ATTACHMENT 1

DOD-HDBK-343 (USAF)

01 FEBRUARY 1986

MILITARY HANDBOOK

DESIGN, CONSTRUCTION, AND TESTING REQUIREMENTS FOR ONE OF A KIND SPACE EQUIPMENT

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01 FEBRUARY 1986

DEPARTMENT OF THE AIR FORCE
Washington, D.C. 20330

Design, Construction, and Testing Requirements for One of a Kind Space Equipment

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FOREWORD

The high reliability required of all 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 space equipment is capable of performing in the 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 space equipment.

For high-priority, long-life, complex space equipment, high reliability is usually achieved by strict compliance to the military specifications and standards that document the requirements and good practices needed to achieve long life. 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 of the components, on each of the space experiments, and on each space vehicle involved.

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. When compared to long-life, more complex programs, these one of a kind space programs often present excellent opportunities to save substantial time and money in the acquisition. There is still a requirement for high reliability, because a flight failure in space is seldom cost effective. 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. This military handbook is intended to address those issues and various other facets of engineering information pertinent to requirements for one of a kind space equipment. The handbook provides the basis for a consistent technical approach for such programs in order to achieve, in a cost-effective way, the high reliability required. The material presented is intended as a baseline of requirements that should be tailored to the needs of each program.

FOREWORD (continued)

Section 1, Scope, states the purpose of this handbook. Section 2 is the list of documents referenced in the text of the handbook. Section 3 presents definitions for various classes of space programs and equipment, as well as the definitions for the various levels of assembly terms used. Note that the program characteristics imposed by the statement of work and data delivery requirements of the acquisition contract determine the program class. The equipment characteristics imposed by the program peculiar specifications referenced in the acquisition contract determines the equipment class. There is no requirement that the equipment class and the program class be the same. That could be the case, but almost any mix can be visualized to meet unique program requirements. Section 4 presents a series of tables comparing typical attributes of the various classes to provide a summary overview that may be helpful. Tables I, II, and III are matrices of some of the baseline program or management related items that may be used by the government in definitizing the Statement of Work or other contract provisions for various classes of programs.

In contrast, Tables IV through IX are matrices that summarize the technical requirements presented in detail in Sections 5 through 10 of this handbook for various classes of vehicles or experiments. A program peculiar specification for a certain class of space equipment would typically incorporate the general technical requirements by extracting or referencing the applicable requirements from Sections 5 through 10 of this handbook. For the convenience of those preparing space equipment specifications, these sections of the handbook address the requirements in essentially the same sequence, format, and organization that would be addressed in a program peculiar specification. Section 5 addresses equipment characteristics, Section 6 general design requirements, Section 7 requirements for computer resources, Section 8 manufacturing requirements, Section 9 storage and handling requirements, and Section 10 addresses quality assurance provisions. Section 11, Notes, provides guidance information on tailoring of requirements and on the classification process.

The requirements documented here for one of a kind space equipment were given guidance from several NASA and Air Force documents. In particular, the Experimenter's Planning Guide for Department of Defense Space Test Program (The Air Force Space Division Report SD-TR-83-24) should be used in coordination with this document in that it provides many lessons learned from flying one of a kind experiments over the last twenty years. In addition, this Experimenter's Planning Guide includes further guidance for integration, launch and orbit operations support.

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SECTION 1

SCOPE

1.1 PURPOSE

This handbook provides definitions of various classes of space programs and of various classes of space equipment. The handbook also provides detailed technical requirements for the design, construction, and testing of various classes of space equipment. These requirements are a composite of those that have previous been found to be cost effective for one of a kind space programs. The information presented is intended to aid in the formulation of more detailed requirements including design, manufacturing, and testing for specific programs.

1.2 APPLICATION

Extracting or referencing applicable requirements for a certain class of space equipment from Sections 5 through 10 of this handbook is intended to assist in the preparation of program peculiar specifications. The material presented for each class is intended as a baseline that should be tailored to the needs of each acquisition as described in Section 11. The terms "component," "experiment," and "vehicle" are increasing levels of assembly of space equipment addressed in this handbook. Space equipment includes both the hardware and the associated software. (See Section 3 in this handbook for definitions.)

1.3 CLASSIFICATIONS

Space equipment covered by this document are categorized into four classes:

Class A	High Priority, Minimum Risk
Class B	Risk with Cost Compromises
Class C	Economically Reflyable or Repeatable
Class D	Minimum Acquisition Cost

A full definition of each class is given in Section 3. Matrices that illustrate differences among the various classes are given in Section 4. Unless otherwise stated in the text of a paragraph, the requirements presented in this document apply to Class A, Class B, and Class C space equipment. Unless requirements are specifically stated for Class D in the text of a paragraph, the Class C requirements are to be used as guidance for Class D.

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SECTION 2

REFERENCED DOCUMENTS

This section does not list the Space Division Regulations or other program management related documents that are only identified in tables as a convenience to the reader.

2.1 GOVERNMENT DOCUMENTS

2.1.1 Specifications, Standards, and Handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this standard to the extent specified herein.

