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DEPARTMENT OF DEFENSE HANDBOOK

TEST REQUIREMENTS FOR LAUNCH, UPPER-STAGE, AND SPACE VEHICLES
Vol I : Baselines

This handbook is for guidance only.
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AMSC N/A **FSC 1810**

FOREWORD

1 .This Military Handbook is approved for use by all Departments and Agencies of the Department of Defense.

2. This handbook is for guidance only. This handbook cannot be sited as a requirement. If it is, the contractor does not have to comply.

3. The high reliability required of all launch and space equipment is achieved by the designs, design margins, and by the manufacturing process controls imposed at each and every level of assembly. The design and design margins should assure that the equipment is capable of performing in the launch and space environment. The manufacturing process controls are intended to assure that a known quality product is manufactured to meet the design requirements and that any changes required can be made based on a known baseline. Attention to every detail is required throughout development, manufacture, qualification, transportation, and preflight testing to assure successful operations of the launch and space equipment

4. For high-priority, long-life, complex space equipment, high reliability is usually achieved by strict compliance to the requirements and good practices that have historically resulted in successful missions. Programs for these types of space equipment are generally structured to provide extensive checks and balances, with detailed reviews of each step by independent personnel, to assure that no problem is overlooked. Particular attention is given in the design to eliminating single-point failure modes, wherever practicable. Special design analysis, special screening during manufacturing, and other quality provisions that will assure reliability, are implemented on any remaining single-point failure items to avoid latent defects. For these programs, a full qualification program is conducted on each level of assembly ranging from units, subsystems, space experiments, and on to each space vehicle involved.

5. Not all space equipment is high priority or long life. Many space programs are for a single mission that is of short duration, and the equipment may be relatively simple, or involve only one experiment. Expendable launch vehicles represent another program class where the mission duration is short, but weight constraints may eliminate redundancy. Regardless of the variations among launch and space programs, there is always a requirement for high reliability, because a flight failure is never cost effective. At the same time there is a constant drive to reduce the life cycle cost. Testing is a primary target for cost reduction because testing costs typically represent a high percentage of the total program cost. The real problem is to identify those cost-saving measures that are reasonable for each program and that will not increase risks in an unacceptable way. Although an in-flight failure can identify deficiencies in the test program used, mission success does not prove that the test program was optimum, cost effective, or even adequate. Nevertheless, mission success will typically be used to suggest that the testing conducted was excessive and should be reduced in the future. Even if the extent of testing was reasonable and justified, it will often be suggested that the costs were excessive!

6. This handbook, MIL-HDBK-340A, has been prepared to provide baseline test programs for launch and space vehicle equipment. The handbook is organized into two volumes. Volume I

presents a test baseline for high priority space and launch vehicles. The Volume I material previously was included in MIL-STD-1540C. For the convenience of contractors, the same weighting factors (3.5.12) have been retained to indicate the relative importance of the baseline requirements. Changing the weighting factor names to provide a softer guidance tone was rejected in the interest of those contractors who may want to extract sections of the baseline requirements for their own applications. Volume II of the handbook documents additional facets of information pertinent to the test baselines presented in Volume I and how the baseline requirements can be tailored for specific programs. The baselines in this handbook are intended to be used as guidance or as the starting point in developing a test program for a particular program. It should be emphasized that the information included is for general guidance and should not be followed if it does not accommodate the needs of a particular program.

7. Beneficial comments (recommendations, additions, or deletions) and any pertinent data which may be of use in improving this document should be addressed to: Space and Missile Systems Center, SMC/AXMP, 160 Skynet Street, Suite 2315, Los Angeles Air Force Base, El Segundo, CA 90245-4683 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1.0 SCOPE This handbook provides guidance for establishing uniform procedures for the control, determination, and documentation of product verification test requirements for launch, upper-stage, and space vehicles.

1.1 Purpose. Volume I of this handbook establishes environmental and structural ground test baselines for high priority launch vehicles, upper-stage vehicles, space vehicles, and for their sub-system and units. In addition, a uniform set of definitions of related terms is established. Volume II of this handbook addresses the tailoring of the testing baselines to meet the requirements of individual programs.

1.2 Application. Volume I of this handbook provides test baselines for use in developing or evaluating proposed test programs. Omissions or additions in proposed test programs when compared to the baselines in this handbook point to areas that may require justification. Volume II provides additional technical information for the testing requirements contained in Vol. I. In all cases, the testing requirements should be tailored to the specific program requirements. Therefore, the information provided is intended for guidance only and could change based on design complexity, design margins used, vulnerabilities, technical state-of-the-art, in-process controls, mission complexity, life cycle cost, number of vehicles involved, prior usage, and acceptable risk.

1.3 Test Categories. The tests are categorized as follows:

a. Development tests. Engineering 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).

2.0 APPLICABLE DOCUMENTS

2.1 General. The documents below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

2.2 Government Documents.

2.2.1 Specificaions, Standards, and Handbooks. 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. When this handbook is used by acquisition, the application issue of the DoDISS must be sited 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-1540D	Product Verification Requirements for Launch, Upper Stage, and 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 19111-5094.)

2.3 Order of Precedence. In the event of a conflict between the text of this document and the references sited herein, the text of this document takes precedence. Nothing in this document, however, supercedes applicable laws and regulations unless a specific exemption has been obtained.

3.0 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 part 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 Launch 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 Airborne Support Equipment (ASE). 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~~7) 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~~ 7), 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 uncertainty 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 uncertainty margin may be reduced as presented in Table II. In addition, the following thermal-uncertainty heat-load margins are recommended: 50% in the conceptual phase, 45% for preliminary design, 35% for critical design review, and 30% 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% 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% heater capacity margin may be used in lieu of the thermal margins at the minimum expected temperature and at minimum bus voltage, which translates into a duty cycle of no more than 80% 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% 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% should be increased in the early phases of the development. For these cases, the following thermal-uncertainty heat-load margins are recommended: 50% in the conceptual phase, 45% for preliminary design, 35%for the critical design review, and 30% for qualification.

3.3.2 <u>Statistical Estimates of Vibration, Acoustic, and Shock Environments</u>. 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% of flights, estimated with 90% confidence (P99/90 level). The level of the maximum expected environment, used for acceptance testing, is that not exceeded on at least 95% of flights, estimated with 50% 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.

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.
	Stored-coolant subsystems.
Thermal storage devices (phase-change or sensible heat).	Resistance heater with commandable or mechanical or electronic controller.
Thermal insulation(multi-layer insulation, foams, or discrete shields).	Capillary-pumped loops.
	Pumped fluid loops.
Radiators (fixed, articulated, or deployable) with louvers or pinwheels.	Thermoelectric cooler.
Surface finishes (coatings, paints, treatments, second-surface mirrors).	

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

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 maximum 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 1-second time segments overlapped by at least 50%. 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/H (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 1-second time segments overlapped by at least 50%. 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% 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 (3.5.7) 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. Shock transients 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 pyroshock 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 (3.5.7) 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% of flights, estimated with 90% confidence.

3.4.7 Maximum Expected Operating Pressure (MEOP). The MEOP is the highest gage pressure that an item in a pressurized subsystem is required to experience during its service life (3.5.7) 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% of flights, estimated with 90% 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 expansion of 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 conditions 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%.

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. Multipacting. Multipacting is the resonant back and forth flow of secondary electrons in a vacuum between two surfaces separated by a distance such that the electron transit time is an odd integral multiple of one half the period of the alternating voltage impressed on the surfaces. Multipacting requires an electron impacting one surface to initiate the action, and requires the secondary emission of one or more electronis at each surface to sustain the action. Multipacting is an unstable self-extinguishing action which can occur at pressures less than 6.65 pascals (0.05 Torr), except that it may become stable at pressures less than 0.0133 pascals (0.0001 Torr). The pitting action resulting from the secondary emission of electrons degrades the impacted surfaces. The secondary electron emission can also increase the pressure in the vicinity of the surfaces causing ionization (corona) breakdown to occur. These effects can cause degradation of performance or permanent failure of the radio frequency cavities, waveguides, or other devices involved.

3.5.4 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~~ 7). Examples: power condition, command mode, readout mode, attitude control mode, redundancy management mode, safe mode, and spinning or despun condition.

