

Subsystem qualification tests shall be conducted on subsystems for any of the following purposes:

a. To verify their design.

b. To qualify those subsystems that are subjected to environmental acceptance tests.

c. When-this. level of testing provides a more realistic or more practical test simulation than testing at another level of assembly.

For purpose c, included are tests such as the required structural static load test, and environmental tests where the entire flight item is too large for existing facilities. Also, the qualification of certain units such as interconnect tubing or wiring may be more readily completed at the subsystem level rather than at the unit level. In this case, the appropriate unit tests may be conducted at the subsystem level to complete required unit qualification tests. Types of subsystems that are not specifically identified herein may be tested in accordance with the vehicle level test requirements. Subsystem qualification test requirements are listed in Table IX.

6.3.1 Structural Static Load Test, Subsystem Qualification.

6.3.1.1 Purpose. The structural static load test demonstrates the adequacy of the subsystem structures to meet requirements of strength and stiffness, with the desired qualification margin, when subjected to simulated critical environments (such as temperature, humidity, pressure, and loads) predicted to occur during its service life (3.5.6).

6.3.1.2 Test Description. The support and load application fixture shall consist of an adequate replication of the adjacent structural section to provide boundary to determine the proper sequencing or simultaneity for application of thermal stresses. When prior loading histories affect the structural adequacy of the test article, these shall be included in the test requirements. If more than one design ultimate load condition is to be applied to the same test specimen, a method of sequential load application shall be developed by which each condition may, in turn, be tested to progressively higher load levels. The final test may be taken to failure to substantiate the capability to accommodate internal load redistribution, and to provide data for any conditions which simulate those existing in the flight article. Static loads representing the design yield load (3.4.5) and the design ultimate load (3.4.4) shall be applied to the structure, and measurements of the strain and deformation shall be recorded. Strain and deformation shall be measured before loading, after removal of the yield loads, and at several intermediate levels up to yield load for post-test diagnostic purposes. The test conditions shall encompass the extreme predicted combined effects of acceleration, vibration, pressure, preloads, and temperature. These effects can be simulated in the test conditions as long as the failure modes are covered and the design margins are enveloped by the test. For example, temperature effects, such as material strength degradation and additive thermal stresses, can often be accounted for by increasing mechanical loads. Analysis of flight profiles shall be used in subsequent design modification effort, and to provide data for use in any weight reduction programs. Failure at design yield load means material gross yielding or deflections which degrade mission performance. Failure at design ultimate load means rupture or collapse. (See 10.3 regarding formation of a Test Evaluation Team.)

TABLE IX. Subsystem Qualification Test Baseline.

TEST	Reference Paragraph	Structure	Space Experiment	Launch Vehicle Subsystem	Payload Faking
Static Load	6.3.1	R	O[4]	O[4]	R
Vibration or Acoustic	6.3.2 / 6.3.3	O[1]	O[1]	O[1,2]	R[5]
Thermal Vacuum	6.3.4	0	R[3]	O[2]	0
Separation	6.3.5	R			R
Mechanical Functional	6.2.1.2	0	0	O[4]	R

All vehicle qualification requirements to be specified by the procuring agency (4.1). Symbols (10.2.1.3) indicate the following:

R = baseline requirement (high probability of being required)
O = "other" (low probability of being required; 3.54)
— = not required (negligible probability of being required).

Notes:
1 Vibration conducted in place of acoustic test for a compact subsystem.
2 Required for subsystems containing critical equipment (for example, guidance equipment). Not required if performed at the vehicle level.
3 Discretionary if performed at the vehicle level.
4 Required if not performed at another level of assembly.
5 Acoustic test required.

6.3.1.3 Test Levels and Duration

a. Static Loads. Unless otherwise specified, the design ultimate load test shall be conducted at 1.4 times the limit load for manned flight, and 1.25 times the limit load for unmanned flight. The design yield load test shall be conducted at 1 .O times limit load for both manned and unmanned flight.

b. Temperature. Critical flight temperature and load combinations shall be simulated or taken into account.

c. Duration of Loading. Loads shall be applied as closely as practicable to actual flight loading times, with a dwell time not longer than necessary to record test data such as stress, strain, deformation, and temperature.

6.3.1.4 Supplementary Requirements. Pretest analysis shall be conducted to identify the locations of minimum design margins and associated failure modes that correspond to the selected critical test load conditions. This analysis shall be used to locate instrumentation, to determine the sequence of loading conditions, and to provide early indications of anomalous occurrences during the test. This analysis shall also form the basis for judging the adequacy of the test loads. In cases where a load or other environment has a relieving, stabilizing, or other beneficial effect on the structural capability, the minimum, rather than the maximum, expected value shall be used in defining limit-level test conditions. In very complex structures where simulation of the actual flight loads is extremely difficult, or not feasible, multiple load cases may be used to exercise all structural zones to design yield and design ultimate loads.

6.3.2 Vibration Test, Subsystem Qualification

6.3.2.1 Purpose. Same as 6.2.5.1.

6.3.2.2 Test Description. Same as 6.2.5.2.

6.3.2.3 Test Levels and Duration. Same as 6.2.5.3.

6.3.2.4 Supplementary Requirements. Same as 6.2.5.4.

6.3.3 Acoustic Test, Subsystem Qualification

6.3.3.1 Purpose. Same as 6.2.4.1.

6.3.3.2 Test Description. Same as 6.2.4.2.

6.3.3.3 Test Levels and Duration. 6.2.4.3.

6.3.3.4 Supplementary Requirements. Same as 6.2.4.4, as applicable.

6.3.4 Thermal Vacuum Test, Subsystem Qualification

6.3.4.1 Purpose. Same as 6.2.9.1..

6.3.4.2 Test Description. Same as 6.2.9.2.

6.3.4.3 Test Levels and Duration. Same as 6.2.9.3.

6.3.4.4 Supplementary Requirements. Same as 6.2.9.4.

6.3.5 Separation Test, Subsystem Qualification

6.3.5.1 Purpose. The separation test demonstrates the adequacy of the separation subsystem to meet its performance requirements on such parameters as: separation velocity, acceleration, and angular motion; time to clear and clearances between separating hardware; flexible-body distortion and loads; amount of debris; and explosive-ordnance shock levels. For a payload fairing using a high-energy separation subsystem, the test also demonstrates the structural integrity of the fairing and its generic attachments under the separation shock loads environment. The data from the separation test are also used to validate the analytical method and basic assumptions used in the separation analysis. The validated method is then used to verify that requirements are met under worst-case flight conditions.

6.3.5.2 Test Description. The test fixtures shall replicate the interfacing structural sections to simulate the separation subsystem boundary conditions existing in the flight article. The remaining boundary conditions for the separating bodies shall simulate the conditions in flight at separation, unless the use of other boundary conditions will permit an unambiguous demonstration that subsystem requirements can be met. The test article shall include all attached flight hardware that could pose a debris threat if detached. When ambient atmospheric pressure may adversely affect the test results, such as for large fairings, the test shall be conducted in a vacuum chamber duplicating the altitude condition encountered in flight at the time of separation. Critical conditions of temperature, pressure, or loading due to acceleration shall be simulated or taken into account. As a minimum, instrumentation shall include high-speed cameras to record the motion of specially marked target locations, accelerometers to measure the structural response, and strain gages to verify load levels in structurally critical attachments. (See 10.3 regarding formation of a Test Evaluation Team.)

6.3.5.3 Test Activations. A separation test shall be conducted to demonstrate that requirements on separation performance parameters are met under nominal conditions. When critical off-nominal conditions cannot be modeled with confidence, at least one additional separation test shall be conducted to determine the effect on the separation process. When force or torque margin requirements are appropriate, a separate test shall be conducted to demonstrate that the margin is at least 100 percent; for separation subsystems involving fracture of structural elements, however, the margin demonstrated shall be at least 50 percent. In addition, debris risk shall be evaluated by conducting a test encompassing the most severe conditions that can occur in flight, or by including loads scaled from those measured in tests under nominal conditions.

6.3.5.4 Supplementary Requirements. A post-test inspection for debris shall be conducted on the test article and in the test chamber.

6.4 UNIT QUALIFICATION TESTS

The unit qualification test baseline shall include all the required tests specified in Table X. The "other" tests (3.5.4) deemed applicable, and additional special tests that are conducted as acceptance tests on the unit, shall also be conducted as part of qualification testing. Unit qualification tests shall normally be accomplished entirely at the unit level. However, in certain circumstances, the required unit qualification tests may be conducted partially or entirely at the subsystem or vehicle levels of assembly. Tests of units such as interconnect tubing, radio-frequency circuits, and wiring harnesses are examples where at least some of the tests can usually be accomplished at higher levels of assembly, If moving mechanical assemblies or other units have static or dynamic fluid interfaces or are pressurized during operation, those conditions should be replicated during unit qualification testing. Unit performance shall meet the applicable mission requirements over the entire qualification environmental test range, to the maximum extent practicable. At the end of all required qualification tests, the qualification unit should be disassembled and inspected (4.5).

Where units fall into two or more categories of Table X, the required tests specified for each category shall be applied. For example, a star sensor may be considered to fit both "Electrical and Electronic" and "Optical" categories. A thruster with integrated valves would be considered to fit both "Thruster" and "Valve" categories.

6.4.1 Functional Test, Unit Qualification

6.4.1.1 Purpose. The functional test verifies that the electrical, optical, and mechanical performance of the unit meets the specified operational requirements of the unit.

6.4.1.2 Test Description. Electrical tests shall include application of expected voltages, impedance, frequencies, pulses,' and waveforms at the electrical interfaces of the unit, including all redundant circuits. These parameters shall be varied throughout their specification ranges and the sequences expected in-flight operation. The unit output shall be measured to verify that the unit performs to specification requirements. Functional performance shall also include electrical continuity, stability, response time, alignment, pressure, leakage, or other special

TABLE X. Unit Qualification Test Baseline.

Test	Reference Paragraph	Suggested Sequence	Electrical and Electronic	Antenna	MMA	Solar Array	Battery	Valve or Propulsion Component	Pressure Vessel or Component	Thruster	Thermal	Optical	Structural Component
Inspection[1]	4.6	1	R	R	R	R	R	R	R	R	R	R	R
Functional[1]	6.4.1	2	R	R	R	R	R	R	R	R	R	R	—
Leakage[2]	6.4.7	3,6,12	R	—	R	—	R	R	R	O	O	—	—
Shock	6.4.6	4	R	O[4]	O[4]	O[4]	O[4]	O[4]	O	O[4]	O[4]	O[4]	O
Vibration	6.4.4	6	R	R[5]	A	R[5]	R	R	R	R	R	R[5]	O[7]
Acoustic	6.4.6	6	0	R[5]	—	R[5]	—	—	—	—	—	R[5]	—
Acceleration	6.4.9	7	0	R	O	O	O	—	0	—	—	R	—
Thermal Cyde	6.4.2	8	R	—	—	—	—	—	—	—	—	—	—
Thermal Vac	6.4.3	9	R	R	R	R	R	R	O	R	R	R	O
Climatic	6.4.12	10	O	0	O	0	O	0	0	0	O	0	—
Proof Pressure[3]	6.4.9	11	O	—	O	—	O	R	R	R	O	—	—
E'MC	6.4.11	13	R	O	O	—	0	—	—	—	—	—	—
Life	6.4.10	14	O	O	O	O	R	O	R[6]	R	O	O	O[8]
Burst [3]	6.4.9	16	0	-	-	-	0	0	R	0	0	—	—

Aii vshicie quelifketion requiremente to be specified by the procuring agency (4.11.

Symbols (10.2.1.3) indicate the following:

R = baseline requirement (high probability of being required)

O = 'other' (low probability of being required; 3.5.4)

— = not required (negligible probability of being required).

Notes:
1 Required before end following each test es appropriate. Include special tests as applicable (6.21.
2 Required when component is reeled or pressurized.
3 Required when component is pressurized.
4 Required when maximum expected shock spectrum in g's exceeds 0.8 times the frequency in Hz.
5 Either vibration or acoustic test required, whichever is more appropriate, with the other discretionary.
6 For pressure veseele, test per MIL-STD-1 522. For pressure components, other then bellows end other flexible fluid devices or lines, life tests are discretionary.
7 Test required if tha structural component her a low margin for fatigue, or is not subjected to a static strength qualification test (6.4.4.6).
8 For pressurized structures, the pressure cycle test (6.4.8.2b end 6.4.8.3c) shall be required.

tests that relate to a particular unit configuration. Moving mechanical assemblies shall be tested in the configuration corresponding to the environment being simulated and shall be passive or operating corresponding to their state during the corresponding environmental exposure. Torque versus angle and time versus angle, or equivalent linear measurements for linear devices, shall be made. Functional tests should include stiffness, damping, friction and breakaway characteristics, where appropriate. Moving mechanical assemblies that contain redundancy in their design shall demonstrate required performance in each redundant mode of operation during the test.

6.4.1.3 Supplementary Requirements. Functional or monitoring tests shall be conducted before, during, and after each of the unit tests to detect equipment anomalies and to assure that performance meets specification requirements.

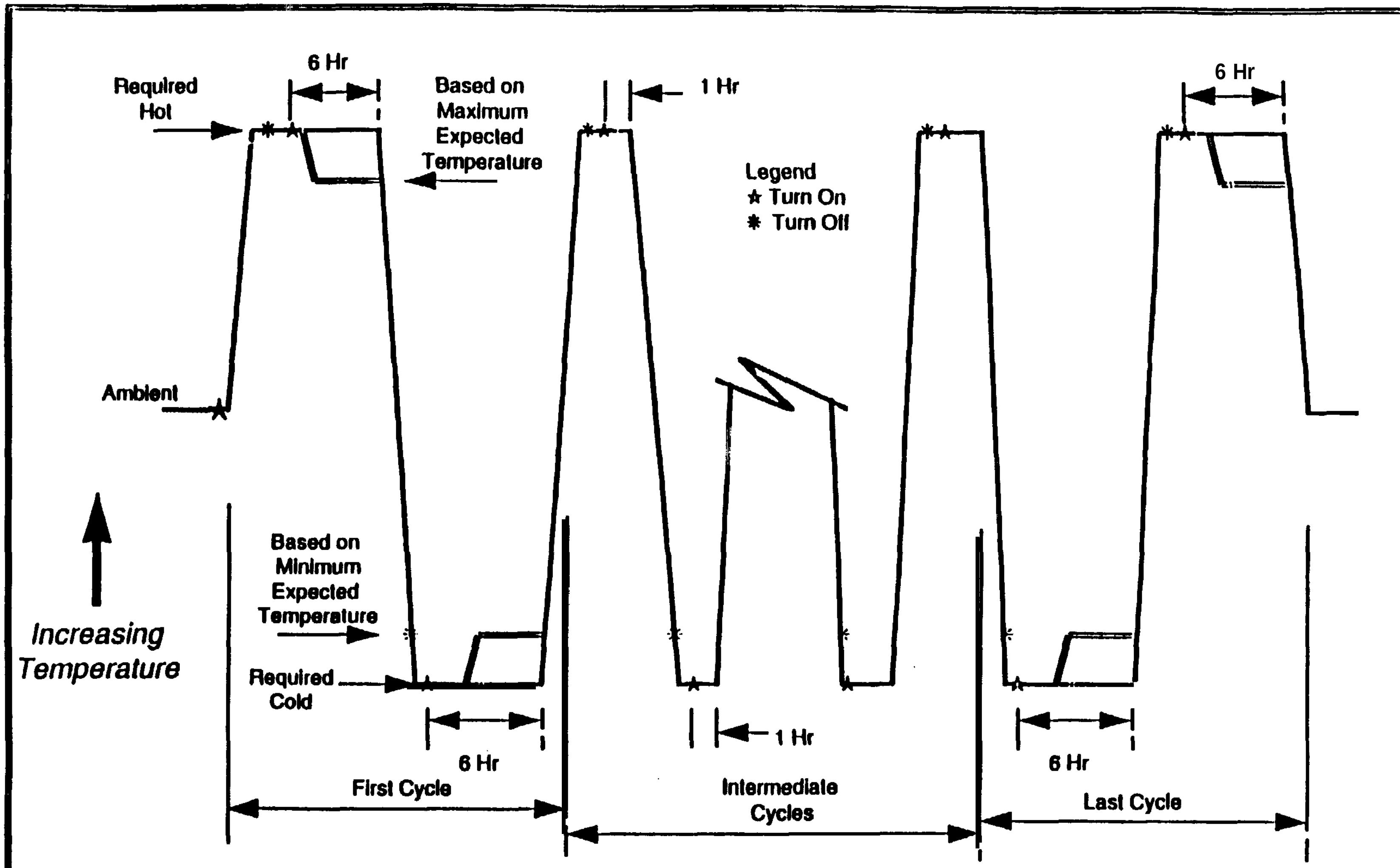
6.4.2 Thermal Cycle Test, Electrical and Electronic Unit Qualification

6.4.2.1 Purpose. The thermal cycle test demonstrates the ability of electrical and electronic units to operate over the qualification temperature range and to endure the thermal cycle testing imposed during acceptance testing.

6.4.2.2 Test Description. With the unit operating (power on) and while perceptive parameters are being monitored, the test shall follow the temperature profile in Figure 1. The test control temperature shall be measured at a representative location on the unit, such as at the mounting point on the baseplate. Each time the control temperature has stabilized (3.5.7) at the hot temperature, the unit shall be turned off and then hot started. Then, with the unit operating, the control temperature shall be reduced to the cold temperature and the unit turned off. To aid in reaching the cold temperature, the unit may be powered off when the temperature of the unit is at least 10°C colder than its minimum expected temperature (3.3.1). After the unit has stabilized at the cold temperature, the unit shall be cold started. Temperature change from ambient to hot, to cold, and return to ambient constitutes one thermal cycle.

6.4.2.3 Test Levels and Duration

a. Pressure and Humidity. Ambient pressure is normally used; however, the thermal cycle test may be conducted at reduced pressure, including vacuum conditions. When unsealed units are being tested, provisions shall be taken to preclude condensation on and within the unit at low temperature. For example, the chamber may be flooded with dry air or nitrogen. Also, the last half cycle shall be hot (Figure 1).