SPECIFICATIONS:

Federal

QQ-N-290	Nickel Plating (Electrodeposited)
QQ-C-320	Chromium Plating (Electrodeposited)

Military

MIL-M-3171	Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-F-7179	Finishes and Coatings, General Specification for Protection of Aerospace Weapons Systems, Structures and Parts
MIL-A-8625	Anodic Coatings, for Aluminum and Aluminum Alloys
DOD-E-8983	Electronic Equipment, Aerospace, Extended Space Environment, General Specification for
DOD-W-83575	Wiring Harness, Space Vehicle, Design and Testing, General Specification for
MIL-S-83576	Solar Cell Arrays, Space Vehicle, Design and Testing, General Specification for

DOD-A-83577	Assemblies, Moving Mechanical, for Space Vehicles, General Specification for
DOD-E-83578	Explosive Ordnance for Space Vehicles, General Specification for

STANDARDS:

Military

MIL-STD-889	Dissimilar Metals
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-STD-1522	Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems
MIL-STD-1539	Electrical Power, Direct Current, Space Vehicle Design Requirements
MIL-STD-1540	Test Requirements for Space Vehicles
MIL-STD-1541	Electromagnetic Compatibility Requirements for Space Systems
MIL-STD-1547	Parts, Materials, and Processes Requirements for Space and Launch Vehicles, Technical
MIL-STD-1574	System Safety Program for Space and Missile Systems
DOD-STD-1578	Nickel-Cadmium Battery Usage Practice for Space Vehicles
MIL-STD-1589	JOVIAL (J73)
MIL-STD-1815	Ada

HANDBOOKS

MIL-HDBK-5	Metallic, Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17	Plastics for Aerospace Vehicles - Part 1, Reinforced Plastics

MIL-HDBK-17	Plastics for Aerospace Vehicles - Part II, Transparent Glazing Materials
DOD-HDBK-263	Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment
MIL-HDBK-340	Application Guidelines for MIL-STD-1540B; Test Requirements for Space Vehicles

2.1.2 Other Government Documents, Drawings, and Publications. The following other Government documents, drawings, and publications form a part of this handbook to the extent specified herein.

JSC 07700	Space Shuttle System Payload Accommodations, Vol XIV, (NASA JSC)
SP-R-0022	Vacuum Stability Requirements of Polymeric Materials for Spacecraft Applications (NASA JSC)
NHB 1700.7	Safety Policy and Requirements for Payloads Using the Space Transportation System (STS) (NASA)
KHB 1700.7	Space Transportation System Payload Ground Safety Handbook (Joint NASA/Air Force document designated by the Air Force as SAMTO HB S-100)
SAMTO HB S-100	Space Transportation System Payload Ground Safety Handbook (Joint NASA/Air Force document designated by NASA as KHB 1700.7)
FIPS PUB 1	Code for Information Interchange (Federal Information Processing Standard; National Bureau of Standards. This document is the same as ANSI-STD X 3.4-1968)

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

2.2 NONGOVERNMENT DOCUMENTS

The following document(s) form a part of this handbook to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DoDISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DoDISS.

ANSI-STD X 3.4-1968 Code for Information Interchange (This document is the same as FIPS PUB 1)

(Application for copies should be addressed to American National Standards Institute, 1430 Broadway, New York, New York, 10018)

(Nongovernment standards and other publications are normally available from the organizations which prepare or which distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 ORDER OF PRECEDENCE

In the event of a conflict between the text of this handbook and the references cited herein, the text of this handbook shall take precedence. Nothing in this handbook, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

SECTION 3

DEFINITIONS

Definitions are in accordance with MIL-STD-1540, and the following:

3.1 CLASS DEFINITIONS.

Space programs, space vehicles, and space experiments are categorized into four classes as follows:

Class A — High Priority, Minimum Risk. Class A is defined as a high-priority, minimum-risk effort. The characteristics for Class A usually also involve some combination of the following features: high national prestige, long life, high complexity, high use of redundancy, soft failure modes, independent qualification items, complete flight spares, highest cost, and a critical launch time. Vehicle and experiment retrievability or in-orbit maintenance is usually not possible.

Class B — Risk with Cost Compromises. Class B is defined as a high-priority, medium-risk effort, with cost-saving compromises made primarily in areas other than design and construction. The characteristics for Class B usually involve some combination of the following features: high national prestige, medium life, high complexity, soft failure modes, protoflight qualification, limited flight spares, limited use of redundancy, high cost, short schedule, and a critical launch time. Vehicle and experiment retrievability or in-orbit maintenance is usually not possible.

Class C — Economically Reflyable or Repeatable. Class C is defined as a medium or higher risk effort that is economically reflyable or repeatable. The characteristics for Class C usually involve some combination of the following features: medium to high national prestige, short life, low to medium complexity, small size, single string designs, hard failure modes, very limited flight spares, medium cost, short schedule, and a noncritical launch time. Vehicle and experiment retrievability or in-orbit maintenance is usually possible, such as typified by Spacelab or Orbiter attached payloads.

Class D Minimum Acquisition Cost. Class D is defined as a higher-risk, minimum-cost effort. The characteristics for Class D usually involve some combination of the following features: medium to low national prestige, short life, low complexity, small size, single string designs, simple interfaces, hard failure modes, no flight spares, lowest cost, short schedule, and a noncritical launch schedule. Vehicle and experiment retrievability or in-orbit maintenance may or may not be possible.