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

a. "Required" tests are the baseline tests that are required because they are generally effective.

b. "Other" tests 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 that an "other" test is effective, it becomes a "required" test for that case.

c. "Not-required" tests are generally ineffective and are not required.

3.5.6 Qualification Margin. An environmental qualification margin is the increase in an environmental condition, over that expected during service life (3.5.7), 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).

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

3.5.8 <u>Temperature Stabilization</u>. 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^{m}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^{m}C of its steady state value, as determined by numerical extrapolation of test temperatures, and the rate of change is less than 1^{m}C per hour.

3.5.9 <u>Test Discrepancy</u>. 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.

3.5.10 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 (3.5.9).

3.5.11 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.

3.5.12 Weighting 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, various categories of weighting factors are associated with the requirements. The primary weighting factors that are incorporated in the Handbook are:

a. Weighting factor “a”. “Will” designates the most important weighting level, the prime requirements.

b. Weighting factor “b”. “Will, 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.

c. Weighting factor “c”. “Should” designates the third weighting level.

d. Weighting factor “d”. “May” designates the lowest weighting level. In some cases, these “may” requirements are stated as examples of acceptable practices.

SECTION 4.

GENERAL REQUIREMENTS

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

4.1 VALIDATION PROCESS.

The development of space and launch systems involves the design, manufacture, test, and integration of very complex equipment and software by a large number of people in many independent organizations. Successful space and launch systems rely heavily on a rigorous prelaunch verification process because repairs after launch are practically impossible and failures tend to be extremely expensive. Documentation required for the validation process also serves as a way to coordinate the many people and activities involved in a space system acquisition. The system engineering process allocates system performance requirements and tolerances to items at lower levels of assembly. A service life cycle profile is developed for each item to document the various phases that the item might encounter in its life. These phases start with release from manufacturing and progress through operational use to removal from service. The phases may include handling, shipping, storage, system integration, prelaunch validation, launch, injection into orbit, operational use, standby use, and return from orbit. For each phase, the possible configurations and operational modes are noted and the possible environments and variations in the environmental range throughout the service life is determined for each item. The life cycle profile data is used in the design development process where hardware and software is designed to perform the allocated functions. The designs, allocated functions, life-cycle profile data, and the associated manufacturing processes and procedures need to be documented in sufficient detail so as to provide a baseline for system validation and a baseline for any subsequent corrective actions or changes that may be needed. By this point, most space programs should have prepared a validation plan to identify all necessary steps to be taken to assure a successful mission. Essentially a list of all required functions, interfaces and other requirements will be prepared. For each item on this requirements list, the method of verifying the requirement will be indicated, as well as the level of assembly involved. Typical validation methods include analysis, inspection, similarity, test, demonstration, and simulation. Note that this handbook does not address many of these validation methods. The handbook focuses only on those requirements where tests are needed to verify the design and manufacturing (qualification tests), and the tests needed for product verification (acceptance).

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 should 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 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 Handbook 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 Handbook. 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 Handbook in that they will 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) will meet the applicable unit requirements of this Handbook.

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 re-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 will either be subjected to such a test on an engine, or will undergo equivalent unit level acceptance testing. Equivalent testing will consider all appropriate environments such as temperature, vibration, pressure, vacuum, and chemical. Testing will 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 will be qualified at a unit level to the requirements of this Handbook.

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 should 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 should 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 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).

Table III. Maximum Allowable Test Tolerances.

Test Parameters	Test Tolerance
Temperature	
-54°C to +100°C	± 3°C
Relative Humidity	± 5%
Acceleration	+10/-0%
Static Load and Pressure	+ 5/-0%
Atmospheric Pressure	
Above 133 pascals (>1 Torr)	±10%
133 to 0.133 pascals (1 Torr to 0.001 Torr)	±25%
Below 0.133 pascal (<0.001 Torr)	±80%
Test Time Duration	+10/-0%
Vibration Frequency	± 2%
Sinusoidal Vibration Amplitude	±10%
Random Vibration Power Spectral Density	
Frequency Range — Maximum Control Bandwidth	
20 to 100 Hz — 10 Hz	± 1.5 dB
100 to 1000 Hz — 10% 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 will 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 will 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% of the spectrum values will be greater than the nominal test specification.	

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 should be conducted using documented test procedures prepared in accordance with the test objectives in the approved test plans. The test objectives, testing criteria, and pass-fail criteria should be stated clearly in the test procedures. The test procedures should 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 should 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 should 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 (3.5.9) occurs while performing any of the required testing steps. In that case, conducting a proper failure 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 During 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 should 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 During Prelaunch Validation. If a discrepancy occurs during prelaunch validation testing (integrated system testing), it should 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 Operational Tests and Evaluations. If a discrepancy occurs during operational tests and evaluations, it should 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

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 should be documented and maintained. The test documentation files should be maintained by the applicable contractors for the duration of their contracts.

4.9.2 Test Data. Pertinent test data should 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 will be documented in a test log. The test log should 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.

4.10 TEST EVALUATION TEAM. As a cost containment and quality assurance measure, it is strongly recommended that a high level, joint contractor and customer, 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 qualificaation tests. The test conductor would typically be the chairman of the Test Evaluation Team. Other members should be provided by the design organizations that will use the results, by safety, and by quality assurance. The customer 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 deviations from the test requirements. The members of the team would typically change for each test. The purpose of each Test Evaluation Team is to:

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.

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 typically the concurrence of the designated representative of the customer.

SECTION 5.

DEVELOPMENT TESTS

5.1 GENERAL

Development tests, or engineering tests, should 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 government approved 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 PART, MATERIAL, AND PROCESS DEVELOPMENT TESTS AND EVALUATIONS

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 design and 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 undertesting, 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 Composite Development Tests. Development tests will 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 Development 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 part 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 (3.5.7). 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 will 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 will 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 ~~will~~ should 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 Heating 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 Heating 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. Thruster Plume-impingement Heating Tests. These tests determine the heating effects due to impingement of the thruster plumes.

f. Transonic 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, should also be simulated.

SECTION 6.

QUALIFICATION TESTS

6.1 GENERAL QUALIFICATION TEST REQUIREMENTS

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

In general, a single qualification test specimen of a given design will 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 Handbook.

6.1.1 Qualification Hardware. The hardware subjected to qualification testing will 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 will 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 demonstrate margin, the qualification environmental conditions will stress the qualification hardware to more severe conditions than the maximum conditions that might occur during service life (3.5.7), 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 53 1/2 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 6.1.4.1 is assumed. Also, durations generally are longer for environments dominated by liquid engine or solid motor operation.

6.1.3 <u>Thermal Vacuum and Thermal Cycle Tests</u>. The required number of qualification thermal cycles is intended to demonstrate a capability for 4 times the thermal fatigue potentially expended in service life (3.5.7). 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 a different limit on number of cycles is used, the required number of qualification cycles will 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 will 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 <u>Acoustic and Vibration Qualification.</u> 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 will 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 (DT_A)	105°C[1]	≥ 50°C	note 3
Qualification (DT_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. $DT_Q = DT_A + 20°C$.
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:
DT_A = Acceptance temperature range.
DT_Q = 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: $N_A = 10(125/DT_A)^{1.4}$ 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. $N_Q = 4N_{AMAX}(DT_A/DT_Q)^{1.4}$, assuming temperature cycling during missionor other service is insignificant; if significant, additional cycling will 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 <u>Accelerated Testing</u>. 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 12. Then 24 minutes of acceptance level testing (6.1.4.2) could be accelerated to 2 minutes of testing at the qualification level. With a typical 1 minute test duration required for flight (4 times a typical 15 second fatigue equivalent duration in flight), the qualification test for this example would apply the extreme expected level for a total of 3 minutes per axis.

6.1.4.2 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)

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 the greater 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 will include all the required tests specified in Table VIII. The "other" tests (3.5.5) 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), will also be conducted as part of qualification testing. Vehicle elements controlled by on-board data processing will have the flight version of the computer software resident in the on-board computer. Verification of the operational requirements will 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]	4.5	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[2] or Vibration	6.2.4 or 6.2.5	6	O	R	R
Thermal Cycle[3]	6.2.7	8	O	O	O
Thermal Balance[4]	6.2.8	9	—	R	R
Thermal Vacuum	6.2.9	10	O	R	R
Modal Survey	6.2.10	any	R	R	R

Recommended vehicle qualification requirements (3.5.5)
R = baseline requirement (high probability of being required)
O = "other" (low probability of being required;

Test	Reference Paragraph	Suggested Sequence	Launch Vehicle	Upper-stage Vehicle	Space Vehicle

— = 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.