Notes: 1. Operation is continuous except the component is turned off prior to cold and hot start.
2. To facilitate cool down, the component may also be turned off during cool down at temperatures below the minimum expected temperature (3.3.1).

Figure 1. Typical Component Thermal Cycle Profile

b. Temperature The unit temperature shall reach the qualification hot temperature,' 10°C above the acceptance hot temperature (7.1.1), during the hot half cycle; the qualification cold temperature, 10°C below the acceptance cold temperature, during the cold half cycle (Table V). For units exposed to cryogenic temperatures in service, qualification margins shall be prescribed on an individual basis. The transitions between hot and cold should, be at an average rate of 3 to 5°C per minute, and shall not be slower than 1°C per minute.

c. Duration. Table VI shows the number of qualification thermal cycles required for various situations. The last 4 thermal cycles shall be failure free. Thermal soak durations (3.5.10) shall be a minimum of 6 hours at the hot and 6 hours at the cold temperature during the first and last cycle (Figure 1). Intermediate cycles shall have at least 1 -hour soaks at the hot and cold temperatures. During thermal soaks, the unit shall be turned off until the temperature stabilizes (3.5.7) and then turned on, remaining on until the next soak period off-on sequence. Measurement of thermal soak durations shall begin at the time of unit turn-on (Figure 1).

6.4.2.4 Supplementary Requirements. The requirements of the thermal cycle test may be satisfied by extending the thermal vacuum test of 6.4.3, to achieve the number of cycles required to meet the requirements of Table VI. Selection of such an alternative requires that the applicable acceptance test be carried out in the same fashion. Functional tests shall be conducted after the unit temperatures have stabilized at the hot and cold temperatures during the first and last thermal cycle, and after return to ambient. During the remainder of the test, electrical and electronic units, including all redundant circuits and paths, shall be cycled through various operational modes. Perceptive parameters shall be monitored for failures and intermittents to the maximum extent practicable. Units shall meet their performance requirements within specification over the maximum expected temperature range (3.3.1) extended at both temperature extremes by 10°C. For digital units, such as computers, the final thermal cycle should employ a sufficiently slow temperature transition to permit a complete functional check to be repeated at essentially all temperatures.

Moisture condensation inside of electrical or electronic units shall be prevented. Condensation is also minimized by requiring the first and last half cycle to be hot (Figure 1).

6.4.3 Thermal Vacuum Test, Unit Qualification

6.4.3.1 Purpose. The thermal vacuum test demonstrates the ability of the unit to perform in the qualification thermal vacuum environment and to endure the thermal vacuum testing imposed on flight units during acceptance testing. It also serves to verify the unit thermal design.

6.4.3.2 Test Description. The unit shall be mounted in a vacuum chamber on a thermally controlled heat sink or in a manner similar to its actual installation in the vehicle. The unit surface finishes, which affect radiative heat transfer or contact conductance, shall be thermally equivalent to those on the flight units. For units designed to reject their waste heat through the baseplate, a control temperature sensor shall be attached either to the unit baseplate or the heat sink. The location shall be chosen to correspond as closely as possible to the temperature limits used in the vehicle thermal design analysis or applicable unit-to-vehicle interface criteria. For components cooled primarily by radiation, a representative location on the unit case shall similarly be chosen. The unit heat transfer to the thermally controlled heat sink and the radiation heat transfer to the environment shall be controlled to the same proportions as calculated for the flight environment. During testing of radio-frequency (rf) equipment with a possibility of multipaction, a space nuclear radiation environment shall be simulated by a gamma-ray or x-ray source at 4 rads per hour.

The chamber pressure shall be reduced to the required vacuum conditions. Units that are required to operate during ascent shall be operating and monitored for arcing and corona during tne reduction of pressure to the specified lowest levels and during the early phase of vacuum operation. At vacuum pressures below 133 millipascals (10^{-3} Torr), units shall be monitored as appropriate to also assure that multipacting does not occur. Units that do not operate during launch shall have electrical power applied after the test pressure level has been reached.

A thermal cycle begins with the conductive or radiant sources and sinks at ambient temperature. With the unit operating and while perceptive parameters are being monitored, the unit temperature is raised to the specified hot temperature and maintained. All electrical and electronic units that operate in orbit shall be turned off, then hot started after a duration sufficient to ensure the unit internal temperature has stabilized (3.5.7), and then functionally tested. With the unit operating, the component temperature shall be reduced to the specified cold temperature. To aid in reaching the cold temperature, the unit may be powered off when the temperature of the unit is at least 10°C colder than its minimum expected temperature (3.3.1). After the unit temperature has reached the specified cold temperature, the unit shall be turned off (if not previously turned off during the transition) until the internal temperature stabilizes (3.5.7) and then cold started and functionally tested, continuing to maintain the unit at the specified temperature until the end of the soak. The temperature of the sinks shall then be raised to ambient conditions. This constitutes one complete thermal cycle.

6.4.3.3 Test Levels and Duration

a. Pressure. For units required to operate during ascent, the time for reduction of chamber pressure from ambient to 20 pascals (0.15 Torr) shall be at least 10 minutes to allow sufficient time in the region of critical pressure. The pressure shall be further reduced from 20 pascals for operating equipment, or from atmospheric for equipment which does not operate during ascent, to 13.3 millipascals (10^{-4} Torr) at a rate that simulates the ascent profile to the extent practicable. For launch vehicle units, the vacuum pressure shall be modified to reflect an altitude consistent with the maximum service altitude.

b. Temperature. The unit hot and cold temperatures shall be the same as those specified in 6.4.2.3b. An exception is made for a propulsion unit in contact with propellant for which the cold temperature shall be limited to 3°C above the propellant freezing temperature. The transitions between hot and cold should be at an average rate greater than 1°C per minute.

c. Duration. The number of thermal cycles shall be as given in Table VI. Thermal soak durations (3.5.10) shall be a minimum of 6 hours at the hot and 6 hours at the cold temperature during the first and last cycle. Intermediate cycles shall have at least l-hour soaks at the hot and cold temperatures with power turned on. Measurement of thermal soak durations shall begin at the time of unit turn-on (Figure 1).

6.4.3.4 Supplementary Requirements. The 25-cycle test is applicable to units containing electrical or electronic elements where environmental stress screening is imposed for. acceptance testing. For nonelectrical and nonelectronic units, the 6-cycle test applies (Table VI).

Functional tests shall be conducted after unit temperatures have stabilized at the hot and cold temperatures during the first and last cycle, and after return of the unit to ambient temperature in vacuum. During the remainder of the test, electrical and electronic units, including all redundant circuits and paths, shall be cycled through various operational modes. Perceptive parameters shall be monitored for failures and intermittents to the maximum extent practicable. Units shall meet their performance requirements within specifications over the maximum expected temperature range extended by 10°C at the hot and cold limits.

For moving mechanical assemblies, performance parameters (such as current draw, resistance torque or force, actuation time, velocity or acceleration) shall be monitored. Where practicable, force or torque margins shall be determined on moving mechanical assemblies at the temperature extremes. Where this is not practicable, minimum acceptable force or torque margin shall be demonstrated. Compatibility with operational fluids shall be verified at test temperature extremes for valves, propulsion units, and other units as appropriate.

6.4.4 Vibration Test, Unit Qualification

6.4.4.1 Purpose. The vibration test demonstrates the ability of the unit to endure a maximum duration of corresponding acceptance testing and then meet requirements during and after exposure to the extreme expected dynamic environment in flight (3.3.5).

6.4.4.2 Test Description The unit shall be mounted to a fixture through the normal mounting points of the' unit. The same test fixture should be used in the qualification and acceptance vibration tests. Attached wiring harnesses and hydraulic and pneumatic lines up to the first attachment point, instrumentation, and other connecting items should be included as in the flight configuration. Such a configuration shall be required when units that employ shock or vibration isolators are tested on their isolators. The suitability of the fixture and test control means shall have been established prior to the qualification testing (6.4.4.5). The unit shall be tested in each of 3 orthogonal axes. Units required to operate under pressure during ascent shall be. pressurized to simulate flight conditions, from structural and leakage standpoints, and monitored for pressure decay. Units designed for operation during ascent, and whose maximum or minimum expected temperatures fall outside the normal temperature range (7.1 .1), are candidates for combined vibration and temperature testing. When such testing is employed, units shall be conditioned to be as close to the worst-case flight temperature as is practicable and monitored for temperature during vibration exposure.

Units mounted on shock or vibration isolators shall typically require vibration testing at qualification levels in two configurations. A first configuration is with the unit hard-mounted to qualify for the acceptance-level testing if, as is typical, the acceptance testing. is performed without the isolators present. The second configuration is with the unit mounted on the isolators to qualify for the flight environment. The unit shall be mounted on isolators of the same lot as those used in service, if practicable. Units mounted on isolators shall be controlled at the locations where the isolators are attached to the structure. Hard-mounted units shall be controlled at the unit mounting attachments.

6.4.4.3 Test Level and Duration. The test shall be conducted per 6.1.4. For hard-mounted units; a typical version of the test involves-accelerated,+ acceptance-level testing per 6.1.4.2 and applies the qualification level spectrum for 3 minutes per axis. This is based on a qualification margin of 6 dB, a maximum of 6 minutes of accumulated acceptance testing on a flight unit, and a fatigue equivalent duration in flight (3.3.3) of not greater than 15 seconds. Operating time should be divided approximately equally between redundant functions. When insufficient test time is available at the full test level to test redundant circuits, functions, and modes, extended testing using a spectrum no lower than 6 dB below the qualification spectrum shall be conducted as necessary to complete functional testing.

6.4.4.4 Supplementary Requirements During the test, all electrical and electronic units shall be electrically energized and functionally sequenced through various operational modes to the maximum extent practicable. This includes all redundant circuits, and all circuits that do not operate during launch. Several perceptive parameters shall be monitored for failures or intermittents during the test. Continuous monitoring of the unit, including the main bus by a power transient monitoring device, shall be provided to detect intermittent failures. When necessary to prevent unrealistic input forces or unit responses for units whose mass exceeds 23 kilograms (50 pounds), the spectrum may be limited or notched, but not below the minimum test spectrum for a unit (7.1.3). The vibration test does not apply to a unit having a large surface causing its vibration response to be due predominantly to direct acoustic excitation (6.4.5).

6.4.4.5 Fixture Evaluation. The vibration fixture shall be verified by test to uniformly impart motion to the unit under test and to limit the energy transfer from the test axis to the other two orthogonal axes (crosstalk). The crosstalk levels should be lower than the input for the respective axis. In 1/6-octave bands above 1000 Hz, exceedances of up to 3 dB are allowed provided that the sum of their bandwidths does not exceed 300 Hz in a cross axis. The dynamic test configuration (fixture and unit) shall be evaluated for crosstalk before testing to qualification levels.

6.4.4.6 Special Considerations for Structural Units. Vibration acceptance tests of structural units are normally not conducted because the process controls, inspections, and proof testing that are implemented are sufficient to assure performance and quality. However, to demonstrate structural integrity of structural units having critical fatigue-type modes of failure, with a low fatigue margin, a vibration qualification test shall be conducted. The test duration shall be 4 times the fatigue equivalent duration in flight at the extreme expected level (3.3.5). When a structural unit is not subjected to a static strength qualification test, a brief random vibration qualification test shall be conducted with an exposure to 3 dB above the extreme expected level. The duration shall be that necessary to achieve a steady-state response, but not less than 10 seconds, to demonstrate that ultimate strength requirements are satisfied.

6.4.5 Acoustic Test, Unit Qualification

6.4.5.1 Purpose. The acoustic test demonstrates the ability of a unit having large surfaces, whose vibration response is due predominantly to direct acoustic excitations, to endure a maximum duration of acoustic acceptance testing and then meet requirements during and after exposure to the extreme expected dynamic environment in flight (3.3.4). For such units, the acoustic test shall be conducted and the vibration test (6.4.4) is discretionary.

6.4.5.2 Test Description. The unit in its ascent configuration shall be installed in an acoustic test facility capable of generating sound fields or fluctuating surface pressures that induce unit vibration environments sufficient for unit qualification. The unit should be mounted on a flight-type support structure or reasonable simulation thereof. Significant fluid and pressure conditions shall be replicated to the extent practicable. Appropriate dynamic instrumentation shall be installed to measure vibration responses. Control microphones shall be placed at a minimum of 4 well-separated locations at one half the distance from the test article to the nearest chamber wall, but no closer than 0.5 meter (20 inches) to both the test article surface and the chamber wall.

64.53 Jest Level and Duration Same as 6.2.4.3 except the qualification test duration shall be 3 minutes based on a maximum of 6 minutes of accumulated acceptance testing on a flight unit.

6.4.5.4 Supplementary Requirements 6.2.4.4.

6.4.6 Shock Test, Unit Qualification

6.4.6.1 Purpose. The shock test demonstrates the capability of the unit to meet requirements during and after exposureto the extreme expected shock environment in flight (3.3.7).

6.4.6.2 Test Description. The unit shall be mounted to a fixture through the normal mounting points of the unit. The same test fixture should be used in the qualification and acceptance shock tests. If shock isolators are to be used in service, they shall be installed. The selected test method shall be capable of meeting the required shock spectrum with a transient that has a duration comparable to the duration of the expected shock in flight. A mounting of the unit on actual or dynamically similar structure provides a more realistic test than does a mounting on a rigid structure such as a shaker armature or slip table. Sufficient prior development of the test mechanism shall have been carried out to validate the proposed test method before testing qualification hardware. The test environment shall comply with the following conditions:

a. A transient having the prescribed shock spectrum can be generated within specified tolerances.

b. The applied shock transient provides a simultaneous application of the frequency components as opposed to a serial application. Toward this end, it shall be a goal for the duration of the shock transient to approximate the duration of the service shock event. In general, the duration of the shock employed for the shock spectrum analysis shall not exceed 20 milliseconds.

6.4.6.3 Test Level and Exposure. The shock spectrum in each direction along each of the 3 orthogonal axes shall be at least the qualification level for that direction. For vibration or shock isolated units, the lower frequency limit of the response spectrum shall be below 0.7 times the natural frequency of the isolated unit. A sufficient number of shocks shall be imposed to meet the amplitude criteria in both directions of each of the 3 orthogonal axes at least 3 times the number of significant events at that unit location. A significant event for the unit being qualified is one that produces a maximum expected shock spectrum within 6 dB of the envelope of maximum expected spectra (3.3.7) from all events.

6.4.6.4 Supplementary Requirements. Electrical and electronic units, including redundant circuits, shall be energized and monitored to the maximum extent practicable, including those that are not normally operating during the service shock. A functional test shall be performed before and after all shock tests, and several perceptive parameters monitored during the shocks to evaluate performance and to detect any failures. Relays shall not transfer and shall not chatter in excess of specification limits during the shock test.

A shock qualification test is not required along any axis for which both the following are satisfied:

a. The qualification random vibration test spectrum when converted to an equivalent shock response spectrum (3-sigma response for $Q = 10$) exceeds the qualification shock spectrum requirement at all frequencies below 2000 Hz.

b. 'The maximum expected shock spectrum above 2000 Hz does not exceed g values equal to 0.8 times the frequency in Hz at all frequencies above 2000 Hz, corresponding to a velocity of 1.27 meters/second (50 inches/second).

6.4.7 Leakage Test, Unit Qualification

6.4.7.1 Purpose. The leakage test demonstrates the capability of pressurized components and hermetically sealed units to meet the specified design leakage rate requirements.

6.4.7.2 Test Description. An acceptable leak rate to meet mission requirements is based upon development tests and appropriate analyses. An acceptable measurement technique is one that accounts for leak rate variations with differential pressure and hot and cold temperatures and has the required threshold, resolution, and accuracy to detect any leakage equal to or greater than the maximum acceptable leak rate. Consideration should be given to testing units at differential pressures greater or less than the maximum or minimum operating differential pressure to provide some assurance of a qualification margin for leakage. if appropriate, the leak rate test shall be made at qualification hot and cold temperatures with the representative fluid to account for geometry alterations and viscosity changes.

6.4.7.3 Test Level and Duration. Unless otherwise specified, the leakage tests shall be performed with the unit pressurized at the maximum differential operating pressure, as well as at the minimum differential operating pressure if the seals are dependent upon pressure for proper sealing. The test duration shall be sufficient to detect any significant leakage.

6.4.8 Pressure Test, Unit Qualification

6.4.8.1 Purpose. The pressure test demonstrates adequate margin, so that structural failure does not occur before the design burst pressure is reached, or excessive deformation does not occur at the maximum expected operating pressure (MEOP).

6.4.8.2 Description

a. Proof Pressure Test. For items such as pressurized structures and pressure components, a proof test with a minimum of 1 cycle of proof pressure shall be conducted. Evidence of either leakage, a permanent set or distortion that exceeds a drawing tolerance, or failure of any kind shall constitute failure to pass the test.

b. Pressure Cycle Test. For pressurized structures and pressure vessels, a pressure cycle test shall be conducted. Requirements for application of external loads in combination with internal pressures during testing shall be evaluated based on the relative magnitude and on the destabilizing effect of stresses due to the external load. If limit combined tensile stresses are enveloped by the test pressure stress, the application of external load is not required.

c. Burst Test. The pressure shall be increased to the design burst pressure, while simultaneously applying the ultimate external load(s), if appropriate. The internal pressure shall be applied at a sufficiently slow rate that dynamic stresses are negligible. For pressure vessels, after demonstrating no burst at the design burst pressure, the pressure shall be increased to actual burst of the vessel, and the actual burst pressure shall be recorded.