Matrices that present typical differences among the various classes of space programs, space vehicles, and space experiments are given in Section 4. The classification process is discussed in Subsection 11.2.

3.2 SYSTEM

A system is the composite of equipment, skills, and techniques capable of performing or supporting an operational role. A system includes all operational equipment, related facilities, material, documentation, services, and personnel required for its operation and maintenance.

3.3 EQUIPMENT

Equipment is a general term that refers to an assembly or set of hardware, including the associated software, that is intended to serve some purpose. Equipment does not include the related facilities, material, documentation, services, or personnel required for operation or maintenance of the items. Equipment constitutes one or more elements of every system.

3.4 COMPUTER RESOURCES.

Computer resources are the total set of computer hardware and software required to function on-line or off-line to perform the required computational functions. For the purposes of this handbook, computer resources are a type or subtier of equipment. Software includes the computer programs, data, and firmware that are associated with computer resources. The highest level of assembly for computer programs is defined as a computer program configuration item. A top level computer program configuration item may consist of other subtier computer program configuration items, or computer program components, or both. Computer program components have subtier elements called computer program modules.

3.5 SPACE EQUIPMENT

Space equipment is a general term that refers to any equipment in a space system that is intended for use in space. The various levels of assembly of space equipment as defined in this handbook are: space vehicle, space experiment, subsystem, component, subassembly, and part.

3.6 LEVELS OF ASSEMBLY OF SPACE EQUIPMENT

The following are definitions for space equipment items at various levels of assembly. They are listed in decreasing levels of complexity, from the most complex to the least complex.

3.6.1 Space Vehicle. A space vehicle is a complete, integrated set of subsystems and components 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 recoverable launch vehicle. The airborne support equipment which is peculiar to programs utilizing a recoverable launch vehicle is considered to be a part of the space vehicle being carried by the launch vehicle.

3.6.2 Space Experiment. A space experiment is an assembly of subsystems and components capable of performing one or more functions in space. A space experiment is usually part of the space vehicle payload and is therefore considered to be a lower level of 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 or a space vehicle is an arbitrary decision of little consequence, since the nomenclature used should not affect the classification or the requirements.

3.6.3 Subsystem. A subsystem is an assembly of two or more components, including the supporting structure to which they are mounted, and any interconnecting cables or tubing. A subsystem is composed of functionally related components that perform one or more prescribed functions. Typical space vehicle subsystems are electrical power, attitude control, telemetry, instrumentation, command, structure, thermal control, and propulsion.

3.6.4 Component. A component is a functional unit that is viewed as an entity for purposes of analysis, manufacturing, maintenance, or record keeping. Examples are hydraulic actuators, valves, batteries, electrical harnesses, and individual electronic boxes such as transmitters, receivers, or multiplexers.

3.6.5 Subassembly. The term subassembly denotes two or more parts joined together to form a stockable unit which is capable of disassembly or part replacement. Examples are a printed circuit board with parts mounted, or a gear train.

3.6.6 Part. A part is a single piece, or two or more pieces joined together, which are not normally subject to disassembly without destruction or impairment of the design use. Some examples are resistors, transistors, integrated circuits, relays, capacitors, gears, screws, and mounting brackets.

SECTION 4

REQUIREMENT MATRICES

This section is an overview that presents a number of comparison matrices to illustrate differences among the various classes of space programs and equipment.

The program classification and management requirements are made visible to the contractor by the contract provisions imposed, including the Statement of Work and the Contract Data Requirements List. Tables are provided to assist program management in preparing these documents. Table I is a matrix of typical program characteristics for each class of space program. Table II provides a matrix of items to include in the Statement of Work for each class of program. Table III is a matrix of program review items to be scheduled and included in the Statement of Work for each class of program. These matrices are not the complete list of items to include in the Statement of Work, but only a partial listing of some of the major items. The requirements implemented in a particular contract Statement of Work should be tailored to the needs of that program. (See Section 11 in this handbook.)

The equipment classification and technical requirements are made visible to the contractor by the equipment specifications imposed. Tables IV through IX are matrices of typical technical requirements to be included in specifications for space vehicles or space experiments of each Class. They summarize the requirements presented in Sections 5 through 10 of this handbook. Table IV is a summary of general characteristics for each Class as presented in Section 5. Table V is a summary of design factors for each Class as presented in Section 6. Table VI is a summary of computer resource requirements for each Class as presented in Section 7. Table VII is a summary of construction factors for each Class as presented in Section 8. Table VIII is a summary of test requirements for each Class as presented in Section 10. Table IX is a comparison of typical fabrication and test requirements for components to support the first flight item of each Class. The requirements implemented in a particular specification should be tailored to the needs of that program. There is no requirement that the program, vehicle, and experiment Classes all correspond. For example, a Class C program as identified by the Statement of Work and other contract provisions might involve the acquisition of a Class B space vehicle that carries a payload mix of Class A, B, C, and D experiments. (See Section 11 in this handbook.)