6.2.1 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 will be functionally tested at the vehicle level in the launch, orbital, or recovery configuration appropriate to the function. Alignment checks will be made where appropriate. Fit checks will 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 will 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 will 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 will 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 will 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, will 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 will 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) will be varied over specification ranges to demonstrate the performance. Autonomous functions will 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, will be provided to detect intermittent failures.

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

6.2.1.4 Supplementary Requirements. Functional tests will 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 will 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 will 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 Description. The operation of the vehicle and selection of instrumentation will be suitable for determining the margin against malfunctions and unacceptable or undesired responses due to electromagnetic incompatibilities. The test will 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 will 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 will be given to areas indicated to be marginal by analysis. Potential electromagnetic interference from the test vehicle to other subsystems will be measured. The tests will be conducted according to the requirements of MIL-STD-1541. The tests will 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, will be installed in the vehicle and monitored during all tests.

6.2.3 Shock Test, Vehicle Qualification

6.2.3.1 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 Test Description. The vehicle will 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 will avoid undue influence of test fixtures, and prevent recontact of separated portions.

In the shock test or series of shock tests, the vehicle will 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 will 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, will also be actuated or simulated and applied through appropriate interfacing structures. Dynamic instrumentation will 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, will be activated at least one time or simulated as appropriate. Significant shock sources 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 will 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 will 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 will 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, will 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 will 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 will be mounted on a flight-type support structure or reasonable simulation thereof. Significant fluid and pressure conditions will be replicated to the extent practicable. Appropriate dynamic instrumentation will be installed to measure vibration responses at attachment points of critical and representative units. Control microphones will 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 will be conducted per 6.1.4. The typical version of the test involves accelerated acceptance-level testing per 6.1.4.1 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 during the launch, ascent, or reentry phase, extended testing will 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, will 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, will 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 <u>Purpose</u>. 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 <u>Test Description</u>. The vehicle and a flight-type adapter, in the ascent configuration, will be vibrated using one or more shakers through appropriate vibration fixtures. Vibration will be applied in each of 3 orthogonal axes, one direction being parallel to the vehicle thrust axis. Instrumentation will 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 <u>Test Levels and Duration</u>. The test will 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 6.1.4.1 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 will be performed at a level no lower than 6 dB below the qualification level.

6.2.5.4 <u>Supplementary Requirements</u>. Same as 6.2.4.4, except that the structural response will also be monitored to ensure that no unrealistic test conditions occur.

6.2.6 <u>Pressure and Leakage Tests, Vehicle Qualification</u>

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

6.2.6.2 <u>Test Description</u>. The vehicle will 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 will 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 will be measured while operating applicable valves, pumps, and motors. The flow checks will verify that the plumbing configurations are adequate. Checks for subsystem cleanliness, moisture levels, and pH levels will also be made. Where pressurized subsystems are assembled with other than brazed or welded connections, the specified torque values for these connections will be verified prior to the initial qualification leak check.

In addition to the high-pressure test, propellant tanks and thruster valves will be tested for leakage under propellant servicing conditions. The subsystem will 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 will 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 will then be reduced to the MEOP for leakage inspection.

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

6.2.6.4 Supplementary Requirements. Applicable safety standards will be followed in conducting all tests. Tests for detecting external leakage will be performed at such locations as joints, fittings, plugs, and lines. The acceptable leakage rate to meet mission requirements will be based upon an appropriate analysis. In addition, the measurement technique will 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 will 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 will 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 will be placed in a thermal chamber at ambient pressure, and a functional test will be performed to assure readiness for the test. The vehicle will 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 will be asynchronous with the temperature cycling, and redundant units will 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 will begin. One complete thermal cycle is a period beginning at ambient temperature, then cycling to one temperature extreme and stabilizing (3.5.8), then to the other temperature extreme and stabilizing, and then returning to ambient temperature. Strategically placed temperature monitors installed on units will 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 will contain cold and hot soaks during which the vehicle will undergo a functional test, including testing of redundant units.

6.2.7.3 Test Level and Duration. The minimum vehicle temperature range will be 70°C from the hot to the cold condition (Table V). With the 70°C qualification temperature range, the required number of cycles will be 10. For other ranges, see Table VI. The average rate of change of temperature will 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, will be provided to detect intermittent failures. Moisture condensation inside of electrical and electronic units will 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) will 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 will be tested to simulate the thermal environment experienced by the vehicle during its mission. Tests will 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 will 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 will be placed on defining the test conditions expected to produce the maximum and minimum temperatures of sensitive units such as batteries. Sufficient measurements will be made on the vehicle internal and external units to verify the vehicle thermal design and analyses. The power requirements of all thermostatically or electronically controlled heaters and coolers will be verified during the test, and appropriate control authority demonstrated.

The test chamber, with the test item installed, will 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 will be incorporated down to the unit level to evaluate total vehicle performance within operational limits as well as to identify unit problems. The vehicle will 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 4.10 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 will 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.

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 will 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 Vacuum Test, Vehicle Qualification.

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 Test Description. The vehicle will be placed in a thermal vacuum chamber and a functional test performed to assure readiness for chamber closure. The vehicle will 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 will be operating and monitored for corona and multipacting, as applicable, as the pressure is reduced to the lowest specified level. The rate of chamber pressure reduction will 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 will 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 (3.5.8). Following the high-temperature soak, the temperature will be reduced to the lowest specified level and stabilized. Following the low-temperature soak, the vehicle will be returned to ambient temperature to complete one thermal cycle. Functional tests will 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 all 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 will be coordinated with expected environmental conditions, and a complete cycling of all equipment will be performed including the operating and monitoring of redundant units and paths. Vehicle electrical equipment will be operating and monitored throughout the test. Temperature monitors will assure attainment of temperature limits. Strategically placed witness plates, quartz crystal microbalances, or other instrumentation will 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 will 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 will not be allowed to go outside their qualification range at any time during the test. The pressure will 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 will include at least 13 complete hot-cold cycles (Table VI). When thermal cycling is performed, the thermal vacuum qualification test will include at least 3 complete hot-cold cycles (Table VI).

The rate of temperature change will equal or exceed the maximum predicted mission rate of change. The temperature soak (3.5.11) will be at least 8 hours at each temperature extreme during the first and last cycles. For intermediate cycles, the soak duration will 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, will 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 will generally be avoided. External baffling, shadowing, or heating will be utilized to the extent feasible. The vehicle will be operated over the qualification temperature range, although performance within specification is not required outside of 10^{m}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 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 will consist of flight-quality structure with assembled units, payloads, and other major subsystems, and will 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 will be avoided.

The data obtained in the modal survey will 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 will 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%. (See 4.10 regarding formation of a Test Evaluation Team.)

6.2.10.3 Test Levels. The test is generally conducted at response levels that are low compared to the expected flight levels. Limited testing will 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 will 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 95% correlation and dissimilar modes are to be orthogonal to within 10%.

b. Analytical model frequencies are to be within 3% 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 will 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 will 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 (3.5.7).

6.3.1.2 Test Description. The support and load application fixture will 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 will 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 will 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) will be applied to the structure, and measurements of the strain and deformation will be recorded. Strain and deformation will 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 will 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 will 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 4.10 regarding formation of a Test Evaluation Team.)

6.3.1.3 Test Levels and Duration

a. Static Loads. Unless otherwise specified, the design ultimate load test will 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 will be conducted at 1.0 times limit load for both manned and unmanned flight.

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

c. Duration of Loading. Loads will 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.

Table IX. Subsystem Qualification Test Baseline.

TEST	Reference Paragraph	Structure	Space Experiment	Launch Vehicle Subsystem	Payload Fairing
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	O	R[3]	O[2]	O
Separation	6.3.5	R	—	—	R
Mechanical Functional	6.2.1.2	O	O	O[4]	R

Recommended vehicle qualification requirements (3.5.5).

R = baseline requirement (high probability of being required)
O = "other" (low probability of being required.)
— = 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.