6.4.8.3 Test Levels and Durations.

a. Temperature and Humidity The test temperature and humidity conditions shall be consist&t with the critical-use temperature and humidity. As an alternative, tests may be conducted at ambient conditions if the test pressures are suitably adjusted to account for temperature and humidity effects on material strength and fracture toughness.

b. Proof Pressure. Unless otherwise specified, the minimum proof pressure for pressurized structures shall be 1.1 times the MEOP. For pressure vessels, and other pressure components such as lines and fittings, the minimum proof pressure shall comply with the requirements specified in MIL-STD-1522. The pressure shall be maintained for a time just sufficient to assure that the proper pressure was achieved. Except that for pressure vessels, the hold time shall be a minimum of 5 minutes unless otherwise specified.

c. Pressure Cycle. Unless otherwise specified, the peak pressure for pressurized structures shall equal the MEOP during each cycle, and the number of cycles shall be 4 times the predicted number of operating cycles or 50 cycles, whichever is greater. For pressure vessels, the test shall comply with the requirements specified in MIL-STD-1522.

d. Burst Pressure. Unless otherwise specified, the minimum design burst pressure for pressurized structures shall be 1.25 times the MEOP. For pressure vessels and pressure components, the minimum design burst pressure shall comply with MIL-STD-1522. The design burst pressure shall be maintained for a period of time just sufficient to assure that the proper pressure was achieved.

6.4.8.4 Supplementary Requirements. Applicable safety standards shall be followed in conducting all tests. Unless otherwise specified, the qualification testing of pressure vessels shall include a demonstration of a leak-before-burst (LBB) failure mode using pre-flawed specimens as specified in MIL-STD-1522. The LBB pressure test may be omitted if available material data are directly applicable to be used for an analytical demonstration of the leak-before-burst failure mode.

64.9 Acceleration Test. Unit Qualification

6.4.9.1 Purpose. The acceleration test demonstrates the capability of the unit to withstand or, if appropriate, to operate in the qualification level acceleration environment.

6.4.9.2 Test Description. The unit shall be attached, as it is during flight, to a test fixture and subjected to acceleration in appropriate directions. The specified accelerations apply to the center of gravity of the test item. If a centrifuge is used, the arm (measured to the geometric center of the test item) should be at least 5 times the dimension of the test item measured along the arm. The acceleration gradient across the test item should not result in accelerations that fall below the qualification level on any critical member of the test item. In addition, any over-test condition should be minimized to prevent unnecessary risk to the test article. Inertial units such as gyros and platforms may require counter-rotating fixtures on the centrifuge arm.

6.4.9.3 Test Levels and Duration

a. Acceleration Level. The test acceleration level shall be at least 1.25 times the maximum predicted acceleration (3.4.8) for each direction of test. The factor shall be 1.4 for manned flight.

b. Duration. Unless otherwise specified, the test duration shall be at least 5 minutes for each direction of test.

6.4.9.4 Supplementary Requirements. If the unit is to be mounted on shock or vibration isolators in the vehicle, the unit should be mounted on these isolators during the qualification test.

6.4.10 Life Test. Unit Qualification

6.4.10.1 Purpose. The life test applies to units that may have a wearout, drift, or fatigue-type failure mode, or a performance degradation, such as batteries. The test demonstrates that the units have the capability to perform within specification limits for the maximum duration or cycles of operation during repeated ground testing and in flight.

6.4.10.2 Test Description. One or more units shall be operated under conditions that simulate their service conditions. These conditions shall be selected for consistency with end-use requirements and the significant life characteristics of the particular unit. Typical environments are ambient, thermal, and thermal vacuum to evaluate weatout and drift failure modes; and pressure, thermal, and vibration to evaluate fatigue-type failure modes. The test shall be designed to demonstrate the ability of the unit to withstand the maximum operating time and the maximum number of operational cycles predicted during its service life (3.5.6) with a suitable margin.

6.4.10.3 Test Levels and Durations.

a. Pressure. For pressurized structures and pressure vessels, the pressure level shall be that specified in 6.4.8.3c. For other units, ambient pressure shall be used except where degradation due to a vacuum environment may be anticipated, such as for some unsealed units. in those cases, a pressure of 13.3 miiiipascais (10^{-4} Torr) or less shall be used.

b. Environmental Levels. The extreme expected environmental levels shall be used. Higher levels may be used to accelerate the life testing, provided that the resulting increase in the rate of degradation is well established and that unrealistic failure modes are not introduced.

c. Duration. For pressurized structures and pressure vessels, the duration shall be that specified in 6.4.8.3c. For other units, the total operating time or number of operational cycles shall be at least 2 times that predicted during the service life (3.5.6), including ground testing, in order to demonstrate an adequate margin. For a structural component having a fatigue-type failure mode that has not been subjected to a vibration qualification test, the test duration shall be at least 4 times the specified service life.

d. Functional Duty Cycle. Complete functional tests shall be conducted before the test begins and after completion of the test. During the life test, functional tests shall be conducted in sufficient detail, and at suffkientiy short intervals, so as to establish trends.

6.4.10.4 Supplementary Requirements. For statistically-based life tests, the duration is dependent upon the number of samples, confidence, and reliability to be demonstrated.. The mechanisms in each unit that are subjected to wearout should be separately tested. For these mechanisms, the duration of the life test should assure with high confidence that the mechanisms will not wear out during their service life. At the end of the life test, mechanisms and moving mechanical assemblies shall be disassembled and inspected for anomalous conditions. The hardware may be disassembled and inspected earlier if warranted. The critical areas of parts that may be subject to fatigue failure shall be inspected to determine their integrity.

6.4.11 Electromagnetic Compatibility (EMC) Test, Unit Qualification

6.4.11.1 Purpose. The electromagnetic compatibility test shall demonstrate that the electromagnetic interference characteristics (emission and susceptibility) of the unit, under normal operating conditions, do not result in malfunction of the unit. It also demonstrates that the unit does not emit, radiate, or conduct interference which could result in malfunction of other units.

6.4.11.2 Test Description. The test shall be conducted in accordance with the requirements of MIL-STD-1541. An evaluation shall be made of each unit to determine which tests shall be performed as the baseline requirements.

6.4.12 Climatic Tests, Unit Qualification

6.4.12.1 Purpose. These tests demonstrate that the unit is capable of surviving exposure to various climatic conditions without excessive degradation, or operating during exposure, as applicable. Exposure conditions include those imposed upon the unit during fabrication, test, shipment, storage, preparation for launch, launch itself, and reentry if applicable. These can include such conditions as humidity, sand and dust, rain, salt fog, and explosive atmosphere. Degradation due to fungus, ozone, and sunshine shall be verified by design and material selection.

It is the intent that environmental design of flight hardware not be unnecessarily driven by terrestrial natural environments. To the greatest extent feasible, the flight hardware shall be protected from the potentially degrading effects of extreme terrestrial natural environments by procedural controls and special suppon equipment. Only those environments that cannot be controlled need be considered in the design and testing.

6.4.12.2 Humidity Test Unit Qualification

6.4.12.2.1 Purpose. The humidity test demonstrates that the unit is capable of surviving or operating in, if applicable, warm humid environments. In the cases where exposure is controlled throughout the life cycle to conditions with less than 55-percent relative humidity, and the temperature changes do not create conditions where condensation occurs on the hardware, then verification by test is not required.

6.4.12.2.2 Test Description and Levels. For Units exposed to unprotected ambient conditions, the humidity test shall conform to the method given in MIL-STD-810. For units located in protected, but uncontrolled environments, the unit shall be installed in a humidity chamber and subjected to the following conditions (time line illustrated in Figure 2):

a. Pretest Conditions. Chamber temperature shall be at room ambient conditions with uncontrolled humidity.

b. Cycle 1. The temperature shall be increased to + 35°C over a l-hour period; then the humidity shall be increased to not less than 95 percent over a l-hour period with the temperature maintained at +35°C. These conditions shall be maintained for 2 hours. The temperature shall then be reduced to + 2°C over a 2-hour period with the relative humidity stabilized at not less than 95 percent. These conditions shall be maintained for 2 hours.

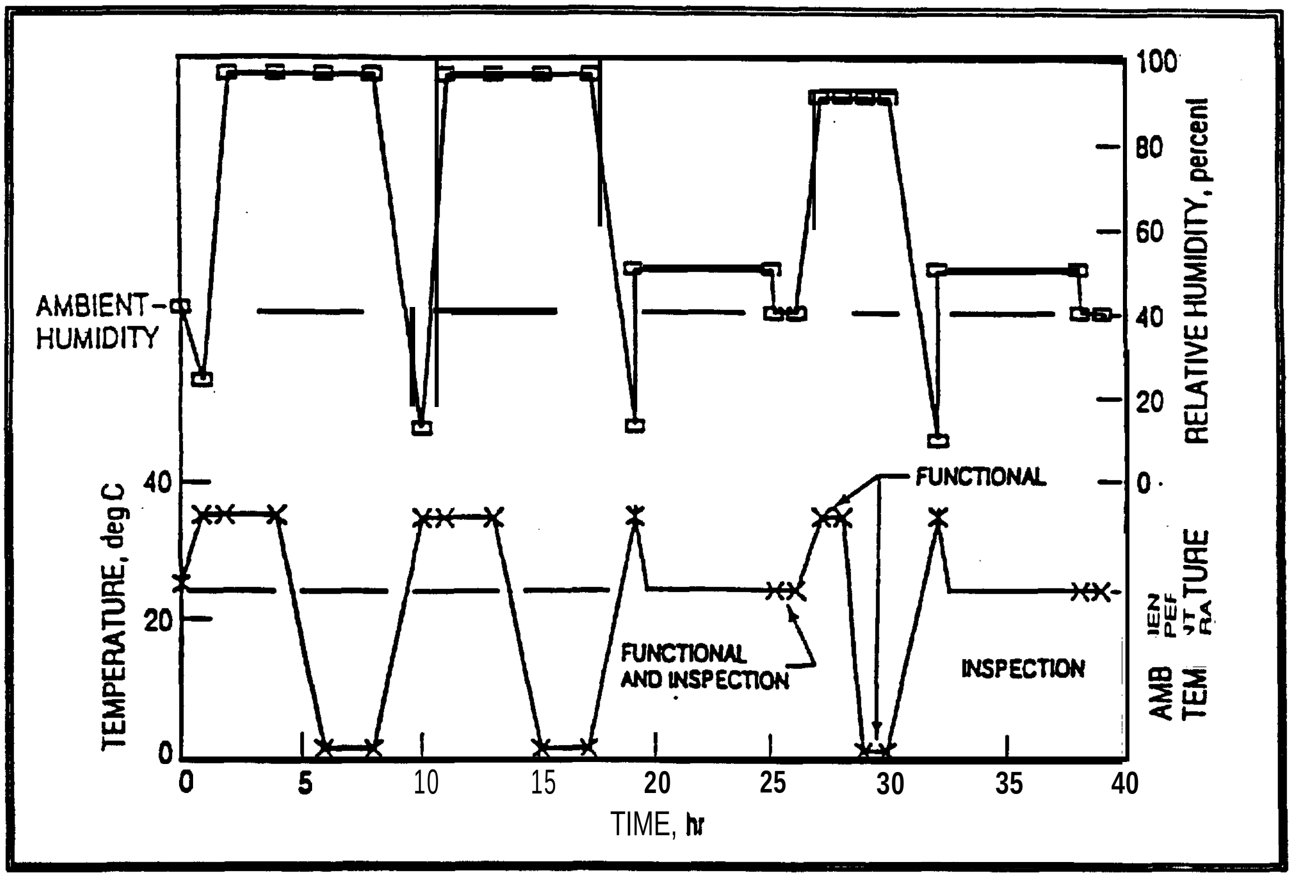


FIGURE 2. Humidity Test Time Line.

c. Cycle 2. Cycle 1 shall be repeated except that the temperature shall be increased from + 2°C to + 35°C over a 2-hour period; moisture is not added to the chamber until +35°C is reached.

d. Cycle 3. The chamber temperature shall be increased to + 35°C over a 2-hour period without adding any moisture to the chamber. The test unit shall then be dried with air at room temperature and 50-percent maximum relative humidity by blowing air through the chamber for 6 hours. The volume of air used per minute shall be equal to 1 to 3 times the test chamber volume. A suitable container may be used in place of the test chamber for drying the test unit.

e. Cycle 4. If it had been removed, the unit shall be placed back in the test chamber and the temperature increased to +35°C and the relative humidity increased to 90 percent over a l-hour period; and these conditions shall be maintained for at least 1 hour. The temperature shall then be reduced to + 2°C over a l-hour period with the relative humidity stabilized at 90 percent; and these conditions shall be maintained for at least 1 hour. A drying cycle should follow (see Cycle 3).

6.4.12.2.3 Supplementary Requirements. The unit shall be functionally tested prior to the test and at the end of Cycle 3 (within 2 hours after the drying) and visually inspected for deterioration or damage. The unit shall be functionally tested during the Cycle 4 periods of stability, after the l-hour period to reach + 35°C and 90-percent relative humidity, and again after the 1 -hour period to reach the +2°C and 90-percent relative humidity.

6.4.12.3 Sand and Dust Test. Unit Qualification

6.4.12.3.1 Purpose. The sand and dust test is conducted to determine the resistance of units to blowing fine sand and dust particles. This test shall not be required for units protected from sand and dust by contamination control, protective shipping and storage containers, or covers. However, in those cases, rain testing demonstrating the adequacy of the protective shelters, shipping and storage containers, or covers, as applicable, may be required instead of a test of the unit itself.

6.4.12.3.2 Test 'De - The test requirements for the sand and dust test shall conform to the method 'given in MIL-STD-810.

6.4.12.4 Rain Test, Unit Qulification

6.4.12.4.1 Purpose. The rain test shall be conducted to determine the resistance of units to rain. Units protected from rain by protective shelters, shipping and storage containers, or covers, shall not require verification by test.

6.4.12.4.2 Test Description. Buildup of the unit, shelter, container, or the cover being tested shall be representative of the actual fielded configuration without any duct tape or temporary sealants. The initial temperature difference between the test item and the spray water shall be a minimum of 10°C. For temperature-controlled containers, the temperature difference between the test item and the spray water shall at least be that between the maximum control temperature and the coldest rain condition in the field. Nozzles used shall produce a square spray pattern or other overlapping pattern (for maximum surface coverage) and droplet size predominantly in the 2 to 4.5 millimeter range at approximately 375 kilopascals gage pressure (40 psig). At least one nozzle shall be used for each approximately 0.5 square meter (6 ft^2) of surface area and each nozzle shall be positioned at 0.5 meter (20 inches) from the test surface. Ail exposed faces shall be sprayed for at least 40 minutes. The interior shall be inspected for water penetration at the end of each 40-minute exposure. Evidence of water penetration shall constitute a failure.

6.4.12.5 Salt Foa Test, Unit Qualification

6.4.12.5.1 Purpose. The salt fog test is used to demonstrate the resistance of the unit to the effects of a salt spray atmosphere. The salt fog test is not required if the flight hardware is protected against the salt fog environment by suitable preservation means and protective shipping and storage containers.

6.4.12.5.2 Jest Description. The requirements for the salt fog test shall conform to the method given in MIL-STD-810.

6.4.12.6 Explosive Atmosphere Test, Unit Qualification

6.4.12.6.1 Purpose. The explosive atmosphere test is conducted to demonstrate unit operability in an ignitable fuel-air mixture without igniting the mixture.

6.4.12.6.2 Test Description The test requirements for the explosive atmosphere test shall conform to'the method given in MIL-STD-810.

SECTION 7

ACCEPTANCE TESTS

7.1 GENERAL ACCEPTANCE TEST REQUIREMENTS

Acceptance tests shall be conducted as required to demonstrate the acceptability of each deliverable item. The tests shall demonstrate conformance to specification requirements and provide quality-control assurance against workmanship or material deficiencies. Acceptance testing is intended to stress screen items to precipitate incipient failures due to latent defects in pans, materials, and workmanship. However, the testing shall not create conditions that exceed appropriate design safety margins or cause unrealistic modes of failure. If the equipment is to be used by more than one program or in different vehicle locations, the acceptance test conditions should envelope those of the various programs or vehicle locations involved. Typical acceptance test levels and durations are summarized in Table XI, and are detailed in subsequent paragraphs.

The test baseline shall be tailored for each program, giving consideration to both the required and other tests (3.5.4). For special items, such as some tape recorders and certain batteries, the specified acceptance test environments would result in physical deterioration of materials or other damage. In those cases, less severe acceptance test environments that still satisfy the system operational requirements shall be used.

7.1.1 Temperature Range and Number of Thermal Cycles, Acceptance Tests. Two requirements on the unit acceptance temperature range (Figure 3) are:

a. The range shall encompass the maximum and minimum expected temperatures (3.3.1).

b. The range should be as large as practicable to meet environmental stress screening purposes. A rang8 of 105°C is recommended, and is the basis used in Tables V and VI.

For units, the range from -44 to +61°C is recommended if requirement "a" is satisfied. The number of cycles shall be in compliance with Table VI. If this 105°C temperature range, plus the 10°C hot and cold extension for qualification, gives rise to unrealistic failure modes or unrealistic design requirements, the rang8 may be shifted or reduced to the extent necessary. To compensate for a reduced range, the number of thermal cycles for acceptance tests shall then be increased per-note 3 of Table VI. For units exposed to cryogenic temperatures, acceptance temperature limits shall encompass the highest and lowest temperatures with appropriate uncertainty margins (Table II). For units which do not contain electrical or electronic elements, the minimum acceptance test shall be 1 thermal vacuum cycle in accordance with 7.4.3.

For vehicle thermal vacuum tests, at least one unit shall reach its acceptance hot temperature during hot soaks. During cold soaks at least one unit shall reach its acceptance cold temperature. If the ambient pressure thermal cycle alternative test is selected, the minimum temperature range shall be 50°C. The number of thermal vacuum and thermal cycles are specified in Table VI.

TABLE XI. Typical Acceptance Test Levels and Durations.