Table X and Table XI outline the suggested applicability of USAF Space Division Regulation SDR 540, the Commander's Policies. These matrices are intended to provide guidance to new Space Division programs considering making requests for waivers for one of a kind space equipment or vehicles.

TABLE I. Comparison of Typical Program Characteristics for Space Programs of Each Class

Characteristics	CLASS A Program	CLASS B Program	CLASS C Program	CLASS D Program
Mission priority or national prestige	Highest	High	Medium to high	Medium to low
Allowed program risk	Lowest feasible	Low	Medium	Medium to high
Management systems imposed in the SOW	Military standards imposed in the SOW	Military standards imposed in the SOW	Reduced compliance to military standards	Only contractor internal management systems
Reviews of contractor	Monthly (formal)	Every two months (formal)	Every three months	Very limited
Program schedule	May take four or more years to launch	May take three or more years to launch	May take two or more years to launch	May take one or more years to launch
Hardware complexity	High, usually involving two or more different experiments	High, often involving two or more different experiments	Low to medium complexity: usually only a single experiment	Low complexity; usually only a single experiment
Flight-type vehicles needed for single flight	Two; one for flight, one for qualification tests	Single unit for flight	Single unit for flight	Single unit for flight
Flight-type components to support first vehicle	Usually six of each type; (includes two spares and redundancy)	Usually three of each type; (includes one spare and redundancy)	Usually two of each type; (includes one spare)	May only be one of each
Contingency plan if there is a hard flight failure	Fly qual. unit with flight spares, or rely on a parallel effort	Repeat program using flight spare, or rely on a parallel effort	Retrieve, repair, then refly; or rely on a parallel effort	Retrieve then refly; or rely on a parallel effort, or repeat program
Acquisition cost	Highest	High	Medium	Lowest

TABLE II. Comparison of Typical Items to Include in the Contract Statement of Work for Space Programs of Each Class

Statement of work items	CLASS A Program	CLASS B Program	CLASS C Program	CLASS D Program
Safety program	MIL-STD-1574 (formal)	MIL-STD-1574 (formal)	MIL-STD-1574 (formal)	MIL-STD-1574
Orbiter safety	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)
Reliability program	MIL-STD-1543 (formal)	MIL-STD-1543	MIL-STD-1543	MIL-STD-1543 (guide)
Reliability analyses	To piece part level	To single point failure	To component level	To subsystem level
Failure mode effects and criticality analyses	To piece part level MIL-STD-1543	To piece part level MIL-STD-1543	To component level MIL-STD-1543 (guide)	To subsystem level MIL-STD-1543 (guide)
Justify single point fail	Required (MIL-STD-1543)	Required (MIL-STD-1543)	For critical items	Not required
Electromagnetic compatibility	MIL-STD-1541 and for STS JSC 07700 Vol. XIV	MIL-STD-1541 and for STS JSC 07700 Vol. XIV	MIL-STD-1541 and for STS JSC 07700 Vol. XIV	MIL-STD-1541 and for STS JSC 07700 Vol. XIV
Human engineering	MIL-STD-1472 (guide)	MIL-STD-1472 (guide)	MIL-STD-1472 (guide)	MIL-STD-1472 (guide)
Configuration control	DOD-STD-480; MIL-STD-483	DOD-STD-480; MIL-STD-483	DOD-STD-480; MIL-STD-483	Not required
Modal survey	Required	Required	Required	Not required
Loads analyses	Iterative analysis (three cycles)	Iterative analysis (three cycles)	Iterative analysis (two cycles)	For safety only
Dynamic loads analyses	Transient events	Transient events	Transient events	As required
Structural test model	Required or use qual.	Use flight item	Use flight item	Use flight item
Computer structural model	Required (software)	Required (software)	Required (software)	For safety only
Computer thermal model	Required (software)	Required (software)	Required (software)	Not required
Thermal verification of computer model	Thermal vacuum test	Thermal vacuum test	Thermal test or thermal vacuum test	Not required
Manufacturing plan	Formal	Informal	Informal	Not required
Program schedule	Formal	Formal	Informal	Informal
Work breakdown structure	MIL-STD-881	MIL-STD-881	MIL-STD-881	Not required

TABLE III. Comparison of Typical Review Items to Include in the Contract Statement of Work for Space Programs of Each Class (see USAF Space Division Regulations SDR 127-8, SDR 540-3, SDR 540-15, SDR 800-12, and SDR 800-13)