6.3.1.4 Supplementary Requirements. Pretest analysis will 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 will 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 will 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 will 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. Same as 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 will 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 will 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 will 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 will 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 will be simulated or taken into account. As a minimum, instrumentation will 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 4.10 regarding formation of a Test Evaluation Team.)

6.3.5.3 Test Activations. A separation test will 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 will be conducted to determine the effect on the separation process. When force or torque margin requirements are appropriate, a separate test will be conducted to demonstrate that the margin is at least 100%; for separation subsystems involving fracture of structural elements, however, the margin demonstrated will be at least 50%. In addition, debris risk will 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 will be conducted on the test article and in the test chamber.

6.4 UNIT QUALIFICATION TESTS

The unit qualification test baseline will include all the required tests specified in Table X. The "other" tests (3.5.5) deemed applicable, and additional special tests that are conducted as acceptance tests on the unit, will also be conducted as part of qualification testing. Unit qualification tests will 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 will 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 will 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 will include application of expected voltages, impedance, frequencies, pulses, and waveforms at the electrical interfaces of the unit, including all redundant circuits. These parameters will be varied throughout their specification ranges and the sequences expected in flight operation. The unit output will be measured to verify that the unit performs to specification requirements. Functional performance will also include electrical continuity, stability, response time, alignment, pressure, leakage, or other special tests that relate to a particular unit configuration. Moving mechanical assemblies will be tested in the configuration corresponding to the environment being simulated and will 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, will be made. Functional tests should include stiffness, damping, friction and breakaway characteristics, where appropriate. Moving mechanical assemblies that contain redundancy in their design will demonstrate required performance in each redundant mode of operation during the test.

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]	4.5	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	5	R	R[5]	R	R[5]	R	R	R	R	R	R[5]	O[7]
Acoustic	6.4.5	5	O	R[5]	—	R[5]	—	—	—	—	—	R[5]	—
Acceleration	6.4.9	7	O	R	O	O	O	—	O	—	—	R	—
Thermal Cycle	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	O	O	O	O	O	O	O	O	O	—
Proof Pressure[3]	6.4.8	11	O	—	O	—	O	R	R	R	O	—	—
EMC	6.4.11	13	R	O	O	—	O	—	—	—	—	—	—
Life	6.4.10	14	O	O	O	O	R	O	R[6]	R	O	O	O[8]
Burst [3]	6.4.8	15	O	—	—	—	O	O	R	O	O	—	—

Recommended unit qualification requirements (3.5.5).

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

Notes:

1 Required before and following each test as appropriate. Include special tests as applicable (6.2).
2 Required when component is sealed 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 vessels, test per MIL-STD-1522. For pressure components, other than bellows and other flexible fluid devices or lines, life tests are discretionary.
7 Test required if the structural component has 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 and 6.4.8.3c) will be required.

6.4.1.3 Supplementary Requirements. Functional or monitoring tests will 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.

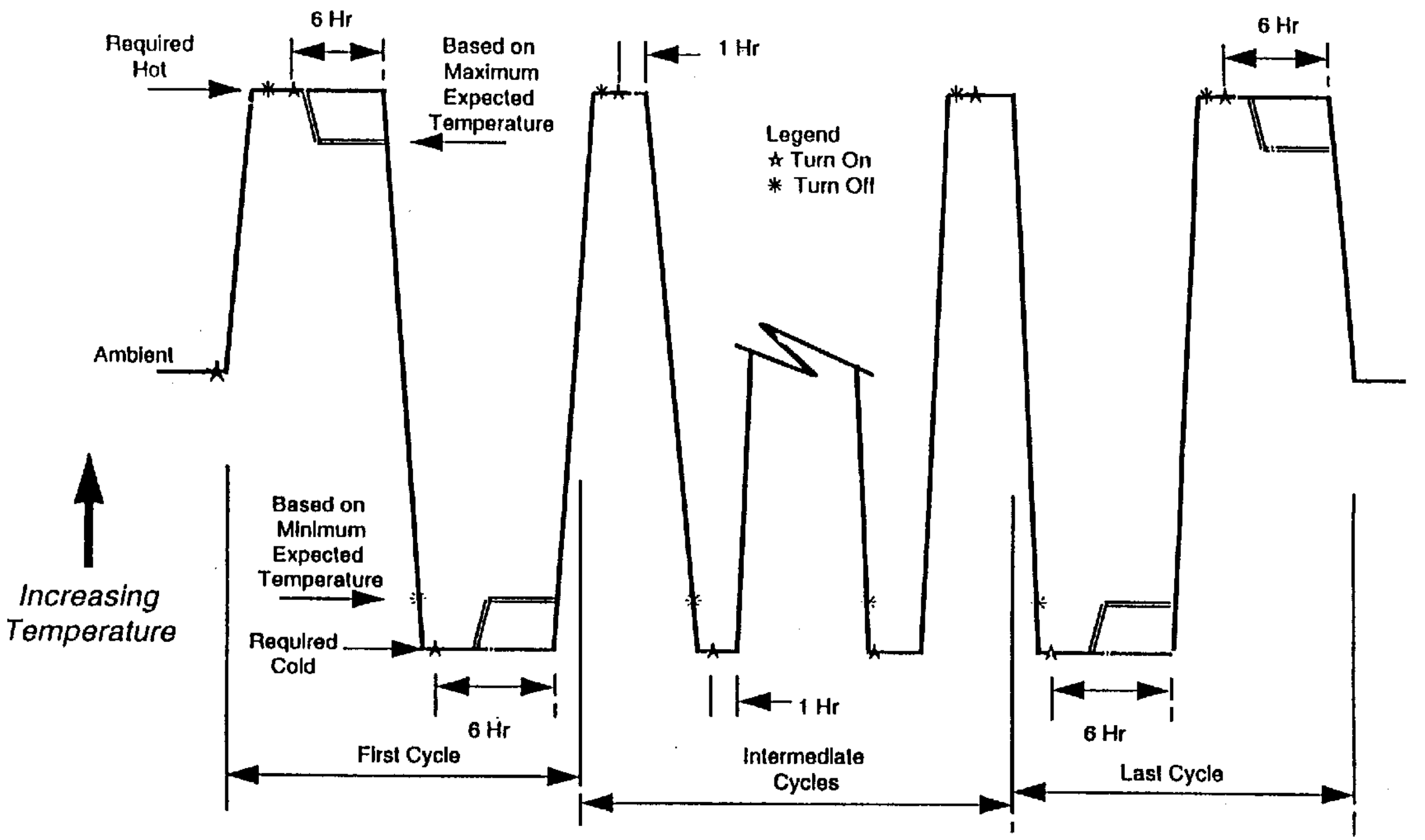
6.4.2.2 Test Description. With the unit operating (power on) and while perceptive parameters are being monitored, the test will follow the temperature profile in Figure 1. The test control temperature will be measured at a representative location on the unit, such as at the mounting point on the baseplate. Each time the control temperature has stabilized (3.5.8) at the hot temperature, the unit will be turned off and then hot started. Then, with the unit operating, the control temperature will 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^{m}C colder than its minimum expected temperature (3.3.1). After the unit has stabilized at the cold temperature, the unit will 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 will 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 will be hot

b. Temperature. The unit temperature will 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 will 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 will 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 will be failure free. Thermal soak durations (3.5.11) will 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 will have at least 1-hour soaks at the hot and cold temperatures. During thermal soaks, the unit will be turned off until the temperature stabilizes (3.5.8) and then turned on, remaining on until the next soak period off-on sequence. Measurement of thermal soak durations will begin at the time of unit turn-on (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

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 will 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, will be cycled through various operational modes. Perceptive parameters will be monitored for failures and intermittents to the maximum extent practicable. Units will meet their performance requirements within specification over the maximum expected temperature range (3.3.1) extended at both temperature extremes by margins indicated in Figure 3. 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 will 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 will 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, will be thermally equivalent to those on the flight units. For units designed to reject their waste heat through the baseplate, a control temperature sensor will be attached either to the unit baseplate or the heat sink. The location will 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 will similarly be chosen. The unit heat transfer to the thermally controlled heat sink and the radiation heat transfer to the environment will be controlled to the same proportions as calculated for the flight environment. During testing of radio-frequency (rf) equipment susceptible to multipaction, a space nuclear radiation environment will be simulated by a gamma-ray or x-ray source at 4 rads per hour.