Test	Units	Vehicles
Shock	Maximum expected spectrum (3.3.7), achieved once in both directions of 3 axes. Discretionary if spectrum is low (7.4.6.4).	1 activation of significant shock-producing events (7.2.3.3).
Acoustic	Same as for vehicles.	Envelope of maximum expected spectrum (3.3.4) and minimum spectrum (Figure 4), 1 minute.
Vibration	Envelope of maximum expected spectrum (3.3.5) and minimum spectrum (Figure 5), 1 minute in each of 3 axes.	Same as for units, except minimum spectrum in Figure 6.
Thermal Vacuum*	1 cycle, -44 to +61°C (7.1.1). Vacuum at 13.3 millipascals (10^{-4} Torr).	4 cycles, -44 to +61°C (7.2.8). Same pressure as for units.
Thermal Cycle*	12.5 cycles, -44 to +61°C.	See 7.2.7.
Combined Thermal Vacuum and Cycle*	8.5 thermal cycles and 4 thermal vacuum cycles, -44 to +61°C.	See 7.2.7.
Proof Load	For bonded structures and structures made of composite material, or having sandwich construction: 1.1 times limit load.	Same as for units, but only tested at subsystem level.
Proof Pressure	For pressurized structures, 1.1 times the MEOP. For pressure vessels and other pressure components, comply with MIL-STD-1522.	Same as for units.

*See Tables V and VI.

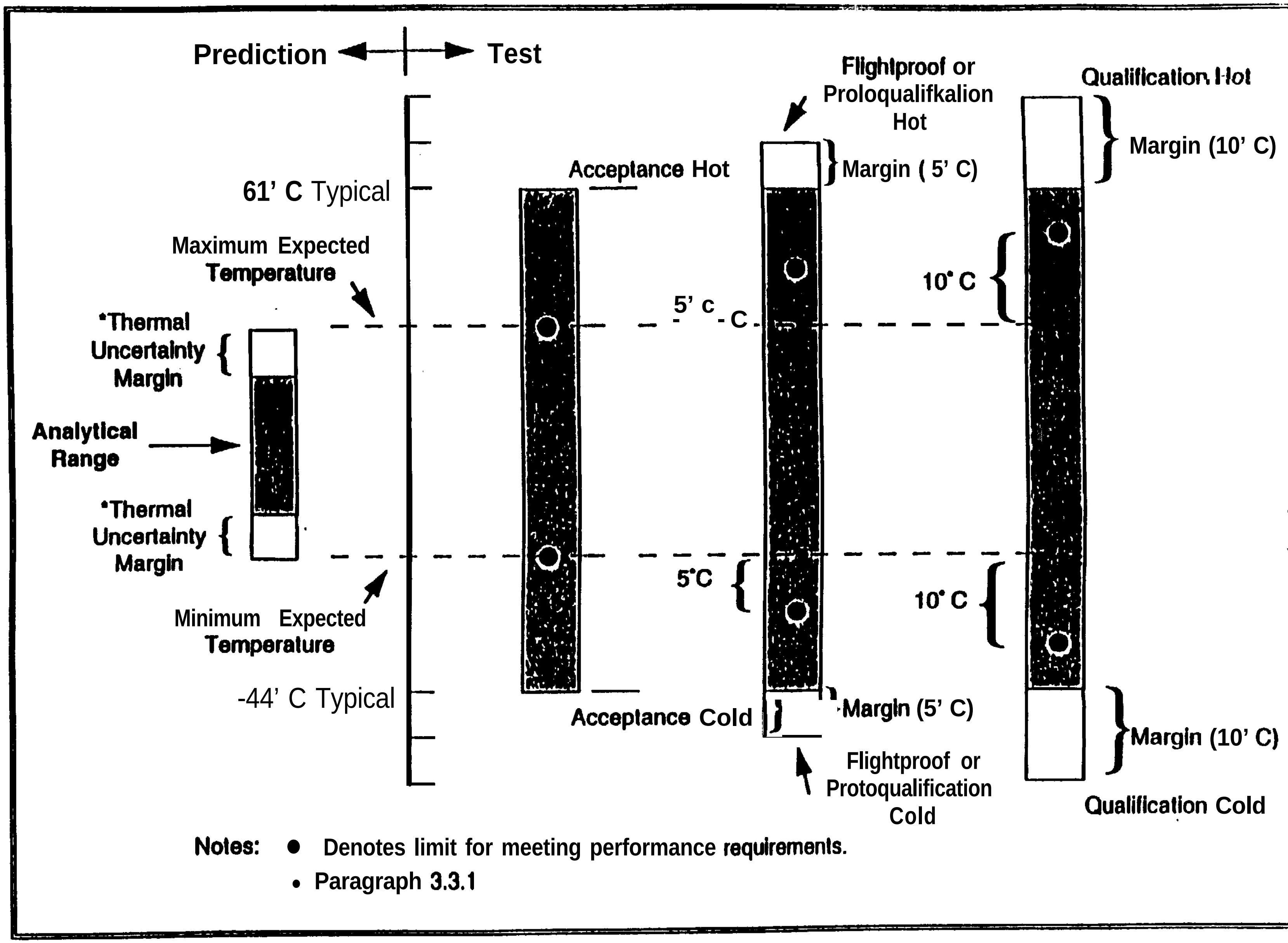


FIGURE 3. Unit Predicted and Test Temperature Ranges.

&‘.‘A”:‘.,”
7.1.2 Acoustic EnvirOnme t. cceotance Tests. The acceptance test acoustic spectrum shall be the maximum expected environment (3.3.4), but not less than the minimum free-field spectrum in Figure 4. The minimum duration of the acceptance acoustic test is 1 minute.

7.1.3 Vibration Environment, Acceptance Tests. The acceptance test random vibration spectrum shall be the maximum expected environment (3.3.5), but not below the minimum spectrum in Figure 5 for a unit or below the minimum spectrum in Figure 6 for a vehicle. The minimum spectrum for a unit whose mass exceeds 23 kilograms (50 pounds) should be evaluated on an individual basis. The acceptance sinusoidal vibration amplitude, if significant, shall be that of the maximum expected sinusoidal vibration environment (3.3.6). When concurrent random and sinusoidal vibration during service life (3.5.6) can be more severe than either considered separately, an appropriate combination of the two types of vibration should be used for the test. The minimum duration of the acceptance random vibration test shall be 1 minute for each of 3 orthogonal axes.

7.1.4 cceptance Tests: Vehicle. Subsvstem. or Unit A . Storage test requirements consist of appropriate testing after storage (such as vibration, thermal, and static load or pressure) based on the vehicle design, and the duration and conditions of storage. Items having age-sensitive material may require periodic retesting and those having rotating elements may require periodic operation.

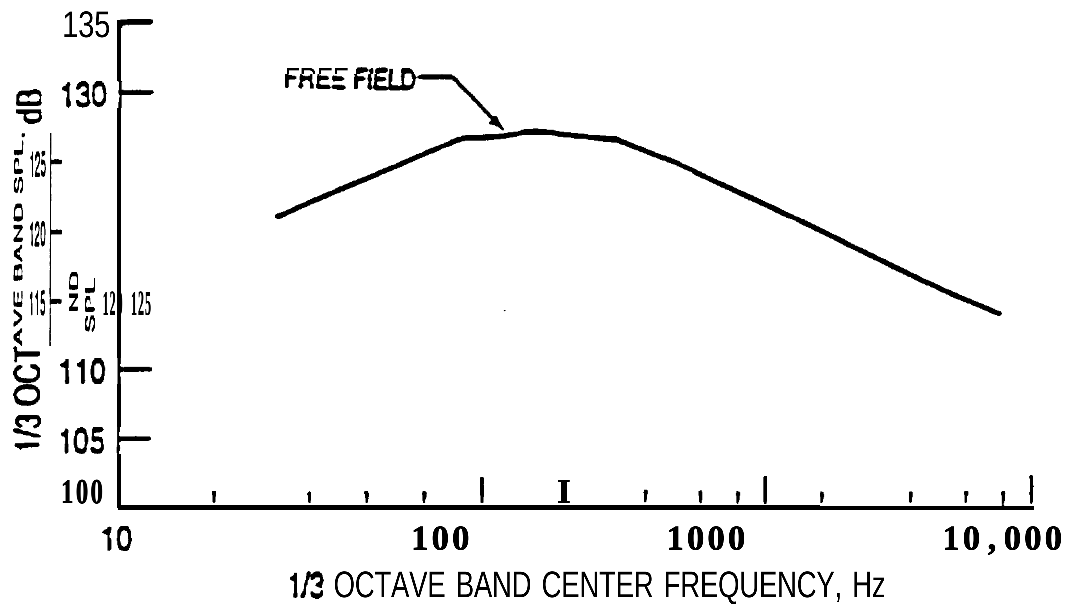
7.2 VEHICLE ACCEPTANCE TESTS

The vehicle acceptance test baseline shall include all the required tests specified in Table XII. The “other” tests (3.5.4) deemed applicable, and any special tests for the vehicle element (such as alignments, instrument calibrations, antenna patterns, and mass properties) shall also be conducted as part of acceptance testing. If the vehicle is controlled by on-board data processing, the flight version of the computer software shall be resident in the vehicle computer for these tests. The verification of the operational requirements shall be demonstrated in these tests to the extent practicable.

7.2.1 Functional Test, Vehicle Acceptance

7.2.1.1 Purpose. The functional test verifies that the electrical and mechanical performance of the vehicle meets the performance requirements of the specifications and detects any anomalous condition.

7.2.1.2 Mechanical Functional Test. Same as the mechanical functional test for vehicle qualification (6.2.1.2), except tests are only necessary at nominal operational conditions.

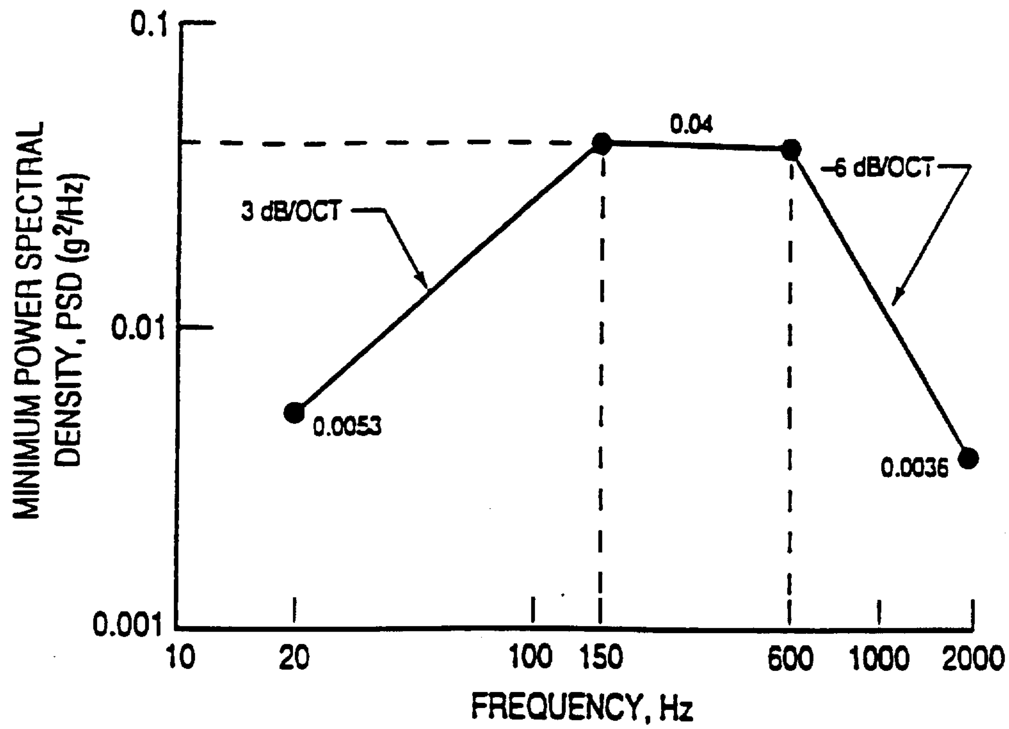


dB reference: 20 micropascals

Curve Values

1/3-Octave-Band Center Frequency (Hz)	Minimum Sound Pressure Level (dB)	1/3-Octave-Band Center Frequency (Hz)	Minimum Sound Pressure Level (dB)
31	121	630	125
40	122	800	124
50	123	1000	123
63	124	1250	122
80	125	1600	121
100	125.7	2000	120
125	126.5	2500	119
160	126.7	3150	118
200	127	4000	117
250	127	5000	116
315	126.7	6300	115
400	126.5	8000	114
500	125.7	10000	113
		Overall	138

FIGURE 4. Minimum Free-field Acoustic Spectrum, Vehicle and Unit Acceptance Tests.

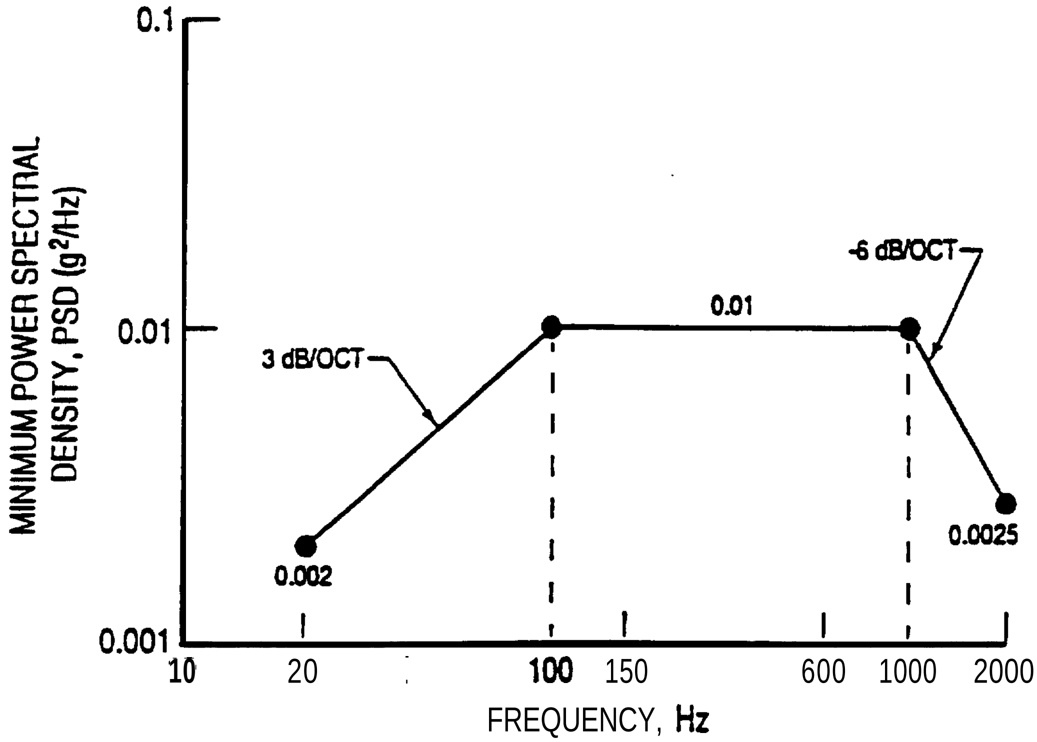


Curve Values	
Frequency (Hz)	Minimum PSD (g^2/Hz)
20	0.0053
20 to 150	+3 dB per octave slope
150 to 600	0.04
600 to 2000	-6 dB per octave slope
2000	0.0036

The overall acceleration level is 6.1 grms.

Note: This spectrum applies only to units whose mass does not exceed 23 kilograms (50 pounds).

FIGURE 5. Minimum Random Vibration Spectrum, Unit Acceptance Tests.



Curve Values	
Frequency (Hz)	Minimum PSD (g^2/Hz)
20	0.002
20 to 100	+3 dB per octave slope
100 to 1000	0.01
1000 to 2000	-6 dB per octave slope
2000	0.0025

The overall acceleration level is 3.8 grms.

FIGURE 6. Minimum Random Vibration Spectrum, Vehicle Acceptance Tests.

TABLE XII. Vehicle Acceptance Test Baseline.

TEST	REFERENCE PARAGRAPH	SUGGESTED SEQUENCE	LAUNCH VEHICLE	UPPER STAGE	SPACE VEHICLE
Inspection'	4.4	1	R	R	R
Functional'	7.2.1	2	R	R	R
Pressure/Leak	7.2.6	3,7,10	R	R	R
EMC	7.2.2	4		0	0
Shock	7.2.3	5	0	0	0
Acoustic Of Vibration 2	7.2.4 or 7.2.5	6	0	R	R
Thermal Cycle	7.2.7	8	0	0	0
Thermal Vac[3]	7.2.0	9	0.	R	R
Storage	7.1.4	any	0	0	0

All vehicle qualification requirements to be specified by the procuring agency (4.1). Symbols (10.2.1.3) indicate the following:

R = baseline requirement (high probability of being required)

o = "other" (low probability of being required; 3.5.4)

— = not required (negligible probability of being required).

Notes: 1 Required before and following each test as appropriate. Include special tests as applicable (7.2).

2 Vibration conducted in place of acoustic test for a compact vehicle„ typically with mass less than 180 kg (400 lb).

3 Requirements modified if thermal cycle test (7.2.7) conducted.

7.2.1.3 Electrical and Fiber-optic Circuit Functional Test Same as the electrical functional test for vehicle qualification (6.2.1.3), except that tests are limited to critical functions and are only necessary at nominal operational conditions. The final ambient functional test conducted prior to shipment of the vehicle to the launch base provides the data to be used as success criteria during launch base testing. For this reason, the functional test should be designed so that its critical features can be duplicated, as nearly as practicable, at the launch base. The results of all factory functional tests, and of those conducted at the launch base, shall be used for trend analysis.

7.2.1.4 Supplementary Requirements. Same as 6.2.1.4.

7.2.2 Electromagnetic Compatibility (EMC) Test. Vehicle Acceptance. Limited EMC acceptance testing shall be accomplished on vehicles to check on marginal EMC compliance indicated during vehicle qualification testing and to verify that major changes have not occurred on successive production equipment. The limited tests shall include measurements of power bus ripple and peak transients, and monitoring of selected critical circuit parameters.

7.2.3 Shock Test. Vehicle Acceptance

7.2.3.1 Purpose. The shock test simulates the dynamic shock environment imposed on a vehicle in flight in order to detect material and workmanship defects.