Reviews Items	CLASS A Program	CLASS B Program	CLASS C Program	CLASS D Program
Program reviews	MIL-STD-1521	MIL-STD-1521	MIL-STD-1521	Limited
Technical reviews	Monthly (formal)	Every two months (formal)	Every three months	Limited
Component level reviews	MIL-STD-1521	MIL-STD-1521	MIL-STD-1521	Limited
Prelim. design review	Required (formal)	Required for new designs	Informal for new designs	Not required
Critical design review	Required (formal)	Required for new designs	Informal for new designs	Not required
Qualification review	Required (formal)	Required for new designs	Informal for new designs	Not required
Component acceptance	Required (formal)	Included in qual. review	Included in qual. review	May be required
Vehicle level reviews	MIL-STD-1521	MIL-STD-1521	MIL-STD-1521	Limited
System design review	Required (formal)	Required (formal)	Not required	Required
Prelim. design review	Required (formal)	Required for new designs	Informal for new designs	Not required
Critical design review	Required (formal)	Required (formal)	Required (informal)	Not required
Phased software reviews	Required (formal)	Required (formal)	Required (informal)	Not required
Qualification reviews	Required (formal)	Required (protoflight)	Required for software	Required for software
Vehicle acceptance	Required (formal)	No, included in protoflt	Required (formal)	Required (formal)
Phased safety reviews	Required	Required	Required	Required
Flight accreditation	Required (formal)	Required (formal)	Required (informal)	Not required
Independent readiness review	Required (formal); before acceptance test	Required (formal); before protoflight test	Required (informal); before acceptance test	Safety related
Mission readiness review	Required (formal)	Required (formal)	Required (formal)	Safety related
Flight readiness review	Required (formal)	Required (formal)	Required (formal)	Safety related

TABLE IV. Comparison of Typical Characteristics for Space Vehicles or Space Experiments of Each Class

Characteristics	CLASS A	CLASS B	CLASS C	CLASS D
Mission priority or national prestige	Highest	High	Medium to high	Medium to low
Allowed risk	Lowest feasible	Low	Medium	Medium to high
Specification compliance	Through all tiers	Through all tiers	Through all tiers	Top level only
Flight-type vehicle or experiment	Two: one for flight, one for qualification tests	Single unit for flight	Single unit for flight	Single unit for flight
Acquisition cost	Highest	High	Medium	Lowest
Vehicle complexity	High, usually with two or more different experiments	High, often with two or more different experiments	Low to medium complexity: usually only a single experiment	Low complexity; usually only a single experiment
Typical launch time	Narrow launch windows	Narrow launch windows	Not critical	Not critical
Typical orbit	Free-flyer	Free-flyer	Attached to host vehicle	Attached to host vehicle
Typical on-orbit time	Years	Years	Months	Days
Experiments carried on vehicle	Usually several Class A, but may include Class B, Class C, and/or Class D	Usually several Class A or Class B, but may include Class C or D	Usually one or more Class C, but could include other classes	Usually one or more Class D, but could include other classes
Use of redundancy in vehicle	Used to assure critical functions, & independent failure of experiments	Used to assure critical functions, & independent failure of experiments	Usually a single string; redundancy used if safety critical	Usually a single string; redundancy used if safety critical
Probable failure mode of vehicle	Soft or only partial loss of data	Soft or only partial loss of data	Partial or total loss of data	Partial or total loss of data
Retrievability or in-orbit maintenance	Not usually possible	Not usually possible	Usually retrievable or maintainable in orbit	May or may not be retrievable
Experiment complexity	Usually complex, or with complex interfaces, or both	Usually complex, or with complex interfaces, or both	Usually low or medium complexity	Usually very simple, but can be of low or medium complexity
Use of redundancy in experiment	Redundancy used in all critical functions, where practical	Redundancy used in some critical functions, and where cost effective	Usually a single string; redundancy used if safety critical	Usually a single string; redundancy used if safety critical
Probable failure mode of experiment	Soft or only partial loss of data	Soft or only partial loss of data	Partial or total loss of data	Partial or total loss of data

TABLE V. Comparison of Typical Design Factors for Space Vehicles or Space Experiments of Each Class

Design Factors	CLASS A	CLASS B	CLASS C	CLASS D
Mean time to fail (See 5.2)	Highest feasible	To meet mission life	To meet mission life	May be low
Use of redundancy (See 5.2)	Redundancy used in all critical functions, where practical	Redundancy used in some critical functions and where cost effective	Usually a single string; redundancy used if safety critical	Usually a single string; redundancy used if safety critical
Single failure points (See 5.2)	To be avoided if feasible	Avoided if critical or where cost effective	Avoided only if clearly cost effective	Acceptable
Analyses of failures of flight items (See 5.2)	At the piece part and higher levels of assembly	At the piece part and higher levels of assembly	At the component and higher levels of assembly	At the system level
Operating environments (See 5.4)	MIL-STD-1540 definition	MIL-STD-1540 definition	MIL-STD-1540 definition	MIL-STD-1540 definition
Environ. design margins (See 5.4.4)	10 deg C; 6 dB	5 deg C; 3 dB	0 deg C; 0 dB	0 deg C; 0 dB
Part specifications (See 6.1)	MIL-STD-1547	MIL-STD-1547	MIL-STD-1547 (guidance)	Contractor option
Materials (See 6.1)	Space quality	Space quality	Space quality	Contractor option
Structures (See 6.2 and 6.12)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)
Pressure vessels (See 6.3 and 6.12)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)
Mechanical assemblies (See 6.4)	DOD-A-83577	DOD-A-83577	DOD-A-83577 (guide)	DOD-A-83577 (guide)
Explosive ordnance (See 6.5)	DOD-E-83578	DOD-E-83578	DOD-E-83578 (guide)	DOD-E-83578 (guide)
Wiring (harnesses) (See 6.6)	DOD-W-83575	DOD-W-83575	DOD-W-83575	DOD-W-83575 (guide)
Electronic components (See 6.7)	DOD-E-8983	DOD-E-8983	DOD-E-8983 (guide)	DOD-E-8983 (guide)
Solar arrays (See 6.8)	MIL-S-83576	MIL-S-83576	MIL-S-83576 (guide)	MIL-S-83576 (guide)
Product marking (See 6.9)	For lot traceability	For lot traceability	For lot traceability	If required for safety
Electromagnetic compat. (See 6.10)	MIL-STD-1541	MIL-STD-1541	MIL-STD-1541 (emissions)	MIL-STD-1541 (emissions)
Safety program (See 6.12)	MIL-STD-1574	MIL-STD-1574	MIL-STD-1574	MIL-STD-1574
Safety (See 6.12)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)	NHB 1700.7 (NASA)
Ground safety (See 6.12)	SAMTO HB S-100	SAMTO HB S-100	SAMTO HB S-100	SAMTO HB S-100
Human engineering (See 6.13)	MIL-STD-1472 (guide)	MIL-STD-1472 (guide)	MIL-STD-1472 (guide)	MIL-STD-1472 (guide)