The chamber pressure will be reduced to the required vacuum conditions. Units that are required to operate during ascent will be operating and monitored for arcing and corona during the 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 will be monitored as appropriate to also assure that multipacting does not occur. Units that do not operate during launch will 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 will be turned off, then hot started after a duration sufficient to ensure the unit internal temperature has stabilized (3.5.8), and then functionally tested. With the unit operating, the component temperature will 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 will be turned off (if not previously turned off during the transition) until the internal temperature stabilizes (3.5.8) 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 will 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) will be at least 10 minutes to allow sufficient time in the region of critical pressure. The pressure will 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 will be modified to reflect an altitude consistent with the maximum service altitude.

b. Temperature. The unit hot and cold temperatures will 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 will be limited to 3°C above the propellant freezing temperature. The transitions between hot and cold should be at an average rate simulating flight conditions.

c. Duration. The number of thermal cycles will be as given in Table VI. Thermal soak durations (3.5.11) will be a minimum of 6 hours at the hot and 6 hours at the cold temperature during the first and last cycle. Intermediate cycles will have at least 1-hour soaks at the hot and cold temperatures with power turned on. Measurement of thermal soak durations will 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 will 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, will be cycled through various operational modes. Perceptive parameters will be monitored for failures and intermittents to the maximum extent practicable. Units will 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) will be monitored. Where practicable, force or torque margins will be determined on moving mechanical assemblies at the temperature extremes. Where this is not practicable, minimum acceptable force or torque margin will be demonstrated. Compatibility with operational fluids will 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 will 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 will be required when units that employ shock or vibration isolators are tested on their isolators. The suitability of the fixture and test control means will have been established prior to the qualification testing (6.4.4.5). The unit will be tested in each of 3 orthogonal axes. Units required to operate under pressure during ascent will 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 will 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 will 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 will be mounted on isolators of the same lot as those used in service, if practicable. Units mounted on isolators will be controlled at the locations where the isolators are attached to the structure. Hard-mounted units will be controlled at the unit mounting attachments.

6.4.4.3 Test Level and Duration. The test will be conducted per 6.1.4. For hard-mounted units, a typical version of the test involves accelerated acceptance-level testing per 6.1.4.1 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 will be conducted as necessary to complete functional testing.

6.4.4.4 Supplementary Requirements. During the test, all electrical and electronic units will 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 will be monitored for failures or intermittents during the test. Continuous monitoring of the unit, including the main bus by a power transient monitoring device, will 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 will 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) will 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 will be conducted. The test duration will 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 will be conducted with an exposure to 3 dB above the extreme expected level. The duration will 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 will be conducted and the vibration test (6.4.4) is discretionary.

6.4.5.2 Test Description. The unit in its ascent configuration will 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 will be replicated to the extent practicable. Appropriate dynamic instrumentation will be installed to measure vibration responses. Control microphones will 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.

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

6.4.5.4 Supplementary Requirements. Same as 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 exposure to the extreme expected shock environment in flight (3.3.7).

6.4.6.2 Test Description. The unit will 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 will be installed. The selected test method will 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 will have been carried out to validate the proposed test method before testing qualification hardware. The test environment will 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 will 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 will 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 will be at least the qualification level for that direction. For vibration or shock isolated units, the lower frequency limit of the response spectrum will be below 0.7 times the natural frequency of the isolated unit. A sufficient number of shocks will 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, will be energized and monitored to the maximum extent practicable, including those that are not normally operating during the service shock. A functional test will 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 will not transfer and will 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 will 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 will 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 will 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 Test 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 will be conducted. Evidence of either leakage, a permanent set or distortion that exceeds a drawing tolerance, or failure of any kind will constitute failure to pass the test.

b. Pressure Cycle Test. For pressurized structures and pressure vessels, a pressure cycle test will be conducted. Requirements for application of external loads in combination with internal pressures during testing will 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 will be increased to the design burst pressure, while simultaneously applying the ultimate external load(s), if appropriate. The internal pressure will 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 will be increased to actual burst of the vessel, and the actual burst pressure will be recorded.

6.4.8.3 Test Levels and Durations.

a. Temperature and Humidity. The test temperature and humidity conditions will be consistent 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 will be 1.1 times the MEOP. For pressure vessels, and other pressure components such as lines and fittings, the minimum proof pressure will comply with the requirements specified in MIL-STD-1522. The pressure will be maintained for a time just sufficient to assure that the proper pressure was achieved. Except that for pressure vessels, the hold time will be a minimum of 5 minutes unless otherwise specified.

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

d. Burst Pressure. Unless otherwise specified, the minimum design burst pressure for pressurized structures will be 1.25 times the MEOP. For pressure vessels and pressure components, the minimum design burst pressure will comply with MIL-STD-1522.

The design burst pressure will 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 will be followed in conducting all tests. Unless otherwise specified, the qualification testing of pressure vessels will 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.

6.4.9 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 will 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 will be at least 1.25 times the maximum predicted acceleration (3.4.8) for each direction of test. The factor will be 1.4 for manned flight.

b. Duration. Unless otherwise specified, the test duration will 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 will be operated under conditions that simulate their service conditions. These conditions will 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 wearout and drift failure modes; and pressure, thermal, and vibration to evaluate fatigue-type failure modes. The test will 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 (3.5.7) with a suitable margin.

6.4.10.3 Test Levels and Durations.

a. Pressure. For pressurized structures and pressure vessels, the pressure level will be that specified in 6.4.8.3c. For other units, ambient pressure will 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 millipascals (10^{-4} Torr) or less will be used.

b. Environmental Levels. The extreme expected environmental levels will 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 will be that specified in 6.4.8.3c. For other units, the total operating time or number of operational cycles will be at least 2 times that predicted during the service life (3.5.7), 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 will be at least 4 times the specified service life.

d. Functional Duty Cycle. Complete functional tests will be conducted before the test begins and after completion of the test. During the life test, functional tests will be conducted in sufficient detail, and at sufficiently 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 will 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 will be inspected to determine their integrity.

6.4.11 Electromagnetic Compatibility (EMC) Test, Unit Qualification

6.4.11.1 Purpose. The electromagnetic compatibility test will 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 will be conducted in accordance with the requirements of MIL-STD-1541. An evaluation will be made of each unit to determine which tests will 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 will 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 will be protected from the potentially degrading effects of extreme terrestrial natural environments by procedural controls and special support equipment. Only those environments that cannot be controlled need be considered in the design and testing.

6.4.12.2 <u>Humidity Test, Unit Qualification</u>

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

a. **<u>Pretest Conditions</u>.** Chamber temperature will be at room ambient conditions with uncontrolled humidity.

b. **<u>Cycle 1</u>.** The temperature will be increased to +35^{m}C over a 1-hour period; then the humidity will be increased to not less than 95% over a 1-hour period with the temperature maintained at +35^{m}C. These conditions will be maintained for 2 hours. The temperature will then be reduced to +2^{m}C over a 2-hour period with the relative humidity stabilized at not less than 95%. These conditions will be maintained for 2 hours.

c. **<u>Cycle 2</u>.** Cycle 1 will be repeated except that the temperature will 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. **<u>Cycle 3</u>.** The chamber temperature will be increased to +35°C over a 2-hour period without adding any moisture to the chamber. The test unit will then be dried with air at room temperature and 50% maximum relative humidity by blowing air through the chamber for 6 hours. The volume of air used per minute will 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. **<u>Cycle 4</u>.** If it had been removed, the unit will be placed back in the test chamber and the temperature increased to +35°C and the relative humidity increased to 90% over a 1-hour period; and these conditions will be maintained for at least 1 hour. The temperature will then be reduced to +2°C over a 1-hour period with the relative humidity stabilized at 90%; and these conditions will be maintained for at least 1 hour. A drying cycle should follow (see Cycle 3).

6.4.12.2.3 Supplementary Requirements. The unit will 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 will be functionally tested during the Cycle 4 periods of stability, after the 1-hour period to reach +35°C and 90% relative humidity, and again after the 1-hour period to reach the +2°C and 90% relative humidity.