7.2.3.2 Test Description. Same as 6.2.3.2, except that the dynamic instrumentation may be reduced.

7.2.3.3 Test Activations Shock acceptance testing of vehicles should be performed in those instances deemed advisable due to severity of the environment or susceptibility of the design. One activation of those events causing significant shocks to critical and shock sensitive units should be conducted. Firing of both primary and redundant explosive-ordnance devices is required in the same relationship as they are to be used in flight. However, when the structure is explosively severed, as in the case of a shaped charge, such testing is discretionary. To aid in fault detection, the shock test should be conducted with subsystems operating and monitored to the greatest extent practicable.

7.2.4 Acoustic Test. Vehicle Acceptance

7.2.4.1 Purpose. The acoustic test simulates the flight or minimum workmanship-screen acoustic environment and the induced vibration on units in order to expose material and workmanship defects that might not be detected in a static test condition. It also serves as an acceptance test for functional subsystems, units, and interconnection items that have not been previously acceptance tested.

7.2.4.2 Test Description. Same as 6.2.4.2, except that the dynamic instrumentation may be reduced.

7.2.4.3 Test Level and Duration. The acoustic environment shall be as defined in 7.1.2. Operating time for launch operating elements should be divided approximately equally between redundant units. Where insufficient time is available to test redundant units, functions, and modes that are operating during the launch, ascent, or reentry phase, extended testing shall be at a level no lower than 6 dB below the acceptance level.

7.2.4.4 Supplementary Requirements. Same as 6.2.4.4, except only units that are operating or pressurized during launch, ascent, or reentry phase need be energized and sequenced through operational modes.

7.2.5 Vibration Test, Vehicle Acceptance

7.2.5.1 Purpose. Same as 7.2.4.1. The vibration test may be conducted in lieu of an acoustic test (7.2.4) for a compact vehicle which can be excited more effectively via interface vibration than by an acoustic field. Such vehicles typically have a mass below 180 kilograms (400 pounds).

7.2.5.2 Test Description. Same as 6.2.5.2, except that dynamic instrumentation may be reduced.

7.2.5.3 Jest Level and Duration. The random vibration environment shall be as defined in 7.1.3. When necessary to prevent excessive input forces or unit responses, the spectrum at the vehicle input may be limited or notched, but not below the minimum spectrum in Figure 6. Vibration shall be applied in each of the 3 orthogonal axes as tested for qualification. Where insufficient time is available to test redundant circuits, functions, and modes that are operating during the launch, ascent, or reentry phase, extended testing shall be at a level no lower than 6 dB below the acceptance level.

7.2.5.4 Supplementary Requirements. Same as 6.2.5.4, except only units that are operating or pressurized during the launch, ascent, or reentry phase need be energized and sequenced through operational modes.

7.2.6 Pressure and Leakage Tests, Vehicle Acceptance

7.2.6.1 Purpose. The pressure and leakage test demonstrates the capability of fluid subsystems to meet the specified flow, pressure, and leakage requirements.

7.2.6.2 Test De -. Same as 6.2.6.2.

7.2.6.3 Test Levels and Durations.

a. Same as 6.2.6.3a.

b. Same as 6.2.6.3b, except only 1 pressure cycle.

7.2.6.4 Supplementary Requirements. Same as 6.2.6.4.

7.2.7 Thermal Cycle Test, Vehicle Acceptance

7.2.7.1 Purpose. The thermal cycle test detects material, process, and workmanship defects by subjecting the vehicle to a thermal cycle environment.

7.2.7.2 Test Description. Same as 6.2.7.2.

7.2.7.3 Test Level and Duration. The minimum temperature range shall be 50°C. The average rat8 of change of temperature from one extreme to the other shall be as rapid as practicable. Operating time should be divided approximately equally between redundant circuits. The minimum number of thermal cycles shall be 4 (Tables V and VI).

7.2.7.4 Supplementary Requirements. Same as 6.2.7.4. If the thermal cycle test is implemented, Only one thermal cycle is required in the thermal vacuum acceptance test specified in 7.2.8.

7.2.8 Thermal Vacuum Test, Vehicle Acceptance

7.2.8.1 Purpose. The thermal vacuum test detects material, process, and -workmanship defects that would respond to vacuum and thermal stress conditions and verifies thermal control.

7.2.8.2 Test Description. Same as 6.2.9.2.

7.2.8.3 Test Levels and Duration. Temperatures in various equipment areas shall be controlled by the external test environment and internal heating resulting from equipment operation so that the hot (or cold) temperature on at least one unit in each equipment area equals the acceptance test temperature as defined in 7.1.1. For space and upper-stage vehicles, the pressure shall be maintained at or below 13.3 millipascals (10^{-4} Torr). For launch vehicles, the pressure shall be maintained at equal to or less than the pressure commensurate with the highest possible service altitude.

Operating time should be divided approximately equally between redundant circuits. The thermal vacuum acceptance test shall include at least 4 complete hot-cold cycles at the maximum predicted orbital rate of temperature change and have at least an 8-hour soak at the hot and cold temperatures during the first and last cycles. For intermediate cycles, the soak duration at each temperature extreme shall be 4 hours minimum. The soak duration shall be extended as necessary to test flight operational conditions including redundancy. If the alternate thermal cycle test (7.2.7) is conducted, then only 1 hot-cold thermal vacuum cycle shall be conducted with an 8-hour minimum soak duration at hot and cold temperatures (Tables V and VI).

During one cycle, thermal equilibrium shall be achieved at both hot and cold temperatures to allow collection of sufficient data to verify the function of any thermostats, louvers, heat pipes, electric heaters, and to assess the control authority of active thermal subsystems.

7.2.8.4 Supplementary Requirements. Same as 6.2.9.4, except that the acceptance temperature limits apply. Performance within specification is not required at temperatures beyond the maximum and minimum expected temperatures.

7.3 SUBSYSTEM ACCEPTANCE TESTS

Except for pressurized subsystems, subsystem-level acceptance tests are considered discretionary. These tests can be effective since failures detected at this level usually are much less costly to correct than are those detected at the vehicle level. Also, certain acceptance tests should be conducted at the subsystem level where this level provides a more perceptive test than would be possible at either the unit or vehicle level. The desirability of conducting these subsystem acceptance tests should be evaluated considering such factors as

a. The relative accessibility of the subsystem and its units.

b. The retest time at the vehicle level.

c. The cost and availability of a subsystem for testing of spare units.

When subsystem level tests are performed, the test requirements are usually based on vehicle-level test requirements.

7.3.1 Proof Load Test, Structural Subsystem Acceptance

7.3.1 .l Purpose. The proof load test shall be required for all bonded structures, and structures made of composite material or having sandwich construction. It detects material, process, and workmanship defects that would respond to structural proof loading. The proof load test is not required if a proven nondestructive evaluation method, with well established accept and reject criteria, is used.

7.3.1.2 Test Descriptions. Same as 6.3.1.2, except that every structural element shall be subjected to its proof load and not to higher loading.

7.3.1.3 Test Level and Duration

a. Static Load. Unless otherwise specified, the proof load for flight items shall be 1 .1 times the limit load (3.4.6).

b. Duration. Loads shall be applied as closely as practicable to actual flight loading times, with a minimum dwell time sufficient to record test data.

7.3.2 Proof Pressure Test, Pressurized Subsystem Acceptance

7.3.2.1 Purpose. The proof pressure test detects material and workmanship defects that could result in failure of the pressurized subsystem.

7.3.2.2 Test Description. Same as 6.4.8.2a.

7.3.2.3 Test Levels and Duration. Same as 6.4.8.3b.

7.4 UNIT ACCEPTANCE TESTS

The unit acceptance test baseline consists of all the required tests specified in Table XIII. Any special tests, and the "other" tests (3.5.4) deemed applicable, shall also be conducted as part of acceptance testing.

Unit acceptance tests shall normally be accomplished entirely at the unit level. Acceptance tests of certain units (such as solar arrays, interconnect tubing, radio-frequency circuits, and wiring harnesses) may be partially accomplished at higher levels of assembly.

Where units fall into two or more categories of Table XIII, the required tests specified for each category shall be applied. For example, a star sensor may be considered to fit both "Electrical and Electronic Equipment" and "Optical Equipment" categories. In this example, a thermal cycle test would be conducted since it is required for electronic equipment, even though there is no requirement for thermal cycling of optics. Similarly, an electric motor-driven-actuator fits both "Electrical and Electrical Equipment" and "Moving Mechanical Assembly" categories. The former makes thermal cycling a required test, even though this is an "other" test (3.5.4) for the moving mechanical assembly category.

7.4.1 Functional Test, Unit Acceptance

7.4.1.1 Purpose. The functional test verifies that the electrical and mechanical performance of the unit meets the specified operational requirements of the unit.

7.4.1.2 Test Description. Same as 6.4.1.2.

7.4.1.3 Supplementary Requirements. Same as 6.4.1.3.

TABLE XIII. Unit Acceptance Test **Baseline.**

Test	Reference Paragraph	Suggested Sequence	Electrical and Electronic	Antenna	MMA	Solar Array	Battery	Valve or Propulsion Component	Pressure Vessel or Component	Thruster	Thermal	Optical	Structural Component
Inspection[1]	4.6	1	R	R	R	R	R	R	R	R	R	R	R
Functional’	7.4.1	3	R	R	R	R	R	R	R	R	R	R	—
Leakage[3]	7.4.9	**4,7,12**	R	—	R	—	R	R	R	O	O	—	—
Shock	**7.4.6**	6	O[4]	—	—	—	—	—	—	—	—	O	—
Vibration	7.4.4	**6**	R	R^5	R	R^5	R^8	R	0	R	R	R^6	—
Arcoustk	7.4.6	6	0	R^5	—	R^5	—	—	—	—	—	R^6	—
Thermal Cycle	7.4.2	**8**	R_2	—	—	—	—	—	—	—	—	—	—
T‘hermal **Vac**	7.4.3	**9**	R^2	O	R^7	O	R^8	R	O	R	R	R	O
Wear-in	7.4.10	2	—	—	R	—	—	R		R	—	—	—
Proof Pressure	7.4.8	**10**	—	—	O	—	O	R	R	O	—	—	—
P‘roof Load	7.4.7	**11**	—	—	—	—	—	—					O^6
EMC	**7.4.11**	13	0	—	—	—	—	—					

All vehicle qualification requirements to be specified by the procuring agency (4.11.

Symbols **(10.2.1.3)** indicate the following:

- R = baseline requirement (high probability of being required)
- O = “other’ flow probability of being required; **3.5.4)**
- — = not required (negligible probability of being required).

Notes:

1 Required before and after each test as appropriate. Include special tests as applicable (6.2).
2 Discretionary for sealed or low-powered components.
3 Applicable only to sealed or pressurized components.
4 Required when shock levels are high **(7.4.6.4)**.
5 Either vibration or acoustic, whichever is more appropriate, with the other discretionary.
6 Test required if composite materials are used. The test may be omitted if proven nondestructive evaluation methods are used with well-established acceptance and reject criteria.
7 Excluding hydraulic components for launch vehicles.
6 Not required for batteries that cannot be recharged after testing.

7.4.2 Thermal Cycle Test. Electrical and Electronic Unit Acceptance If qualification thermal cycle testing (6.4.2) was conducted in vacuum, the thermal cycle acceptance test shall be performed in vacuum and combined with the test of 7.4.3. The combined number of cycles shall meet the requirements of Table

7.4.2.1 Purpose. The thermal cycle test detects material and workmanship defects prior to installation of the unit into a vehicle, by subjecting the unit to thermal cycling.

7.4.2.2 Test Description. Same as 6.4.2.2 except, to aid in reaching the cold temperature, the unit may be powered off when the temperature of the unit is at or below its minimum expected temperature (3.3.1).

7.4.2.3 Test Levels and Duration

a. Pressure and Humidity. Same as 6.4.2.3a.

b. Temperature. The hot and cold temperatures shall be the acceptance temperature limits (7.1.1).

c. Duration. The minimum number of thermal cycles shall be 12.5, the last two of which shall be failure free. For units subjected to the thermal vacuum test of 7.4.3, the number of cycles is reduced by the number of thermal vacuum cycles imposed (Table VI). Temperature soak durations (3.5.10) shall be a minimum of 6 hours at the hot and 6 hours at the cold temperature during the first and last cycle. For the intermediate cycles, the soaks shall be at least 1 hour long. During soak periods, the unit shall be turned off until the temperature stabilizes (3.5.7) and then turned on. Measurement of each temperature soak duration shall begin at the time of unit start (Figure 1). The transitions between cold and hot temperatures should be at an average rate of 3 to 5°C per minute and shall not be slower than 1 °C per minute. Additional operation at the hot acceptance temperature shall be accumulated so that the combined duration of thermal cycling, thermal vacuum (7.4.3), and the additional hot operation is at least 200 hours. If desired, the added hot operation can be accomplished by extending hot soak durations during thermal or thermal vacuum cycling. The last 100 hours of operation shall be failure free. For internally redundant units, the operating hours shall consist of at least 150 hours of primary operation and at least 50 hours of redundant operation, The last 50 hours of each shall be failure free.

7.4.2.4 Supplementary Reauiremenp. Same as 6.4.2.4, except that units are only required to meet their performance requirements within specification over the maximum expected temperature range.

7.4.3 Thermal Vacuum Test, Unit Acceptance

7.4.3.1 Purpose. The thermal vacuum test detects material and workmanship defects by subjecting the unit to a thermal vacuum environment.

7.4.3.2 Test Description. Same as 6.4.3.2, except that the space nuclear radiation environment need not be simulated.

7.4.3.3 Test Levels and Duration

a. Pressure. The pressure shall be reduced from atmospheric to 13.3 millipascals (10^{-4} Torr) for on-orbit simulation, or to the functionally appropriate reduced pressure, at a rate that simulates the ascent profile, to the extent practicable. For launch vehicle units, the vacuum pressure shall be modified to reflect an altitude consistent with the maximum service altitude. For units that are proven to be free of vacuum related failure modes, the thermal vacuum acceptance test may be conducted at ambient pressure.

b. Temperature. The hot and cold temperatures shall be the acceptance temperature limits (7.1.1).

c. Duration. The basic requirement, except for electrical and electronic units, is a single cycle with 6-hour hot and cold soaks (Table VI). For electrical and electronic units, a minimum of 4 thermal vacuum cycles shall be used (Table VI). Temperature soak durations shall be at least 6 hours at the hot temperature and 6 hours at the cold temperature during the first and last cycle. During the two intermediate cycles, the soaks shall be 1 hour long. During each soak period, the unit shall be turned off until the temperature has stabilized and then turned on. Measurement of temperature soak durations (3.5.10) shall begin at the time of unit turn-on (Figure 1).

7.4.3.4 Supplementary Requirements. Functional tests shall be conducted at the hot and cold temperatures during the first and last cycle, and after return of the unit to ambient temperature in vacuum. During the remainder of the test, electrical and electronic units, including all redundant circuits and paths, shall be cycled through various operational modes. Perceptive parameters shall be monitored for failures and intermittents to the maximum extent practicable. Units shall meet their performance requirements over the maximum expected temperature range. Units shall be operated over the entire acceptance temperature range, although performance within specification is not required if the acceptance test temperatures extend beyond the minimum or maximum expected temperatures.

For moving mechanical assemblies, performance parameters, such as current draw, resistance torque or force, actuation time, velocity or acceleration, shall be monitored, Compatibility of thrusters with their operational fluids shall be verified at test temperature extremes.

7.4.4 Vibration Test, Unit Acceptance

7.4.4.1 Purpose. The vibration test detects material and workmanship defects by subjecting the unit to a vibration environment.

7.4.4.2 Test Description. Same as 6.4.4.2, except that attached hydraulic and pneumatic lines are not required. Units mounted on shock or vibration isolators shall normally be tested hard mounted to assure that the minimum spectrum shown in Figure 5 is input to the test item.

7.4.4.3 Test Level and Duration. The vibration environment shall be as defined in 7.1.3. The minimum spectrum is shown in Figure 5. Where insufficient time is available to test all modes of operation, extended testing at a level no lower than 6 dB below the acceptance test level shall be conducted as necessary to complete functional testing.

7.4.4.4 Supplementary Requirements. Same as 6.4.4.4 and if the dynamic test configuration (unit and fixture) changes from the qualification configuration, then the fixture evaluation (6.4.4.5) shall be repeated before testing to acceptance levels.

7.4.4.5 Special Considerations for Isolators. All isolators shall be lot tested in at least one axis, with rated supported mass, to verify that dynamic amplification and resonant frequency are within allowable limits. Test inputs may either be the maximum expected random vibration level applied for at least 15 seconds, or be a reference sinusoidal input having a frequency sweep rate not greater than 1 octave per minute.

7.4.5 Acoustic Test, Unit Acceptance

7.4.5.1 Purpose. The acoustic test detects material and workmanship defects by subjecting the unit to an acoustic environment.

7.4.5.2 Test Description. Same as 6.4.5.2.

7.4.5.3 Test Level and Duration. The unit acoustic environment shall be as defined in 7.1.2. Where insufficient time is available during the l-minute to check redundant circuits, functions, and modes that are operating during the launch, ascent, or reentry phase, extended testing at a level no lower than 6 dB below the acceptance level shall be conducted as necessary to complete functional testing.

7.4.5.4 Supplementary Requirements. 6.2.4.4.

7.4.6 Shock Test, Unit Acceptance

7.4.6.1 Purpose. The shock test is intended to reveal material and workmanship defects in units subject to high-level shock environments in flight.

7.4.6.2 Test Description. The unit shall be attached at its normal points to the same fixture or structure used for its shock qualification test (6.4.6.2). The unit shall be electrically energized and monitored. The test technique employed shall be identical to that selected for its qualification, differing only in level and the number of repetitions. A functional test of the unit shall be performed before and after the shock test. The unit shall be electrically energized during the testing. Circuits should be monitored for intermittents to the maximum extent practicable.

7.4.6.3 Test Level and Exposure. The shock response spectrum in both directions of each of 3 orthogonal axes shall be at least the maximum expected level for that direction. A sufficient number of shocks shall be imposed to meet the required level in each of these 6 directions at least once.

7.4.6.4 Supplementary Requirements A shock acceptance test becomes a required test (3.5.4) if the maximum expected shock response spectrum in g's exceeds 1.6 times the frequency in Hz (corresponding to a velocity of 2.54 meters/second or 100 inches/second). For example, if the maximum expected shock response spectrum value at 2000 Hz exceeds 3200g, the test is required.