TABLE VI. Comparison of Typical Computer Resource Requirements for Space Vehicles or Space Experiments of Each Class

Computer Resources	CLASS A	CLASS B	CLASS C	CLASS D
Operational computers (See 7.1.1)	2 times the rate and 1.5 times the memory	2 times the rate and 1.5 times the memory	2 times the rate and 1.5 times the memory	As required
Operating system (See 7.1.2)	Existing	Existing	Existing	As required
Application software (See 7.1.3)	Develop to standards	Develop to standards	Develop to standards	As required
Software maintenance (See 7.2)	Delivered facility	Development guide	Development guide	Development guide
Verification/validation (See 10.4.3 - SOW Item)	Independent V & V	Walkthrough and test cases	Walkthrough and test cases	Guidance

TABLE VII. Comparison of Typical Construction Requirements for Space Vehicles or Space Experiments of Each Class

Construction Factors	CLASS A	CLASS B	CLASS C	CLASS D
Supplier selection	Has controlled process for space quality	Has controlled process for space quality	Has controlled process for space quality	Contractor option
Parts traceability (See 8.1)	Required	Required	Required	Contractor option
Materials traceability (See 8.1)	Required	Required	Required	Contractor option
In-process screening (See 8.1)	To assure performance and quality	To assure performance and quality	To assure performance and quality	Contractor option
Manufacturing processes (See 8.1)	Documented in detail	Documented	Limited documentation	Contractor option
Assembly lots (See 8.2)	For all parts and materials	For all parts and materials	For critical parts and materials	Contractor option
Cleanliness (See 8.3)	For everything	For everything	For everything	Contractor option
Electrostatic discharge (See 8.4)	DOD-HDBK-263	DOD-HDBK-263	DOD-HDBK-263	Contractor option
Outgassing (See 6.1.1 and 8.3.3)	SP-R-0022 (NASA)	SP-R-0022 (NASA)	SP-R-0022 (NASA)	SP-R-0022 (NASA)

TABLE VIII. Comparison of Typical Test Requirements for Space Vehicles or Space Experiments of Each Class

Test Requirements	CLASS A	CLASS B	CLASS C	CLASS D
Maximum operating environments	MIL-STD-1540 definitions for each assembly level	MIL-STD-1540 definitions for each assembly level	MIL-STD-1540 definitions for each assembly level	MIL-STD-1540 definitions for each assembly level
Testing tolerances	MIL-STD-1540	MIL-STD-1540	MIL-STD-1540	MIL-STD-1540
Development tests	As required	As required	As required	Not required
Component acceptance (See 10.4.1)	MIL-STD-1540 (component acceptance)	Not required on 1st item; protoflight test only	MIL-STD-1540 (component acceptance)	Not required
Component qualification (See 10.4.1)	MIL-STD-1540 (qual.) to design levels	MIL-STD-1540(protoflight) to design levels	Not required (acceptance test only)	Not required
Qual. thermal margin	10 deg C	5 deg C	0 deg C	0 deg C
Qual. vibration margin	6 dB	3 dB	0 db	0 dB
Qual. acoustic margin	6 dB	3 dB	0 db	0 dB
Qual. shock margin	6 dB	3 dB	0 db	0 dB
Experiment acceptance (See 10.4.3)	MIL-STD-1540 (vehicle acceptance)	Not required on 1st item; protoflight test only	MIL-STD-1540 (vehicle acceptance)	MIL-STD-1540 (vehicle acceptance)
Experiment qualification (See 10.4.3)	MIL-STD-1540 (vehicle) (vehicle qualification)	MIL-STD-1540(protoflight) to design levels	Not required (acceptance test only)	Not required (acceptance test only)
Qual. margins (environ.)	10 deg C; 6 dB	10 deg C; 6 dB	0	0
Vehicle acceptance (See 10.4.3)	MIL-STD-1540 (vehicle acceptance)	Not required on 1st item; protoflight test only	MIL-STD-1540 (vehicle acceptance)	MIL-STD-1540 (vehicle acceptance)
Vehicle qualification (See 10.4.3)	MIL-STD-1540 (vehicle qualification)	MIL-STD-1540(protoflight) 1st item to design levels	Not required (acceptance test only)	Not required (acceptance test only)
Qual. margins (environ.)	10 deg C; 6 dB	10 deg C; 6 dB	0	0