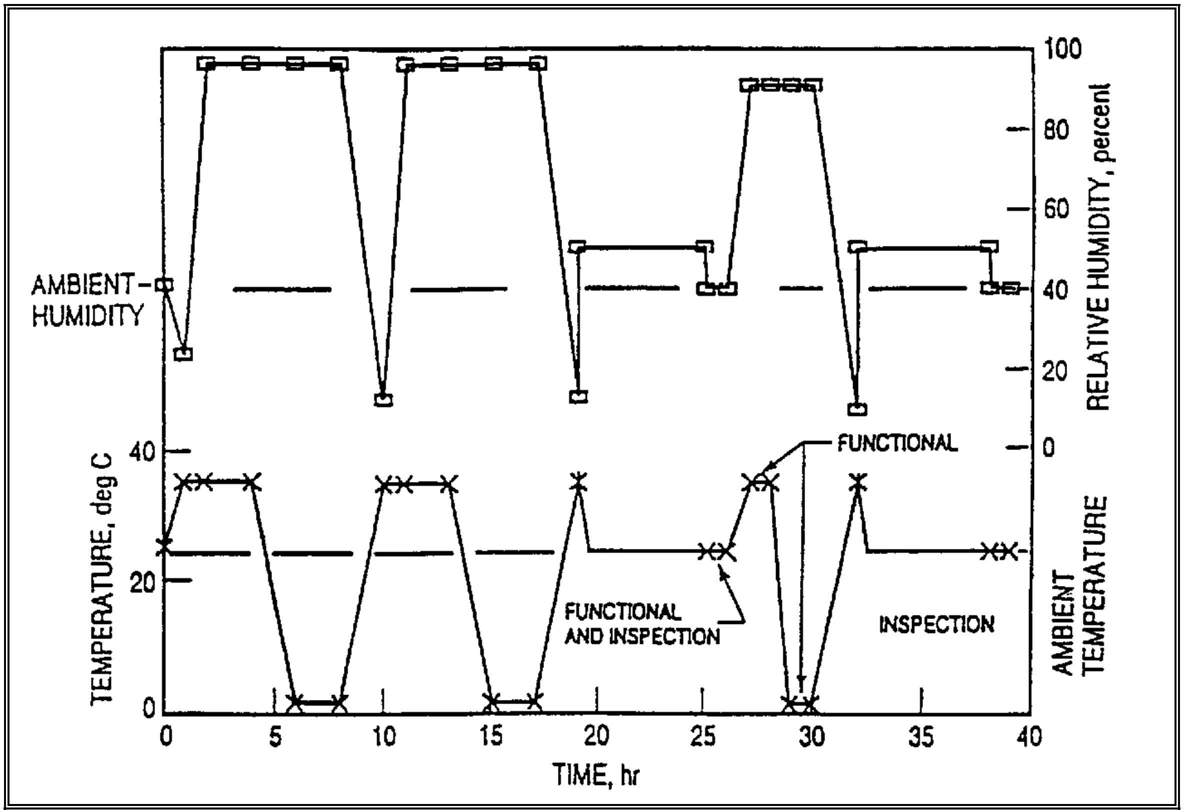


Figure 2. Humidity Test Time Line.

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 will 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 <u>Test Description</u>. The test requirements for the sand and dust test will conform to the method given in MIL-STD-810.

6.4.12.4 <u>Rain Test, Unit Qualification</u>

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

6.4.12.4.2 <u>Test Description</u>. Buildup of the unit, shelter, container, or the cover being tested will 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 will be a minimum of 1°C. For temperature-controlled containers, the temperature difference between the test item and the spray water will at least be that between the maximum control temperature and the coldest rain condition in the field. Nozzles used will 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 will be used for each approximately 0.5 square meter (6 ft^2) of surface area and each nozzle will be positioned at 0.5 meter (20 inches) from the test surface. All exposed faces will be sprayed for at least 40 minutes. The interior will be inspected for water penetration at the end of each 40-minute exposure. Evidence of water penetration will constitute a failure.

6.4.12.5 <u>Salt Fog Test, Unit Qualification</u>

6.4.12.5.1 <u>Purpose</u>. 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 <u>Test Description</u>. The requirements for the salt fog test will conform to the method given in MIL-STD-810.

6.4.12.6 <u>Explosive Atmosphere Test, Unit Qualification</u>

6.4.12.6.1 <u>Purpose</u>. 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 <u>Test Description</u>. The test requirements for the explosive atmosphere test will conform to the method given in MIL-STD-810.

SECTION 7.

ACCEPTANCE TESTS

7.1 GENERAL ACCEPTANCE TEST REQUIREMENTS

Acceptance tests will be conducted as required to demonstrate the acceptability of each deliverable item. The tests will 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 parts, materials, and workmanship. However, the testing will 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 will be tailored for each program, giving consideration to both the required and other tests (3.5.5). 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 will 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 will 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 range 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 will be in compliance with Table VI. If this 105°C temperature range, plus the 1-°C hot and cold extension for qualification, gives rise to unrealistic failure modes or unrealistic design requirements, the range may be shifted or reduced to the extent necessary. To compensate for a reduced range, the number of thermal cycles for acceptance tests will then be increased per note 3 of Table VI. For units exposed to cryogenic temperatures, acceptance temperature limits will 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 will be 1 thermal vacuum cycle in accordance with 7.4.3.

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

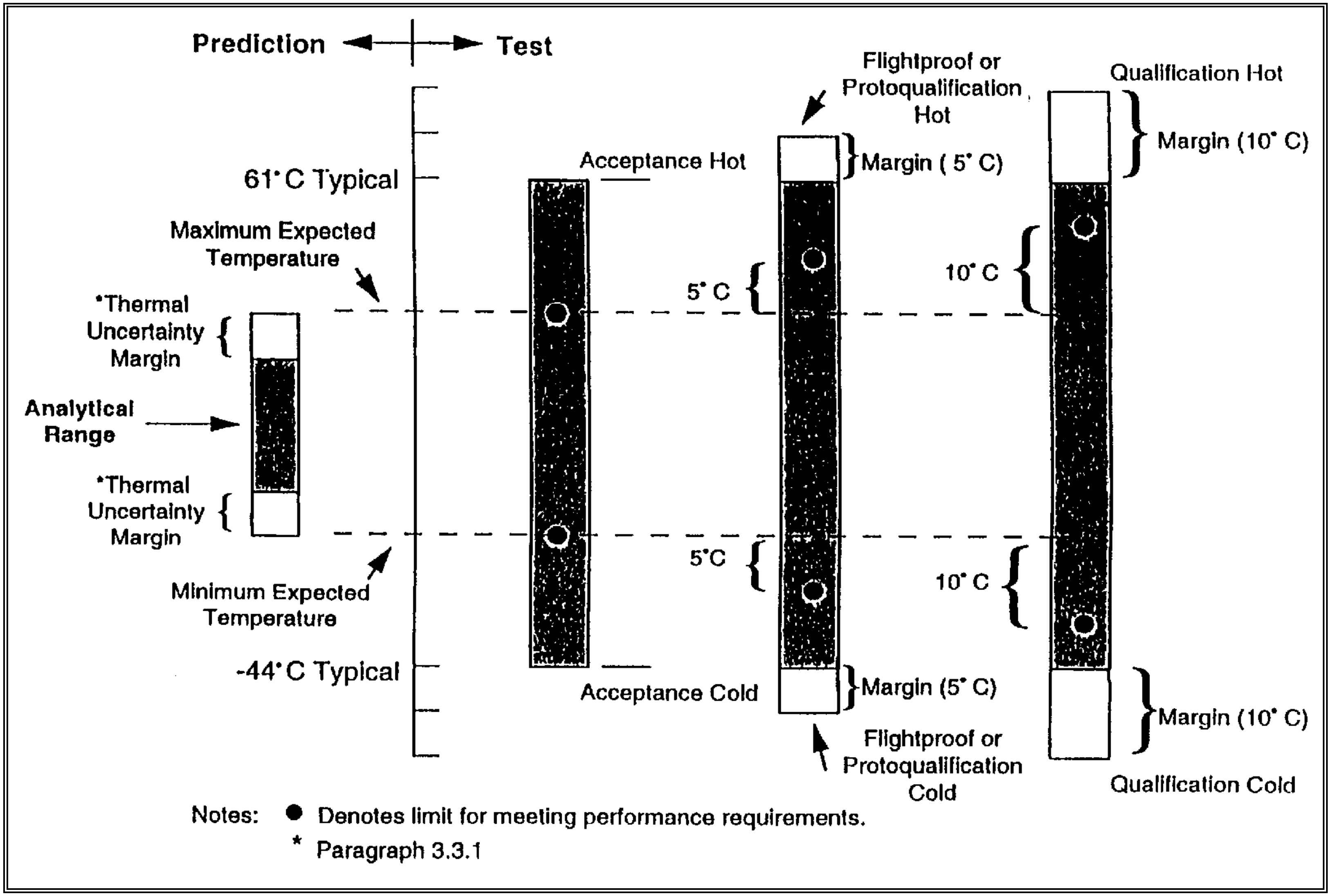


Figure 3. Unit Predicted and Test Temperature Ranges.