7.4.7 Proof

7.4.7.1 Purpose. The proof load test shall be conducted for ail structural units made from composite material or having adhesively bonded parts. The proof load test detects material, process, and workmanship defects that would respond to structural proof loading. The requirement for the proof load test is waived if a proven nondestructive evaluation method, with well established accept and reject criteria, is used instead.

7.4.7.2 Test Descriptions. Same as 7.3.1.2.

7.4.7.3 Test Level and Duration. Same as 7.3.1.3.

7.4.8 Proof Pressure Test, Unit Acceptance

7.4.8.1 Purpose. The proof pressure test detects material and workmanship defects that could result in failure of the pressure vessel or other units in usage.

7.4.8.2 Test Description. Same as described in 6.4.8.2a.

7.4.8.3 Test Level and Duration. Same as 6.4.8.3a and b.

7.4.8.4 Supplementary Requirements. MIL-STD-1522 and applicable safety standards shall be followed.

7.4.9 Leakage Test, Unit Acceptance

7.4.9.1 Purpose. The leakage test demonstrates the capability of units to meet the specified leakage requirements.

7.4.9.2 Test Description. The unit leak checks shall be made using the same method as used for qualification.

7.4.9.3 Test Level and Duration. Same as 6.4.7.3.

7.4.10 Wear-in Test, Unit Acceptance

7.4.10.1 Purpose. The wear-in test detects material and workmanship defects that occur early in the unit life, and to wear-in or run-in of mechanical units so that they perform in a smooth, consistent, and controlled manner.

7.4.10.2 Test Description. While the unit is operating under conditions representative of operational loads, speed, and environments and while perceptive parameters are being monitored, the unit shall be operated for the specified time period. For valves, thrusters, and other items where the number of cycles of operation rather than hours of operation is a better method to ensure detecting infant mortality failures, functional cycling shall be conducted at ambient temperature. For thrusters, a cycle is a hot firing that includes a start, steady-state operation, and shutdown. For hot firings of thrusters utilizing hydrarine propellants, action shall be taken to assure that the flight valves are thoroughly cleaned of all traces of hydrazine following the test firings. Devices that have extremely limited life cycles, such as positive expulsion tanks, are excluded from wear-in test requirements.

7.4.10.3 Test Levels and Duration.

a. Pressure. Ambient pressure should normally be used.

b. Temperature. Ambient temperature shall be used for operations if the test objectives can be met. Otherwise, temperatures representative of the operational environment shall be used.

c. Duration. The number of cycles shall be either 15 or 5 percent of the total number of expected cycles during service life (3.5.6), whichever is greater.

7.4.10.4 Supplementary Requirements. Perceptive parameters shall be monitored during the wear-in test to detect evidence of degradation.

7.4.11 EMC Test, Unit Acceptance. Limited EMC acceptance testing shall be accomplished on units that exhibit emission or susceptibility characteristics, which may adverseiy affect vehicle performance, to verify that these characteristics have not deteriorated from the qualification test levels. The tests should be restricted to only those necessary to evaluate these Critical characteristics.

SECTION 8

ALTERNATIVE STRATEGIES

The qualification testing in Section 6 provides a demonstration that the design, manufacturing, and acceptance testing produces flight items that meet specification requirements. In a minimum-risk program, the hardware items subjected to qualification tests are themselves not eligible for flight, since there has been no demonstration of remaining life from fatigue and wear standpoints. Yet, programmatic realities of limited production, tight schedules, and budgetary limits do not always provide for dedicated nonflight qualification items. In response, strategies have evolved to minimize the risk engendered by this situation. The three strategies or combinations thereof, described in this section, may be used at the vehicle, subsystem, and unit levels. It should be recognized that these strategies present a higher risk than the use of standard acceptance tested items for flight that have margins demonstrated by testing of a dedicated qualification item. The higher risk of these alternate strategies may be partially mitigated by enhanced development testing and by increasing the design factors of safety.

The strategies are intended for use in space vehicle programs that have a very limited number of vehicles.

8.1 SPARES STRATEGY

This strategy does not alter the qualification and acceptance test requirements presented in Sections 6 and 7. Yet, in some cases, qualification hardware may be used for flight if the risk is minimized. in a typical case, the qualification test program results in a qualification test vehicle that was built using units that had been qualification tested at the unit level. After completing the qualification tests, the critical units can be removed from the vehicle and the qualification vehicle can then be refurbished, as necessary. Usually a new set of critical units would be installed that had only been acceptance tested. This refurbished qualification vehicle would then be certified for flight when it satisfactorily completes the vehicle acceptance tests in 7.2. In vehicles where redundant units are provided, only one of the redundant units would have been qualification tested at the unit level, so only it would be removed and replaced. The qualification units that were removed would be refurbished, as necessary, and would typically be used as flight spares. However, qualification units that are mission or safety critical (3.2.2) should never be used for flight.

8.2 FLIGHTPROOF STRATEGY

With a flightproof strategy, all flight items are subjected to enhanced acceptance testing, and there is no qualification item. The risk taken is that there has been no formal demonstration of remaining life for the flight items. This risk is alleviated to some degree by the fact that each flight item has met requirements under acceptance testing at higher than normal levels. The test levels are mostly less than those specified in Section 6 for qualification, but are never less than those specified in Section 7 for acceptance. The test durations for the flightproof test strategy are the same as those specified for acceptance. It is recommended that development testing be used to gain confidence that adequate margin, especially in a fatigue or wear sense, remains after the maximum allowed accumulated acceptance testing at the enhanced levels.

8.2.1 Vehicle Flightproof Tests. The vehicle flightproof tests shall be conducted as in 7.2 (Table XII), with the following modifications:

a. The vehicle shock test shall be conducted as in 6.2.3 for the first flight vehicle. For subsequent vehicles, only 1 activation of significant events is required (7.2.3).

b. The vehicle acoustic and random vibration tests shall be conducted as in 7.2.4 and 7.2.5, except that the test level shall be 3 dB above the acceptance test environment (7.1.2 and 7.1.3). For the first flight vehicle, the tests shall be conducted with power on, to the extent practicable.

c. The vehicle thermal vacuum tests shall be conducted as in 7.2.8, except that the hot and cold temperatures shall be 5°C beyond the acceptance temperatures for units (7.1.1).

d. The vehicle thermal balance test shall be conducted on the first flight vehicle as in 6.2.8.

e. If a thermal cycle test is conducted as in 7.2.7, then the minimum vehicle temperature range shall be 60°C.

f. EMC tests shall be conducted as in 6.2.2 for the first flight vehicle. For subsequent vehicles, the EMC test of 7.2.2 shall be required.

g. The modal survey shall be conducted as in 6.2.10 on the first flight vehicle.

8.2.2 Subsystem Flightproof Tests. The subsystem flightproof tests shall be conducted as in 7.3. In addition, a proof load test shall be conducted on all structures in the structural subsystem. The proof load shall be equal to 1.1 times the limit load.

8.2.3 Unit Flightproof Tests The unit flightproof tests shall be conducted as in 7.4 (Table XIII), with the following modifications:

a. For the first flight unit only, the shock test shall be conducted as in 6.4.6, except that the shock level shall be 3 dB above the acceptance test level, achieved once in both directions of 3 axes. For subsequent units, the shock test shall be conducted if required as described in 7.4.6, except that the shock test level shall be 3 dB above the acceptance test level.

b. Vibration and acoustic tests shall be conducted as in 7.4.4 and 7.4.5, except that the test level shall be 3 dB greater than the acceptance test level (7.1.2 and 7.1.3).

c. The unit thermal vacuum tests shall be conducted as in 7.4.3, except that the hot and cold temperatures shall be 5°C beyond the acceptance test temperatures (7.1.1). For the first flight antenna and solar array units, this thermal vacuum test shall be required.

d. The unit thermal cycle tests shall be conducted as in 7.4.2, except that the hot and cold temperatures shall be 5°C beyond the acceptance test temperatures (7.1.1).

e. The unit EMC test shall be conducted on the first unit as in 6.4.11.

The unit flightproof test approach shall not be allowed for pressure vessels, pressure components, structural components with a low fatigue margin, and nonrechargeable batteries. These units shall follow a normal qualification and acceptance program as specified in Sections 6 and 7.

8.3 PROTOQUALIFICATION STRATEGY

With a protoquallfication strategy, a modified qualification (protoqualification) is conducted on a single item and that test item is considered to be available for flight. The normal acceptance program in Section 7 is then conducted on all other flight items.

8.3.1 Vehicle Protoqualification Tests. The protoqualification tests shall be conducted as in 6.2 (Table Viii), with the following modifications:

a. The shock test shall be conducted as in 6.2.3, except that only 2 repetitions of activated events are required.

b. The acoustic or random vibration tests shall be conducted as in 6.2.4 and 6.2.5, except that the duration factors shall be 2 (instead of 4) and the level margin for the flight environment shall be 3 dB (instead of 6 dB typically) in place of the requirements in 6.1.4. if the test is accelerated (6.1.4.2), the time reduction factor shall be based on the reduced level margin per Table Vii.

c. The thermal vacuum test shall be conducted as in 6.2.9, except that the hot and cold temperatures shall be 5°C beyond the acceptance temperatures for units (7.1 .1) and the number of cycles shall be half of those in Table Vi.

d. if the alternate thermal cycle test is conducted as in 6.2.7, then the minimum vehicle temperature range shall be 60°C and the number of cycles shall be half of those in Table Vi.

8.3.2 Subsystem Protoqualification Tests. The subsystem protoquaiification tests shall be conducted as in 8.3.1, except that the structural subsystem tests shall be conducted as in 6.3 (Table IX) with an ultimate load test factor of 1.25. No detrimental deformation shall be allowed during the test. In addition, the design safety factor for ultimate shall be 1.4 and the design safety factor for yield shall be 1.25.

8.3.3 Unit Protoqualification Tests. The protoqualification unit tests shall be conducted as in 6.4 (Table X), with the following modifications:

a. The shock test shall be conducted as in 6.4.6, except that only 2 repetitions and only a 3 dB level margin for the flight environment (instead of 6 dB typically, Table IV) shall be required.

b. The random vibration or acoustic tests shall be conducted as in 6.4.4 and 6.4.5, except that the duration factors shall be 2 (instead of 4) and the level margin for the flight environment shall be 3 dB (instead of 6 dB typically). if the test is accelerated (6.1.4.2), the time reduction factor shall be based on the reduced level margin per Table VII.

c. The thermal vacuum tests shall be conducted as in 6.4.3, except that the hot and cold temperatures shall be 5°C beyond the acceptance temperatures for units (7.1.1) and the number of cycles shall be half of those in Table VI.

d. The thermal cycle tests shall be conducted as in 6.4.2, except that the hot and cold temperatures shall be 5°C beyond the acceptance temperatures for units (7.1 .1) and the number of cycles shall be half of those in Table VI.

8.4 COMBINATION TEST STRATEGIES

Various combinations of strategy may be considered depending on specific program considerations and the degree of risk deemed acceptable. For example, the protoqualification strategy for units (8.3.3) may be combined with the flightproof strategy for the vehicle (8.2.1). In other cases, the flightproof strategy would be applied to some units (8.2.3) peculiar to a single mission, while the protoqualification strategy may be applied to multi-mission units (8.3.3). In such cases, the provisions of each method would apply and the resultant risk would be increased correspondingly.

SECTION 9

PRELAUNCH VALIDATION AND OPERATIONAL TESTS

9.1 PRELAUNCH VALIDATION TESTS, GENERAL REQUIREMENTS

Prelaunch validation testing is accomplished at the factory and at the launch base, with the objective of demonstrating launch system and on-orbit system readiness. Prelaunch validation testing is usually divided into two phases:

Phase a. Integrated system tests (Step 3 tests, MIL-STD-1833).

Phase b. Initial operational tests and evaluations (Step 4 tests, MIL-STD-1833).

During Phase a, the test series establishes the vehicle baseline data in the factory preshipment acceptance tests. All factory test acceptance data should accompany delivered flight hardware. When the launch vehicle(s), upper-stage vehicle(s), and space vehicle(s) are first delivered to the launch site, tests shall be conducted as required to assure vehicle readiness for integration with the other vehicles. These tests also verify that no changes have occurred in vehicle parameters as a result of handling and transportation to the launch base. The launch vehicle(s), upper-stage vehicle(s), and space vehicle(s) may each be delivered as a complete vehicle or they may be delivered as separate stages and first assembled at the launch site as a complete launch system. The prelaunch validation tests are unique for each program in the extent of the operations necessary to ensure that all interfaces are properly tested. For programs that ship a complete vehicle to the launch site, these tests primarily confirm vehicle performance, check for transportation damage, and demonstrate interface compatibility.

Duiing Phase b, initial operational tests and evaluations (Step 4 tests) are conducted following the integrated system tests to demonstrate successful integration of the vehicles with the launch facility, and that compatibility exists between the vehicle hardware, ground equipment, computer software, and within the entire launch system and on-orbit system. The point at which the integrated system tests end and the initial operational tests and evaluations begin is somewhat arbitrary since the tests may be scheduled to overlap in time. To the greatest extent practicable, the initial operational tests and evaluations are to exercise all vehicles and subsystems through every operational mode in order to ensure that all mission requirements are satisfied. These Step 4 tests shall be conducted in an operational environment, with the equipment in its operational configuration, by the operating personnel in order to test and evaluate the effectiveness and suitability of the hardware and software. These tests should emphasize reliability, contingency plans, maintainability, supportability, and logistics. These tests should assure compatibility with scheduled range operations including range instrumentation.

9.2 PRELAUNCH VALIDATION TEST FLOW

Step 4 testing (MIL-STD-1833) of new or modified ground facilities, ground equipment, or software should be completed prior to starting the prelaunch validation testing of the vehicles at the launch base. The prelaunch validation test flow shall follow a progressive growth pattern to ensure proper operation of each vehicle element prior to progressing to a higher level of assembly and test. In general, tests should follow the launch base buildup cycle. As successive vehicles or subsystems are verified, assembly proceeds to the next level of assembly. Following testing of the vehicles and their interfaces, the vehicles are electrically and mechanically mated and integrated into the launch system. Upper-stage vehicles and space vehicles employing a recoverable flight vehicle shall utilize a flight vehicle simulator to perform mechanical and electrical interface tests prior to integration with the flight vehicle. Following integration of the launch vehicle(s), upper-stage vehicle(s), and space vehicle(s), functional tests of each of the vehicles shall be conducted to ensure its proper operation following the handling operations involved in mating. Vehicle cleanliness shall be monitored by use of witness plates. In general, the Step 4 testing of the launch system is conducted first, then the Step 4 testing of the on-orbit space system is conducted.

9.3 PRELAUNCH VALIDATION TEST CONFIGURATION

During each test, the applicable vehicle(s) should be in their flight configuration to the maximum extent practicable, consistent with safety, control, and monitoring requirements. For programs utilizing a recoverable flight vehicle, the test configuration shall include any airborne support equipment required for the launch, ascent, and space vehicle deployment phases. This equipment shall be mechanically and electrically mated to the space vehicle in its launch configuration. Whenever practicable, ground support equipment should have a floating-point-ground scheme that is connected to the flight vehicle single-point ground. Isolation resistance tests shall be run to verify the correct grounding scheme prior to connection to the flight vehicle. This reduces the possibility of ground equipment interference with vehicle performance. All ground equipment shall be validated prior to being connected to any flight hardware, to preclude the possibility of faulty ground equipment causing damage to the flight hardware or inducing ambiguous or invalid data. Test provisions shall be made to verify integrity of circuits into which flight jumpers, arm plugs, or enable plugs have been inserted.

9.4 PRELAUNCH VALIDATION TEST DESCRIPTIONS

The prelaunch validation tests shall exercise and demonstrate satisfactory operation of each of the vehicles through all of their mission phases, to the maximum extent practicable. Test data shall be compared to corresponding data obtained in factory tests to identify trends in performance parameters. Each test procedure used shall include test limits and success criteria sufficient to permit a rapid determination as to whether or not processing and integration of the launch system should continue. However, the final acceptance or rejection decision, in most tests, depends upon the results of post-test data analysis.

9.4.1 Functional Tests. Electrical functional tests shall be conducted that duplicate, as nearly as practicable, the factory functional tests performed for vehicle acceptance. Mechanical tests for leakage, valve and mechanism operability, and fairing clearance shall be conducted.

9.4.1.1 Simulators Simulation devices shall be carefully controlled and shall be permitted only when-there is no feasible alternative for conducting the test. When it is necessary to employ simulators in the conduct of prelaunch validation tests, the interfaces disconnected in the subsequent replacement of the simulators with flight hardware shall be revalidated. Simulators shall be used for the validation of ground support equipment prior to connecting it to flight hardware.

9.4.1.2 &&&e-ordnance Firina Circuits If not performed at an earlier point in the factory test cycle, validation that proper ignition energy levels are present at each electro-explosive device (EED) shall be performed prior to final connection of the firing circuit .to the EEDs. A simulation of the EED characteristics shall be used during these tests. The circuits shall be commanded through power-on, arm, and fire cycles. The circuits are to be monitored during the tests to detect energy densities exceeding ignition threshold during power-on and arm cycles, and to validate that proper ignition energy density is transmitted to the conducting pins of the EED at the fire command. Circuit continuity and stray energy checks shall be made prior to connection of a firing circuit to ordnance devices and this check shall be repeated whenever that connection is opened and prior to reconnection.

9.4.1.3 Transportation and Handling Monitoring. Monitoring for shock and vibration should be performed at a minimum of the forward and aft interfaces between the shipping container transporter and the article being shipped, and on the top of the article. Measurements should be on the article side of the interface in all three axes at each location. The monitoring requires a sensing and recording subsystem capable of providing complete time histories of the most severe events, as well as condensed summaries of the events, including their time of occurrence. A frequency response up to 300 Hz is required. Monitoring should cover the entire shipment period and the data evaluated as part of the receiving process. Exposure to shock or vibration having a spectrum above the acceptance spectrum may require additional testing or analysis.