TABLE IX. Comparison of Typical Fabrication and Test Requirements for Components to Support the First Flight Item of Each Class

Item	CLASS A Equipment	CLASS B Equipment	CLASS C Equipment	CLASS D Equipment
Component development test items	For all newly developed items. Development tests as required.	For newly developed mission-critical items (tests as required)	For newly developed safety-critical items (tests as required)	None required
Number of flight-type components required to support first flight	Usually six of each type	Usually three of each type	Usually two of each type	May only be one of each type
Component serial 1 (first fabricated)	Component qualification tests, then use for reliability margin tests	For flight vehicle (first string) (protoflight tested)	For flight vehicle (single string) (acceptance tested)	For flight vehicle (component tests optional)
Component serial 2 (second fabricated)	For qualification vehicle (first string); then spare;(acceptance tested)	For flight vehicle (second string); (acceptance tested)	A "true" flight spare (acceptance tested)	Flight spare if planned (component tests optional)
Component serial 3 (third fabricated)	For qualification vehicle (second string); then spare;(acceptance tested)	A "true" flight spare (acceptance tested)	Usually none planned	Usually none planned
Component serial 4 (fourth fabricated)	For flight vehicle (first string) (acceptance tested)	Usually none planned	Usually none planned	Usually none planned
Component serial 5 (fifth fabricated)	For flight vehicle (second string) (acceptance tested)	Usually none planned	Usually none planned	Usually none planned
Component serial 6 (sixth fabricated)	A "true" flight spare (acceptance tested)	Usually none planned	Usually none planned	Usually none planned

TABLE X. Suggested Applicability of USAF SDR 540 (Commander's Policies) in Technical Areas for Space Programs*

Commander's Policies (technical)	CLASS A	CLASS B	CLASS C	CLASS D
SDR 540-4 INDEPENDENT MASS PROPERTIES, STABILITY & CONTROL	yes	yes	yes	yes
SDR 540-5 INDEPENDENT STRUCTURAL LOADS ANALYSIS	yes	yes	yes	yes
SDR 540-6 SPACE VEHICLE TESTING	yes	yes	yes	no
SDR 540-8 SPACE SERVICING	yes	yes	yes	yes
SDR 540-9 "B" NUTS	yes	yes	yes	yes
SDR 540-10 FMEA'S	yes	yes	yes	yes
SDR 540-12 PIECE PARTS PROCUREMENT	yes	yes	no	no
SDR 540-17 INDEPENDENT MISHAP RISK ASSESSMENT	yes	yes	yes	yes
SDR 540-18 TT&C SUPPORT PLANNING	yes	yes	yes	yes
SDR 540-23 USE OF MULTILAYER PRINTED-WIRING BOARDS	yes	yes	no	no
SDR 540-25 PRESSURIZED STRUCTURES	yes	yes	yes	yes
SDR 540-39 SPACEFLIGHT ENGINEERS	yes	yes	yes	yes

* NOTE: USAF Space Division Regulations (SDRs), including the Commander's policies in SDR 540, are applicable to all USAF Space Division programs unless the requirement is waived by the Commander. Many policies allow compliance tailored to the actual program needs; however, this matrix is intended to provide guidance to new programs that may consider making a request for a waiver.

TABLE XI. Suggested Applicability of USAF SDR 540 (Commander's Policies) in Management Areas for Space Programs*

Commander's Policies (program management)	CLASS A	CLASS B	CLASS C	CLASS D
SDR 540- 3 SYSTEMS ACQ. REVIEWS AND AUDITS	yes	yes	no	no
SDR 540-14 SD/NASA JOHNSON COORDINATION	yes	yes	yes	yes
SDR 540-15 MISSION READINESS	yes	yes	yes	yes
SDR 540-16 SECURITY	yes	yes	yes	yes
SDR 540-21 CONTRACTOR PERFORMANCE	yes	yes	yes	yes
SDR 540-31 ENGINEERING DESIGN REVIEWS	yes	yes	no	no
SDR 540-33 PROGRAM DIRECTOR'S FINAL REPORT	yes	yes	yes	yes
SDR 540-41 OPTIMIZING COMPETITION	yes	yes	yes	yes

* NOTE: USAF Space Division Regulations (SDRs), including the Commander's policies in SDR 540, are applicable to all USAF Space Division programs unless the requirement is waived by the Commander. Many policies allow compliance tailored to the actual program needs; however, this matrix is intended to provide guidance to new programs that may consider making a request for a waiver.

SECTION 5

SPACE EQUIPMENT CHARACTERISTICS

Unless specifically stated otherwise, all requirements apply to Class A, Class B, and Class C. Unless specifically stated otherwise, the requirements for Class C are guidance for Class D.

5.1 PHYSICAL CHARACTERISTICS

5.1.1 Mass Properties The weight of the space equipment shall be controlled and monitored during the acquisition process for the preservation of performance margins and as a control of other mass properties.