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.

7.1.2 <u>Acoustic Environment, Acceptance Tests</u>. The acceptance test acoustic spectrum will 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 will 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, will be that of the maximum expected sinusoidal vibration environment (3.3.6). When concurrent random and sinusoidal vibration during service life (3.5.7) 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 will be 1 minute for each of 3 orthogonal axes.

7.1.4 Storage Tests: Vehicle, Subsystem, or Unit Acceptance. 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 will include all the required tests specified in Table XII. The "other" tests (3.5.5) deemed applicable, and any special tests for the vehicle element (such as alignments, instrument calibrations, antenna patterns, and mass properties) will 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 will be resident in the vehicle computer for these tests. The verification of the operational requirements will be demonstrated in these tests to the extent practicable.

Table XII. Vehicle Acceptance Test Baseline.

TEST	REFERENCE PARAGRAPH	SUGGESTED SEQUENCE	LAUNCH VEHICLE	UPPER STAGE	SPACE VEHICLE
Inspection[1]	4.5	1	R	R	R
Functional[1]	7.2.1	2	R	R	R
Pressure/Leak	7.2.6	3,7,10	R	R	R
EMC	7.2.2	4	—	O	O
Shock	7.2.3	5	O	O	O
Acoustic[2] or Vibration	7.2.4 or 7.2.5	6	O	R	R
Thermal Cycle	7.2.7	8	O	O	O
Thermal Vac[3]	7.2.8	9	O	R	R
Storage	7.1.4	any	O	O	O

Recommended vehicle acceptance requirements. (3.5.5)
R = baseline requirement (high probability of being required)

O = "other" (low probability of being required)
— = 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 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.

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, will 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 will 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 will 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.

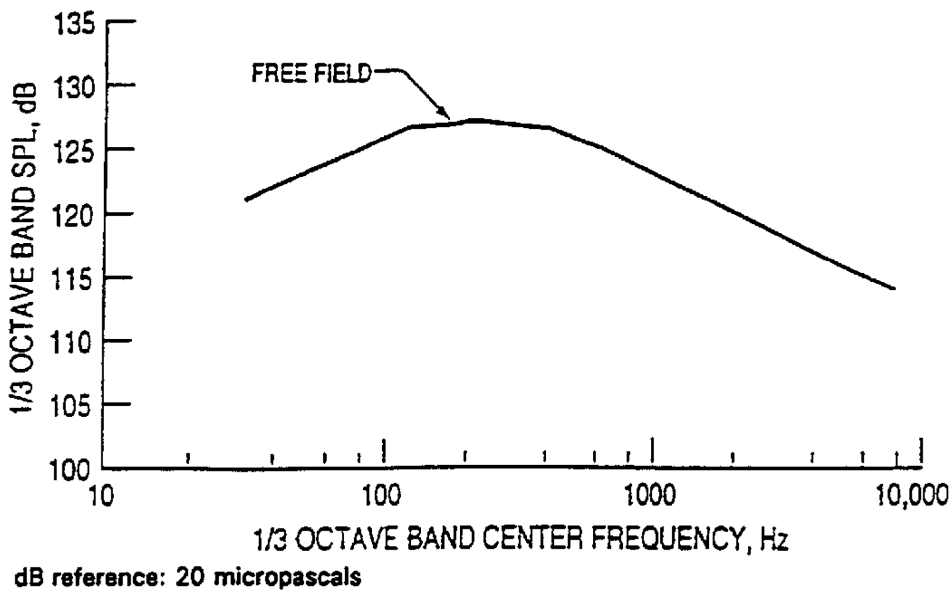
7.2.3.2 Test Description. Same as 6.2.3.2, except that the dynamic instrumentation may be reduced.

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.

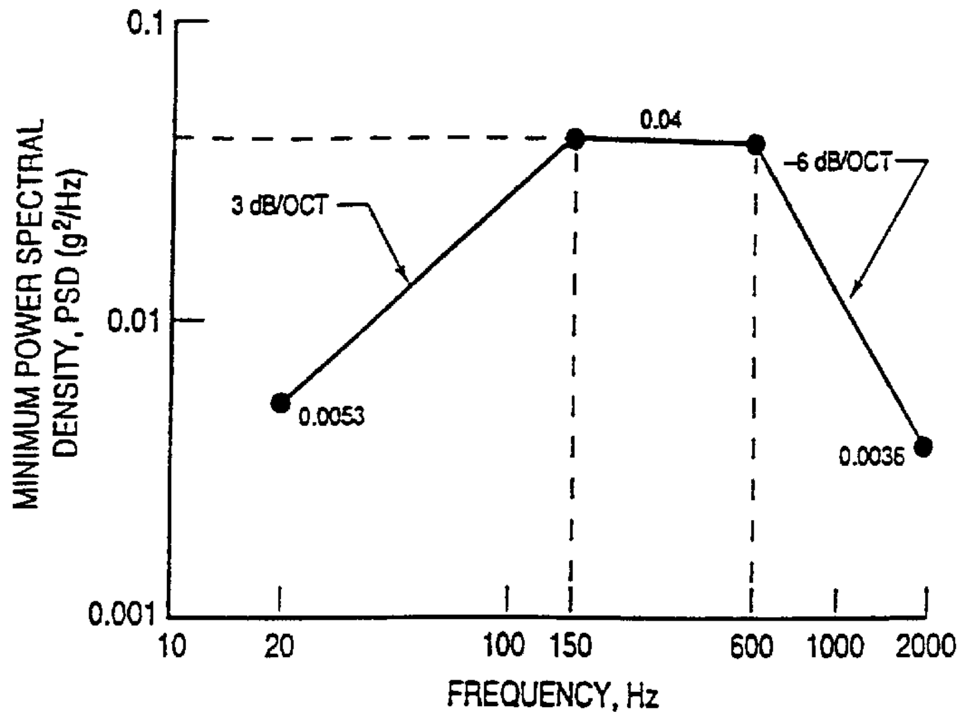


dB reference: 20 micropascals

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.

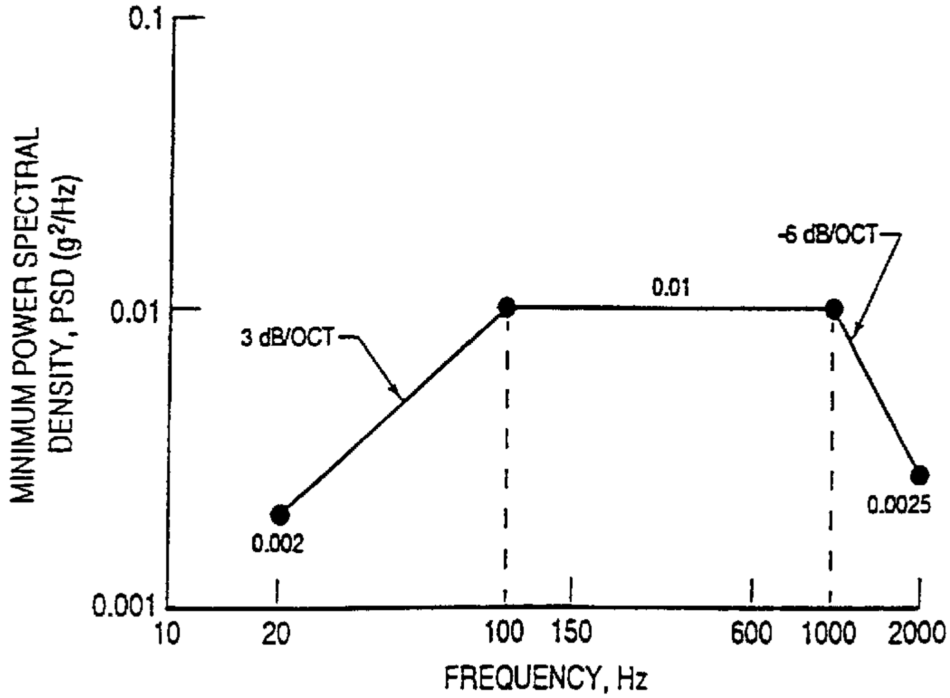


Curve Values	
Frequency (Hz)	Minimum PSD (g^2/Hz)
20	0.0053
20 to 150	+3 dB per octave slope
150 to 600	0.04
600 to 2000	–6 dB per octave slope
2000	0.0036

The overall acceleration level is 6.1 grms.