9.4.2 Propulsion Subsystem Leakage and Functional Tests. Functional tests of the vehicle propulsion subsystem(s) shall be conducted to verify the proper operation of all units, to the maximum extent practicable. Propulsion subsystem leakage rates shall be verified to be within allowable limits.

9.4.3 Launch-critical Ground Support Equipment Tests. Hardware associated with ground subsystems that are flight critical and nonredundant (such as umbilicals) shall have been subjected to appropriate functional tests under simulated functional and environmental conditions of launch. These tests shall include an evaluation of radio-frequency (rf) interference between system elements, electrical power interfaces, and the command and control subsystems, On a new vehicle design or a significant design change to the telemetry, tracking, or receiving subsystem of an existing vehicle, a test shall be run on the first vehicle to ensure nominal operation and that explosive-ordnance devices do not fire when the vehicle is subjected to the worst-case electromagnetic interference environment.

9.4.4 Compatibility Test, On-orbit System.

9.4.4.1 Purpose. The compatibility test validates the compatibility of the upper-stage vehicle, the space vehicle, the on-orbit command and control network, and other elements of the space system. For the purpose of establishing the compatibility testing baseline, it is assumed that the on-orbit command and control network is (or operationally interfaces with) the Air Force Satellite Control Network (AFSCN). The compatibility test demonstrates the ability of the upper-stage vehicle and space vehicle, when in orbit, to properly respond to the AFSCN hardware, software, and operations team as specified in the AFSCN Program Support Plan. For programs that have a dedicated ground station, compatibility tests shall also be performed with the dedicated ground station.

9.4.4.2 Test Description. Facilities to perform on-orbit system compatibility tests exist at the Western Range (WR) and the Eastern Range (ER). At both locations, there are facilities that can command the launch, upper-stage, and space vehicles, process telemetry from the vehicles, as well as perform tracking and ranging, thus verifying the system compatibility, the command software, the telemetry processing software, and the telemetry modes. The required tests include the following:

a. Verification of the compatibility of the radio frequencies and signal waveforms used by the flight unit's command, telemetry, and tracking links.

b. Verification of the ability, of the flight units to accept commands from the command and control network(s).

c. Verification of the command and control network(s) capability to receive, process, display, and record the vehicle(s) telemetry link(s) required to monitor the flight units during launch, ascent, and on-orbit mission phases.

d. Verification of the ability of the flight units to support on-orbit tracking as required for launch, ascent, and on-orbit mission phases.

9.4.4.3 Supplementary Requirements. The compatibility test should be run as soon as feasible after the vehicles arrives at the launch base. The test is made with every vehicle to verify system interface compatibility. The test shall be run using the software model versions that are integrated into the operational on-orbit software of the vehicle under test. A preliminary compatibility test may be run prior to the arrival of the vehicle at the launch base by the use of prototype subsystems, units, or simulators as required to prove the interface. Preliminary compatibility tests may be run using preliminary software. Normally, a preliminary compatibility test is run once for each series of vehicles to check design compatibility, and is conducted well in advance of the first launch to permit orderly correction of hardware, software, and procedures as required. Changes in the interface from those tested in the preliminary test shall be checked by the compatibility tests conducted just prior to launch. Following the completion of the compatibility test, the on-orbit command and control network configuration of software, hardware, and procedures should be frozen until the space vehicle is in orbit and initialized.

9.5 FOLLOW-ON OPERATIONAL TESTS

9.51 Follow-on Operational Tests and Evaluations. Follow-on Operational Tests and Evaluations shall be conducted at the launch site in an operational environment, with the equipment in its operational configuration. The assigned operating personnel shall identify operational system deficiencies. (Step 5 in MIL-STD-1833).

9.5.2 On-orbit Testing. On-orbit testing should be conducted to verify the functional integrity of the space vehicle following launch and orbital maneuvering. Other on-orbit testing requirements are an important consideration in the design of any space vehicle. For example, there may be a need to calibrate on-line equipment or to verify the operational status of off-line equipment while in orbit. However, on-orbit testing is dependent on the built-in design features, and if. testing provisions were not provided, the desired tests cannot be accomplished.

On-orbit tests are, therefore, so program peculiar that specific requirements are not addressed in this Standard.

9.5.3 Tests of Reusable Flight Hardware. Tests of reusable flight hardware shall be conducted as required to achieve a successful space mission. Reusable hardware consists of the vehicles and units intended for repeated missions. Airborne support equipment, that performs its mission while attached to a recoverable launch vehicle, is an example of a candidate for reuse. The reusable equipment would be subjected to repeated exposure to test, launch, flight, and recovery environments throughout its service life. The accumulated exposure time of equipment retained in a recoverable vehicle and of airborne support equipment is a function of the planned number of missions involving this equipment and the retest requirements between missions. The environmental exposure time of airborne support equipment is further dependent on whether or not its use is required during the acceptance testing of other nonrecoverable flight equipment. In any case, the service life of reusable hardware should include all planned reuses and all planned retesting between uses.

The testing requirements for reusable space hardware after the completion of a mission and prior to its reuse on a subsequent mission depends heavily upon the design of the reusable item and the allowable program risk. For those reasons, specific details are not presented in this Standard. Similarly, orbiting space vehicles that have completed their useful life spans may be retrieved by means of a recoverable flight vehicle, refurbished, and reused. Based on present approaches, it is expected that the retrieved space vehicle would be returned to the contractor's factory for disassembly, physical inspection, and refurbishment. All originally specified acceptance tests should be conducted before reuse.

SECTION 10

NOTES

This Notes section is not a mandatory part of this Standard. The contents of this section are intended for use by government acquisition personnel for guidance and information Only.

10.1 INTENDED USE.

This Standard is intended for reference in applicable program specifications or in other documents, to establish general test requirements for launch, upper-stage, and space vehicles; and for their subsystems and units (components). The application of these test requirements to a particular program is intended to assure a high level of confidence in achieving a successful space mission. This Standard is not intended to be used in the acquisition of space system ground equipment and associated computer software, whose test requirements are outlined in MIL-STD-1833, "Test Requirements for Ground Equipment and Associated Computer Software Supporting Space Vehicles" and not included in this document. DOD-STD-2167, "Defense System Software Development" and DOD-STD-2168, "Defense System Software Quality Program," also address computer software. Test requirements for space parts and materials are in their detailed specifications and not in this document.

10.2 TAILORED APPLICATION.

The technical requirements in each contract should be tailored to the needs of that particular acquisition. Only the minimum requirements needed to provide the basis for achieving the program requirements should be imposed. The cost of imposing each requirement of this Standard should be evaluated against the benefits. However, the risks and potential costs of not imposing requirements must also be considered.

Tailoring is a continuing process throughout the acquisition that should be implemented by the wording used to stat8 the testing requirements. MIL-HDBK-340, 'Application Guidelines for MIL-STD-1540," is a companion document to this Standard that is intended to provide helpful guidance information for tailoring.

10.2.1 Tailoring in the Specifications. The Standard is Organized to provide self-tailoring of the requirements to various applications when referenced in the specifications. These features include an organization of requirements by test categories, by item categories, by required/other/not-required categories, by weighting factors, and by alternative test strategies. The tailoring desired should be implemented by the wording used to Stat8 the testing requirements in the specifications or in other applicable contractual documents.

10.2.1.1 Test Categories. The major test categories in this Standard are:

a. Development tests (Section 5).
b. Qualification tests (Section 6).
c. Acceptance tests (Section 7).
d. Flightproof and protoqualification tests (Section 8).
8. Prelaunch validation tests (Section 9).
f. Operational tests (Section 9).

The general requirements stated in Section 4 apply for all of the test categories.

10.2.1.2 Item Categories. Space systems are composed of items in various categories including ground equipment, computer software, procedures, personnel, as well as flight equipment. All items are tested to Some degree to assure successful space missions. The major item categories covered by the testing requirements in this Standard are:

a. Vehicles (launch, upper-stage and space vehicles; Tables VIII and XII).
b. Subsystems (Table IX and 6.3).
C. Units (Tables X and XIII).
d. Integrated vehicles (flight vehicle, flight system, and on-orbit system).

10.2.1.3 "Required", "Other", and "Not-required" Tests. "Required", "other", and "not-required" tests for each vehicle category are indicated by an "R", "0", and "—", respectively, in Tables VIII, IX, X, XII, and XIII. The following basis has been used:

a. "Required" tests are the baseline tests that are required by this Standard because they are generally effective.
b. "Other" tests (3.5.4) are those that are usually ineffective and have a low probability of being required. Such tests must be evaluated on a case-by-case basis. If the evaluation shows than an "other" test is effective, it becomes a "required" test for that case.
c. "Not-required" tests are generally ineffective and are not required by this Standard.

Unless modified by contract, the contractual compliance requirements include all of the "required" tests plus all "other" tests evaluated as required.

10.2.1.4 Weiahtina Factors. Even for the required tests, not all of the testing requirements have an equal importance or equal weight. To avoid overstating testing requirements, and hence avoid excessive costs, or numerous waivers, various categories of weighting factors are associated with the requirements. The primary weighting factors that are incorporated in the Standard are:

a. Weiahtina factor "a". *"Shall"* designates the most important weighting level, the mandatory requirements. Unless modified by the contract, the *"shall"* requirements constitute the firm contractual compliance requirements. Any deviations require the approval of the contracting officer.

b. Weighting factor "b". *"Shall, where practicable"* designates requirements or practices at the second highest weighting level. Alternative requirements or practices may be used for specific applications, when the use of the alternative is substantiated by documented technical trade studies. These trade studies should be made available for review when requested, or provided to the government in accordance with the contract provisions. Unless required by other contract provisions, noncompliance with the *'shall, where practicable"* requirements does not require approval of the contracting officer.

c. Weighting factor "c". *"Should"* designates the third weighting level. Unless required by other contract provisions, noncompliance with these *"should"* requirements does not require documented technical substantiation, and does not require approval of the contracting officer.

d. Weighting factor "d". *"May"* designates the lowest weighting level. In some cases, these *"may"* requirements are stated as examples of acceptable practices. Unless required by other contract provisions, noncompliance with the *"may"* requirements does not require approval of the contracting officer and does not require documented technical substantiation.

10.2.1.5 Alternative Test Strategies. The application of the alternative test strategies outlined in Section 8 should be based on life-cycle cost considerations that include the number of units being manufactured, the potential launch delay costs of a prelaunch failure, the potential cost of the loss of mission capability due to a failure, and other life-cycle costs. The fact that an alternative test strategy may have lower testing costs does not mean it provides the lowest life-cycle cost. Any constraints on the use of the alternative test strategies must be stated in the contract.

10.2.2 Tailoring in the Statement of Work (SOW).

10.2.2.1 Tailoring Summary. To make the requirements clear for a particular contract, and to assist in the tailoring process, the procuring agency may provide a summary of tailoring requirements. To accomplish this, the procuring agency should complete either Table XIV or Table XV, or an adaption thereof, and include one or the other in the contract, usually as a statement of work (SOW) task. Table XIV can be used when primarily broad, general tailoring of the requirements is desired, with only a few specific test or test items to be specially treated differently. Table XV can be used when detailed tailoring of the requirements is desired. These tables provide a recommended format for stating changes to the stringency or applicability of the baseline requirements appearing in the Standard, relating to the use of "shall' versus "should" and to "required" versus "other" (3.54). The latter pair appear in tables stating the applicability of various tests to categories of vehicles, subsystems, and units. The implication of these terms is discussed in 10.2.1.3 and 10.2.1.4. For example, the "fully applicable' degree may be used to allow the procuring agency to impose the highest level of stringency for some requirements without being constrained by the baseline requirements of this Standard. A sample of a completed Table XIV and XV appears in Tables XVI and XVII, respectively. Suggested wording for the SOW is as follows:

> "XX.XXX Tailoring of MIL-STD-1540C. Preliminary tailoring of MIL-STD-1540C is provided in the attached Requirements Applicability Matrix. The contractor shall review these tailored requirements and provide additional recommended tailoring and supporting rationale for approval by the contracting officer."

10.2.2.2 Test Plans. Depending on the particular acquisition phase, it may be difficult for the procuring agency to identify which "required" and "other" tests are most effective for a panicular subsystem or test article. In these cases, the procuring agency may request that the contractor review the "required" and "other" tests and propose an effective test plan, subject to approval by the procuring agency. Suggested wordings for the Statement of Work is as follows:

> "xx.xxx Review of Test. Plans. Test plans and test procedures shall be prepared based upon the test requirements stated in the program specifications and the guidance provided in MIL-STD-1540. Technical review meetings shall be conducted to present to the procuring agency the recommended test plans and procedures applicable to each item category. These presentations shall include the evaluation of the "required, other and not-required' tests that form the basis of the test plans.

If the procuring agency wishes to formally review the applicable test plans or procedures prepared by contractors, requirements for their preparation should be stated in the Contract Data Requirements List (CDRL; 10.5).

TABLE XIV. Requirements Applicability **Matrix, General** Form.

The matrix designators are as follows:

A = Applicable as written -	"Shall" defines minimum **requirements.** "Should" and "may" language denotes guidance. "Other" test denotes conduct to be evaluated.
F = Fuliy Applicable	All "should" or "may" language replaced with "shall". All "other" tests changed to "required" tests.
G = Guidance only	All information provided as good practice.
N = Not Applicable.	Requirements are not applicable.

Level of Assembly or Specific Item	Section							
	4. General Requirements	5. Development Tests	6. Qualification Tests	7. Acceptance Tests	8. Alternative Strategies: 8.1 Spares	8.2 Flightproof	8.3 Proto-qualification	9. Prelaunch Validation & Operational Tests
Units								
Subsystems								
Vehicles								
Integrated System								
<u>Other items</u>:								

TABLE XV. Requirements Applicability Matrix, Detailed Form.
(first of 5 pages)

The matrix designators are as follows:

A = Applicable as written	-	"Shall" defines minimum requirements.
	-	"Should" and "may" language denotes guidance.
	-	"Other" denotes test that may be required subject to an evaluation.
F = Fully Applicable	-	Ail 'should" and "may" language replaced with "shall". Ail "other" tests changed to "required" tests.
G = Guidance only		All information provided as good practice.
N = Not Applicable.		Requirements are not applicable.

Section		Units	Sub-systems	Vehicles	Integrated Systems
3.	DEFINITIONS				
4.2	TESTING PHILOSOPHY				
4.3	PROPULSION EQUIPMENT TESTS				
4.3.1	Engine LRU Acceptance Testing				
4.3.2	Engine LRU Qualification Testing				
4.4	FIRMWARE TESTS				
4.5	INSPECTIONS				
4.6	TEST CONDITION TOLERANCES				
4.7	TEST PLANS AND PROCEDURES				
4.7.1	Test Plans				
4.7.2	Test Procedures				
4.8	RETEST				
4.8.1	During Qualification or Acceptance				
4.8.2	During Prelaunch Validation				
4.8.3	During Operational Tests and Evaluations				
4.9	DOCUMENTATION				
4.9.1	Test Documentation Files				
4.9.2	Test Dam				
4.9.3	Test Log				

(table continued next page)

TABLE XV. Requirements Applicability Matrix, Detailed Form (Continued).
(second of 5 pages)

Section		Units	Sub-systems	Vehicles	Integrated Systems
5.1	GENERAL DEVELOPMENT TESTS				
5.2	PMP DEVELOPMENT TESTS AND EVALUATIONS				
5.3	SUBASSEMBLY DEVELOPMENT TESTS				
5.3	IN-PROCESS TESTS AND INSPECTIONS				
5.4	UNIT DEVELOPMENT TESTS				
54.1	Structural Composite Development Tests				
5.4.2	Thermal Development Tests				
5.4.3	Shock & Vibration Isolator Development				
5.5	VEHICLE AND SUBSYSTEM DEVELOPMENT TESTS				
5.5.1	Mechanical Fit Development Tests				
5.5.2	Mode Survey Development Tests				
5.5.3	Structural Development Tests				
5.5.4	Acoustic and Shock Development Tests				
5.5.5	Thermal Balance Development Tests				
5.5.6	Transport & Handling Development Tests				
5.5.7	Wind-tunnel Development Tests				

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TABLE XV. Requirements Applicability Matrix, Detailed Form (Continued). (third of 5 pages)

Section		Units	Sub-systems	Vehicles	Integrated Systems
6.1	GENERAL QUALIFICATION TESTS				
6.1.1	Qualification Hardware				
6.1.2	Test Levels and Durations				
6.1.3	Thermal Vacuum and Cycle Tests				
6.1.4	Acoustic & Vibration Qualification Tests				
6.2	VEHICLE QUALIFICATION TESTS - Baseline				
6.2.1	Functional Test, Vehicle Qualification				
6.2.2	EMC, Vehicle Qualification				
6.2.3	Shock Test, Vehicle Qualification				
6.2.4	Acoustic Test, Vehicle Qualification				
6.2.5	Vibration Test, Vehicle Qualification				
6.2.6	Pressure and Leakage, Vehicle Qualification				
6.2.7	Thermal Cycle Test, Vehicle Qualification				
6.2.8	Thermal Balance Test, Vehicle Qualification				
6.2.9	Thermal Vacuum Test, Vehicle Qualification				
6.2.11	Mode Survey Test, Vehicle Qualification				
6.3	SUBSYSTEM QUALIFICATION TESTS - Baseline				
6.3.1	Structural Static Load Test				
6.3.2	Vibration Test				
6.3.3	Acoustic Test				
6.3.4	Thermal Vacuum Test				
6.3.5	Separation Test				
6.4	UNIT QUALIFICATION TESTS - Baseline				
6.4.1	Functional Test				
6.4.2	Thermal Cycle Test				
6.4.3	Thermal Vacuum Test				
6.4.4	Vibration Test				
6.4.5	Acoustic Test				
6.4.6	Shock Test				
6.4.7	Leakage Test				
6.4.8	Pressure Test				
6.4.9	Acceleration Test				
6.4.10	Life Test				
6.4.11	EMC Test				
6.4.12	Climatic Tests				

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TABLE XV. Requirements Applicability Matrix, Detailed Form (Continued).
(fourth of 5 pages)