Note: This spectrum applies only to electrical and electronic 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.

7.2.4.3 Test Level and Duration. The acoustic environment will 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 will 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 Test Level and Duration. The random vibration environment will 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 will 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 will 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 Description. 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 will be 50°C. The average rate of change of temperature from one extreme to the other will be as rapid as practicable. Operating time should be divided approximately equally between redundant circuits. The minimum number of thermal cycles will 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 will 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 will be maintained at or below 13.3 millipascals (10^{-4} Torr). For launch vehicles, the pressure will 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 will 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 will be 4 hours minimum. The soak duration will 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 will be conducted with an 8-hour minimum soak duration at hot and cold temperatures (Tables V and VI).

During one cycle, thermal equilibrium will 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

7.3.1.1 Purpose. The proof load test will 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 will 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 will be 1.1 times the limit load (3.4.6).

b. Duration. Loads will 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 (3.5.5) deemed applicable, will also be conducted as part of acceptance testing.

Unit acceptance tests will 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 will 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 (3.5.5) 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.

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 will be performed in vacuum and combined with the test of 7.4.3. The combined number of cycles will 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 will be the acceptance temperature limits (7.1.1).

c. Duration. The minimum number of thermal cycles will be 12.5, the last two of which will 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 (3.5.11) will 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 will be at least 1 hour long. During soak periods, the unit will be turned off until the temperature stabilizes (3.5.8) and then turned on. Measurement of each temperature soak duration will 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 will not be slower than 1°C per minute. Additional operation at the hot acceptance temperature will 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 will be failure free. For internally redundant units, the operating hours will consist of at least 150 hours of primary operation and at least 50 hours of redundant operation, The last 50 hours of each will be failure free.

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]	4.5	1	R	R	R	R	R	R	R	R	R	R	R
Functional[1]	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	5	O[4]	—	—	—	—	—	—	—	—	O	—
Vibration	7.4.4	6	R	R[5]	R	R[5]	R[8]	R	O	R	R	R[5]	—
Acoustic	7.4.5	6	O	R[5]	—	R[5]	—	—	—	—	—	R[5]	—
Thermal Cycle	7.4.2	8	R	—	—	—	—	—	—	—	—	—	—
Thermal 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	—	—	—
Proof Load	7.4.7	11	—	—	—	—	—	—	—	—	—	—	O[6]
EMC	7.4.11	13	O	—	—	—	—	—	—	—	—	—	—

Recommended vehicle qualification requirements.

R = baseline requirement (high probability of being required)
O = "other" (low probability of being required; 3.5.5)
— = 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.
8 Not required for batteries that cannot be recharged after testing.

7.4.2.4 Supplementary Requirements. 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 will 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 will 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 will 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 will be used (Table VI). Temperature soak durations will 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 will be 1 hour long. During each soak period, the unit will be turned off until the temperature has stabilized and then turned on. Measurement of temperature soak durations (3.5.11) will begin at the time of unit turn-on (Figure 1).

7.4.3.4 Supplementary Requirements. Functional tests will 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, will be cycled through various operational modes. Perceptive parameters will be monitored for failures and intermittents to the maximum extent practicable. Units will meet their performance requirements over the maximum expected temperature range. Units will 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, will be monitored. Compatibility of thrusters with their operational fluids will 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. Electrical and electronic units mounted on shock or vibration isolators will 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 will 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 will 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) will be repeated before testing to acceptance levels.

7.4.4.5 Special Considerations for Isolators. All isolators will 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 will be as defined in 7.1.2. Where insufficient time is available during the 1-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 will be conducted as necessary to complete functional testing.

7.4.5.4 Supplementary Requirements. Same as 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 will be attached at its normal points to the same fixture or structure used for its shock qualification test (6.4.6.2). The unit will be electrically energized and monitored. The test technique employed will be identical to that selected for its qualification, differing only in level and the number of repetitions. A functional test of the unit will be performed before and after the shock test. The unit will 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 will be at least the maximum expected level for that direction. A sufficient number of shocks will 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 (3.5.5) 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 Load Test, Structural Unit Acceptance

7.4.7.1 Purpose. The proof load test will be conducted for all 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 will 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 will 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 will 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 will 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 hydrazine propellants, action will 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 will be used for operations if the test objectives can be met. Otherwise, temperatures representative of the operational environment will be used.

c. Duration. The number of cycles will be either 15 or 5% of the total number of expected cycles during service life (3.5.7), whichever is greater.

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

7.4.11 EMC Test, Unit Acceptance. Limited EMC acceptance testing will be accomplished on units that exhibit emission or susceptibility characteristics, which may adversely 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 will be conducted as in 7.2 (Table XII), with the following modifications:

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

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

d. The vehicle thermal balance test will 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 will be 60°C.

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

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

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

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

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

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

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

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

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

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

8.3 PROTOQUALIFICATION STRATEGY

With a protoqualification 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 will be conducted as in 6.2 (Table VIII), with the following modifications:

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

b. The acoustic or random vibration tests will be conducted as in 6.2.4 and 6.2.5, except that the duration factors will be 2 (instead of 4) and the level margin for the flight environment will 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 will be based on the reduced level margin per Table VII.

c. The thermal vacuum test will be conducted as in 6.2.9, except that the hot and cold temperatures will be 5°C beyond the acceptance temperatures for units (7.1.1) and the number of cycles will 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 will be 60°C and the number of cycles will be half of those in Table VI.

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

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

a. The shock test will 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) will be required.

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

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

d. The thermal cycle tests will be conducted as in 6.4.2, except that the hot and cold temperatures will be 5°C beyond the acceptance temperatures for units (7.1.1) and the number of cycles will 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).
Phase b. Initial operational tests and evaluations (Step 4 tests).

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 will 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.

During 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 will 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 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 will 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 will 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 will be conducted to ensure its proper operation following the handling operations involved in mating. Vehicle cleanliness will 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 will include any airborne support equipment required for the launch, ascent, and space vehicle deployment phases. This equipment will 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 will 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 will 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 will 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 will exercise and demonstrate satisfactory operation of each of the vehicles through all of their mission phases, to the maximum extent practicable. Test data will be compared to corresponding data obtained in factory tests to identify trends in performance parameters. Each test procedure used should 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 will 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 will be conducted.

9.4.1.1 Simulators. Simulation devices will be carefully controlled and will 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 will be revalidated. Simulators will be used for the validation of ground support equipment prior to connecting it to flight hardware.

9.4.1.2 Explosive-ordnance Firing 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) will be performed prior to final connection of the firing circuit to the EEDs. A simulation of the EED characteristics will be used during these tests. The circuits will 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 will be made prior to connection of a firing circuit to ordnance devices and this check will 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) will be conducted to verify the proper operation of all units, to the maximum extent practicable. Propulsion subsystem leakage rates will 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) will have been subjected to appropriate functional tests under simulated functional and environmental conditions of launch. These tests will 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 will 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 will 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 will 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 will 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

9.5.1 Follow-on Operational Tests and Evaluations. Follow-on Operational Tests and Evaluations will be conducted at the launch site in an operational environment, with the equipment in its operational configuration. The assigned operating personnel will identify operational system deficiencies.

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 Handbook.

9.5.3 Tests of Reusable Flight Hardware. Tests of reusable flight hardware will 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 Handbook. 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.

CONCLUDING MATERIAL

Custodians:
Air Force - 19

Preparing Activity:
Air Force - 19
Project 1810-9901