Section		Units	Sub-systems	Vehicles	integrated Systems
7.1	GENERAL ACCEPTANCE TESTS				
7.1.1	Temperature Range & No. of Thermal Cycles				
7.1.2	Acoustic Environment				
7.1.3	Vibration Environment				
7.1.4	Storage Tests				
7.2	VEHICLE ACCEPTANCE TESTS - Baseline				
7.2.1	Functional Test				
7.2.2	EMC Test				
7.2.3	Shock Test				
7.2.4	Acoustic Test				
7.2.5	Vibration Test				
7.2.6	Pressure & Leakage Test				
7.4.7	Thermal Cycle Test				
7.2.8	Thermal Vacuum Teat				
7.3	SUBSYSTEM ACCEPTANCE TESTS				
7.3.1	Proof Load Test				
7.3.2	Proof Pressure				
7.4	UNIT ACCEPTANCE TESTS - Baseline				
7.4.1	Functional Teat				
7.4.2	Thermal Cycle Test				
7.4.3	Thermal Vacuum Test				
7.4.4	Vibration Test				
7.4.5	Acoustic Test				
7.4.6	Shock Test				
7.4.7	Leakage Teat				
7.4.8	Proof Pressure Test				
7.4.9	Proof Load Test				
7.4.10	Wear-in Teat				
7.4.11	EMC Teat				

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TABLE XV. Requirements Applicability Matrix, Detailed Form (Continued).
(last of 5 pages)

Section		Units	Sub-systems	Vehicles	Integrated Systems
8.1	SPARES STRATEGY	☐			
8.2	FLIGHTPROOF STRATEGY	☐	☐	☐	
8.2.1	Vehicle Tests			☐	
8 2.2	Subsystem Tests		☐		
8.2.3	Unit Tests	☐			
8.3	PROTOQUALIFICATION STRATEGY	☐	☐	☐	
8.3.1	Vehicle Tests			☐	
8.3.2	Subsystem Tests		☐		
8.3.3	Unit Tests	☐			
8.4	COMBINATION TEST STRATEGIES	☐	☐	☐	
9	PRELAUNCH VALIDATION TESTS			☐	☐
9.1	GENERAL REQUIREMENTS			☐	☐
9.2	TEST FLOW			☐	☐
9.3	TEST CONFIGURATION			☐	☐
9.4	TEST DESCRIPTIONS			☐	☐
9.4.1	Functional Tent			☐	☐
9.4.2	Propulsion Leakage & Functional Tests			☐	☐
9.4.3	Critical Ground Support Tests			☐	☐
9.4.4	Compatibility Test, On-orbit System			☐	☐
9.5	FOLLOW-ON OPERATIONAL TESTS			☐	☐
9.5.1	Operational Tests and Evaluations				☐
9.5.2	On-orbit Testing				☐
9.5.3	Tests of Reusable Flight Hardware	☐	☐	☐	

TABLE XVI. Sample of Table XIV, Requirements Applicability Matrix, General Form.

The matrix designators are **as** follows:

A = Applicable as written
- "Shall" defines minimum requirements.
- "Should" and "may" language denotes guidance.

"Other" test denotes conduct to be evaluated.

F = Fully Applicable — All "should" or "may" language replaced with "shall". All "other" tests changed to "required" tests.

G = Guidance only — All information provided as good practice.

N = Not Applicable. — Requirements are not applicable.

Level of Assembly or Specific Item	Section							
	4. General Requirements	5. Development Tests	6. Qualification Tests	7. Acceptance Tests	8. Alternative Strategies			9. Prelaunch Validation & Operational Tests
					8.1 Spares	8.2 Flightproof	8.3 Proto-qualification	
Units	F	F	F	F	N	N	N	F
Subsystems	F	F	F	F	N	N	N	F
Vehicles	F	F	A	G	N	N	N	F
Integrated System	F	F	G	G	N	N	N	F
Other items:								
Space Experiment	G	G	G	G	G	G	G	G

TABLE XVII. Sample of Table XV, Requirements Applicability Matrix, Detailed Form. (first of 5 pages)

The matrix designators are as follows:

A = Applicable as written
- **"Shall" defines minimum requirements.**
- **"Should" and "may" language denotes guidance.**
- **"Other" denotes test that may be required subject to an evaluation.**

F = Fully Applicable — **All "should" and "may" language replaced with "shall". All "other" tests changed to "required" tests.**

G = Guidance only — **All information provided as good practice.**

N = Not Applicable. — **Requirements are not applicable.**

Section		Units	Sub-systems	Vehicles	Integrated Systems
3.	DEFINITIONS	A	A	A	A
4.2	TESTING PHILOSOPHY	A	A	A	A
4.3	PROPULSION EQUIPMENT TESTS	A			
4.3.1	Engine LRU Acceptance Testing	A			
4.3.2	Engine LRU Qualification Testing	F			
4.4	FIRMWARE TESTS	G			
4.5	INSPECTIONS	A	A	A	A
4.6	TEST CONDITION TOLERANCES	A	A	A	A
4.7	TEST PLANS AND PROCEDURES	A	A	A	A
4.7.1	Test Plans	F	F	F	A
4.7.2	Tut Procedures	F	F	F	A
4.8	RETEST	A	A	A	A
4.8.1	During Qualification or Acceptance	F	F	F	A
4.8.2	During Prelaunch Validation			A	A
4.8.3	During Operational Tests and Evaluations				A
4.9	DOCUMENTATION				
4.9.1	Test Documentation Files	F	F	F	A
4.9.2	Test Data	F	F	F	A
4.9.3	Test Log	F	F	F	A

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TABLE XVII. Sample of Table XV, Requirements Applicability Matrix, Detailed Form (Continued). (second of 5 pages)

	Section	Units	Sub-systems	Vehicles	Integrated Systems
5.1	GENERAL DEVELOPMENT TESTS	A	A	A	A
5.2	PMP DEVELOPMENT TESTS AND EVALUATIONS	F			
5.3	SUBASSEMBLY DEVELOPMENT TESTS	A			
5.3	IN-PROCESS TESTS AND INSPECTIONS	A			
5.4	UNIT DEVELOPMENT TESTS	A			
5.4.1	Structural Composite Development Tests	F			
5.4.2	Thermal Development Tests	A			
5.4.3	Shock & Vibration Isolator Development	A			
5.5	VEHICLE AND SUBSYSTEM DEVELOPMENT TESTS		G	G	
5.5.1	Mechanical Fit Development Tests		G	A	
5.5.2	Mode Survey Development Tests		G	F	
5.5.3	Structural Development Tests		A	A	
5.5.4	Acoustic and Shock Development Tests		A	F	
5.5.5	Thermal Balance Development Tests		G	F	
5.5.6	Transport & Handling Development Tests		G	A	
5.5.7	Wind-tunnel Development Tests		G	A	

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TABLE XVII. Sample of Table XV, Requirements Applicability Matrix, Detailed Form (Continued). (third of 5 pages)

Section		Units	Sub-systems	Vehicles	Integrated Systems
6.1	GENERAL QUALIFICATION TESTS	A	A	A	
6.1.1	Ouolificstion Hardware	A	A	A	
6.1.2	Test Levels and Durations	A	A	A	
6.1.3	Thermal Vacuum and Cycle Tests	A	A	A	
6.1.4	Acoustic & Vibration Qualification	A	A	A	
6.2	VEHICLE QUALIFICATION TESTS - Baseline			A	
6.2.1	Functional Test, Vehicle Qualification			A	
6.2.2	EMC, Vehicle Qualification			A	
6.2.3	Shock Test, Vehicle Qualification			A	
6.2.4	Acoustic Test, Vehicle Qualification			F	
6.2.5	Vibration Test, Vehicle Qualification			G	
6.2.6	Pressure & Leakage, Vehicle Qualiication			A	
6.2.7	Thermal Cycle Test, Vehicle Qualification			G	
6.2.8	Thermal Balance Test, Vehicle Qualiication			A	
6.2.9	Thermal Vacuum Test, Vehicle Qualification			A	
6.2.11	Mode Survey Test, Vehicle Qualification			F	
6.3	SUBSYSTEM QUALIFICATION TESTS - Baseline		A		
6.3.1	Structural Static Load Teat		A		
6.3.2	Vibration Test		A		
6.3.3	Acoustic Test		A		
6.3.4	Thermal Vacuum Test		A		
6.3.5	Separation Teat		A		
6.4	UNIT QUALIFICATION TESTS - Baseline	A			
6.4.1	Functional Test	A			
6.4.2	Thermal Cycle Test	A			
6.4.3	Thermal Vacuum Test	A			
6.4.4	Vibration Test	A			
6.4.5	Acoustic Test	A			
6.4.6	Shock Test	A			
6.4.7	Leakage Test	A			
6.4.8	Pressure Tut	A			
6.4.9	Acceleration Tut	A			
6.4.10	Life Test	A			
6.4.11	EMC Test	A			
6.4.12	Climatic Tests	A			

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TABLE XVII. Sample of Table XV, Requirements Applicability Matrix, Detailed Form (Continued). (fourth of 5 pages)

Section		Units	Sub-systems	Vehicles	Integrated Systems
7.1	GENERAL ACCEPTANCE TESTS	A	G	A	
7.1.1	Temperature Range & No. of Thermal Cycles	A	G	A	
7.1.2	Acoustic Environment	A	G	A	
7.1.3	Vibration Environment	A	G	A	
7.1.4	Storage Tests	A		A	
7.2	VEHICLE ACCEPTANCE TESTS - Baseline			A	
7.2.1	Functional Test			A	
7.2.2	EMC Test			A	
7.2.3	Shock Test			A	
7.2.4	Acoustic Test			A	
7.2.5	Vibration Test			A	
7.2.6	Pressure & Leakage Test			A	
7.4.7	Thermal Cycle Test			A	
7.2.0	Thermal Vacuum Test			A	
7.3	SUBSYSTEM ACCEPTANCE TESTS		A	A	
7.3.1	Proof Load Test		A		
7.3.2	Proof Pressure		A		
7.4	UNIT ACCEPTANCE TESTS - Baseline	A			
7.4.1	Functional Test	A			
7.4.2	Thermal Cycle Test	A			
7.4.3	Thermal Vacuum Test	A			
7.4.4	Vibration Tut	A			
7.4.5	Acoustic Test	A			
7.4.6	Shock Test	A			
7.4.7	Leakage Test	A			
7.4.0	Proof Pressure Test	A			
7.4.9	Proof Load Test	A			
7.4.10	Wear-in Test	A			
7.4.11	EMC Test	A			

(table continued next page)

TABLE XVII. Sample of Table XV, Requirements Applicability Matrix. Detailed Form (Continued). (last of 5 pages)

	Section	Units	Sub-systems	Vehicle	Integrated Systems
8.1	SPARES STRATEGY	G			
a.2	FLIGHTPROOF STRATEGY	N	N	N	
8.2.1	Vehicle Tests			N	
8 2.2	Subsystem Tests		N		
8.2.3	Unit Tests	N			
8.3	PROTOQUALIFICATION STRATEGY	N	N	N	
8.3.1	Vehicle Tests			N	
8.3.2	Subsystem Tests		N		
8.3.3	Unit Tests	N			
0.4	COMBINATION TEST STRATEGIES	G	N	N	
9	PRELAUNCH VALIDATION TESTS			G	A
9.1	GENERAL REQUIREMENTS			G	A
9.2	TEST FLOW			G	A
9.3	TEST CONFIGURATION			G	A
9.4	TEST DESCRIPTIONS			G	A
9.4.1	Functional Tests			G	A
9.4.2	Propulsion Leakage & Functional Tests			G	A
9.4.3	Critical Ground Support Tests			G	A
9.4.4	Compatibility Test, On-orbit System			G	A
9.5	FOLLOW-ON OPERATIONAL TESTS			G	A
9.5.1	Operational Tests & Evaluations				A
9.5.2	On-orbit Testing				A
9.5.3	Tests of Reusable Flight Hardware	A	A	A	

10.3 TEST EVALUATION TEAM.

As a cost containment and quality assurance measure, it is strongly recommended that a joint contractor/procuring agency test evaluation team be established for each of the major vehicle level tests, particularly the mode survey qualification test, the thermal balance qualification test, the subsystem structural static load qualification test, and major separation qualification tests. The test conductor would typically be the chairman of the Test Evaluation Team. Other members should be provided by the design organization that will use the results, by safety, and by quality assurance. The procuring agency should provide a qualified technical representative to the team to perform the usual customer monitoring of the test and to facilitate the timely approval of technically justified or minor deviations from the test requirements. The members of the team would typically change for each test.

Formation of this team would be accomplished by the contract terms, usually as a Statement of Work (SOW) task. Suggested wording for the SOW is as follows:

> "xx.xxx Joint Agency/Contractor Test Evaluation Team. As a cost containment and quality assurance measure, the contractor shall establish a test evaluation team for the mode survey qualification test, the thermal balance qualification test, and the (any other appropriate tests). The Test Evaluation Team shall:
>
> a. Evaluate the adequacy of the test configuration, including instrumentation, prior to the start of testing.
>
> b. Provide guidance in resolving technical problems and issues arising during testing.
>
> c. Expedite the disposition of discrepancies and the approval of corrective actions, if required.
>
> d. Verify adequacy of the test results.
>
> e. Recommend tear-down of the test setup.
>
> (The procuring agency) will provide a technical representative to the Test Evaluation Team to support team activities, monitor the test, and facilitate timely approval of technically justified or minor deviations from test requirements. In particular, during the mode survey test, the Test Evaluation Team may deviate from the completeness requirement for modes judged to be unimportant, and from the orthogonality standard for problem modes. Such deviations require adequate technical justification and the concurrence of the designated representative of (the procuring agency)."

10.4 JN-PROCESS CONTROLS.

in-process controls are almost always a more cost-effective way of avoiding defects than the imposition of tests and inspections on completed units. Therefore, appropriate in-process controls and other quality management steps should be imposed to achieve the high-quality and reliability goals of space and launch systems. The acceptance testing requirements specified in this Standard are intended to be the last step in assuring the quality of each production item, When It has been thoroughly demonstrated that the purpose of an acceptance testing requirement has been met by the in-process controls or other quality management steps implemented by the manufacturer, the manufacturer should petition the procuring agency for approval to reduce the test to a sampling test, or if appropriate, for deletion of the test.

10.5 DOCUMENTATION.

Documents, forms, technical manuals, and data are prepared and distributed in accordance with the Contract Data Requirements List (CDRL) of the applicable contract. The data and data items discussed in this Standard are not deliverable unless invoked by the CDRL or the applicable contract.

The following Data Item Descriptions (DIDs) are among those most frequently used in the Contract Data Requirements List (CDRL - DD Form 14231 to establish detail requirements for the preparation of test plans, procedures, and reports.

DID Number	DID Title
DI-T-30714	Master Test Plan/Program Test Plan.
DI-MCCR-80014A	Software Test Plan.
DI-MCCR-80017A	Software Test Report.
DI-ATTS-80041	Test Requirement Document.
DI-QCIC-805 11	Installation Test Procedure.
DI-QCIC-805 12	Installation Test Report.
DCNDTC80808	Test Plans/Procedures .
DCNDTI-80809A	Test/Inspection Reports.
DI-FACR-80810	Test Facility Requirement Document (TFRD).
DI-ENVR-80861	Environmental Design Test Plan.
DI-MGMT-80882	Structural Test Plans.
DI-MISC-80946	Launch Vehicle Post-Flight Analysis.
DI-MISC-80963	Reentry Vehicle Data Report.
DI-EMCS-81295	Electromagnetic Compatibility Test Plan.

10.6 GUIDANCE DOCUMENTS

MIL-HDBK-340	Application Guidelines for MIL-STD-1540; Test Requirements for Launch, Upper-stage, and Space Vehicles.
MIL-HDBK-343	Design, Construction, and Testing Requirements for One of a Kind Space Equipment.
MIL-STD-1757	Lightning Qualification Test Techniques for Aerospace Vehicles and Hardware.
MIL-STD-1795	Lightning Protection of Aerospace Vehicles and Hardware.
MIL-STD- 1809	Standard Space Environment for Air Force Space Vehicles.
DOD-STD-2167	Defense System Software Development.
DOD-STD-2168	Defense System Quality Program.
DOD-E-83578	Explosive Ordnance for Space Vehicles, General Specification for.
MIL-A-83577	Assemblies, Moving Mechanical, for Space and Launch Vehicles.
DNA-TR-84- 140	Satellite Hardness and Survivability; Testing Rationale for Electronic Upset and Burnout Effects.

10.7 MANAGEMENT OF OPERATIONAL JESTS AND EVALUATIONS

The Air Force Operational Test and Evaluation Center (AFOTEC) manages Air Force operational tests and evaluations (OT&E) as directed or designated in one of its three levels of involvement:

a. Conducts OT&E.
b. Monitors OT&E.
c. Provides advisory role in the conduct of OT&E.

10.8 SUBJECT TERM (KEY WORD) LISTING

Acceptance	Software
Development	Test Baseline
Hard ware	Test Plan
Inspections	Test Procedure
Operational	Test Step
Qualification	Testing
Records	Test Requirements

10.9 <u>CHANGES FROM PREVIOUS ISSUES</u> Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes. The title and content have been changed to show extension of the test requirements to launch vehicles and upper-stage vehicles.

Custodians
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Preparing Activity
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INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2. 3, and 8. In block 1, both the document number *and* revision *letter* should be given.
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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-STD-1540C	2. DOCUMENT DATE *(YYMMDD)* 940915

3. DOCUMENT TITLE
Test Requirements for Launch, Upper-Stage, and Space Vehicles

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)* (1) Commercial (2) AUTOVON *(If applicable)*	7. DATE SUBMITTED *(YYMMDD)*

8. PREPARING ACTIVITY

a. NAME Space and Missile Systems Center, SMC/SDFC	b. TELEPHONE *(Include Area Code)* (1) Commercial (310) 363-2406 (2) AUTOVON 833-2406
c. ADDRESS *(Include Zip Code)* 160 Skynet Street, Suite 2315 Los Angeles AFB, CA 902454683	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403. Fells Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340