5.1.2 Power. Vehicles and experiments shall be designed to operate from a 28 $\pm$ 6 Volt dc, two-wire, single-point negative grounded power subsystem conforming to MIL-STD-1539. Nickel-cadmium battery usage shall be in accordance with MIL-STD-1578.

5.1.3 Durability. The space equipment shall be so designed and constructed that no fixed part or assembly shall become loose, no movable part or assembly shall become undesirably free or sluggish, and no degradation shall be caused in the performance beyond that specified for the space equipment during operation or after storage.

5.2 RELIABILITY

The probability of mission success for the nominal mission life of Class A and Class B space vehicles and experiments shall be at least 0.95. The probability of mission success shall include consideration of any potential failures in associated ground operations, such as commanding, that might not be corrected in time to avoid an impact on the space equipment. The reliability allocations shall assure that the overall mission reliability requirements are met, considering the most severe extremes of storage, transportation, testing, and operations.

Reliability analyses and failure mode effects and criticality analyses shall be to the piece part level for Class A. For Class B, the analysis shall be to the level required to identify all single point failure modes or component redundancy. For Class C the analysis shall be to the component level and for Class D, to the subsystem level.

The design of Class A, Class B, and Class C space equipment shall be such that a failure in one component shall not propagate to other components. Space experiments shall be capable of initiating protective measures to avoid catastrophic loss of the space experiment or of the host space vehicle. The design of Class D space experiments shall be such that a failure shall not propagate to the host space vehicle.

5.3 MAINTAINABILITY

Unless maintenance or servicing in space is specifically stated as a program requirement, space vehicles and experiments shall be designed so as to not require any scheduled maintenance, repair, or servicing during their service life. The design shall incorporate test and telemetry points to allow verification of functional performance. The design shall accommodate easy installation and replacement of major components during factory assembly and of explosive ordnance devices, batteries, and other site replaceable items at the launch site when mated to the launch vehicle. Access shall be provided to those test plugs, harness break-in points, external umbilical connections, safe and arm devices, explosive ordnance devices, pressurant and propellant fill and drain valves, and other devices as might be required for prelaunch maintenance, alignment, and servicing. Alignment references for critically aligned components shall be visible directly or through windows or access doors.

5.4 ENVIRONMENTAL CONDITIONS

5.4.1 Launch, Reentry, and Landing Environments. The space equipment shall be designed to function within performance specifications after or, if appropriate, during exposure in the launch configuration to their design environmental levels. These design environmental levels for launch exceed the maximum predicted launch environments for each item by the environmental design margin.

5.4.2 On-Orbit Environments. The space equipment shall be designed to function within performance specifications following or, if appropriate, during exposure in the on-orbit configuration to their design environmental levels. These design environmental levels for on orbit exceed the maximum predicted on-orbit environments for each item by the environmental design margin.

5.4.3 Ground Environments. These environments are those associated with all ground operations except testing, including storage, transportation, and prelaunch operations. The space equipment shall be designed to function within performance specifications following or, if appropriate, during exposure in the ground configuration to environmental levels that exceed the maximum predicted ground environments. The design shall be capable of sustaining exposures up to 12 hours in humid and mildly corrosive environments that could inadvertently occur while the equipment is unprotected during manufacture or handling, such as possible industrial environments or sea coast fog that could be expected prior to launch. Relative humidities up to 100 percent can be encountered.

5.4.4 <u>Design Environments for Various Classes.</u> The required environmental design margins for Class A equipment are those specified in MIL-STD-1540. Therefore, the required environmental design values for each item of Class A are as follows:

a. The thermal design range shall be 10 deg C beyond the minimum and maximum predicted temperatures. Where practicable, each component shall be designed to operate continuously within an ambient temperature range of at least -34 deg C to +71 deg C. To prevent generating a possible ignition source, the temperature of any part exposed to the atmosphere shall not exceed 178 deg C.

b. The vibration design range shall be 6 dB greater than the maximum predicted level but not less than 12 g's (rms).

c. The acoustic design range shall be 6 dB greater than the maximum predicted level but not less than 144 dB overall.

d. The shock spectrum design range shall be 6 dB greater than the maximum predicted level.

Because of the greater allowable risk for Class B equipment, the required environmental design margins are reduced and the resulting environmental design values for Class B are modified from those specified in MIL-STD-1540 as follows:

a. The thermal design range shall be 5 deg C beyond the minimum and maximum predicted temperatures (instead of 10 deg C). Where practicable, each component shall be designed to operate continuously within an ambient temperature range of at least -29 deg C to +66 deg C. To prevent generating a possible ignition source, the temperature of any part exposed to the atmosphere shall not exceed 178 deg C.

b. The vibration design range shall be 3 dB greater than the maximum predicted level (instead of 6 dB) but not less than 9 g's (rms).

c. The acoustic design range shall be 3 dB greater than the maximum predicted level (instead of 6 dB) but not less than 141 dB overall.

d. The shock spectrum design range shall be 3 dB greater than the maximum predicted level (instead of 6 dB).

Because of the greater allowable risk, and the recoverable nature of most Class C and Class D equipment, no environmental design margins are required and no allowance for testing tolerance need be made. The environmental design values for Class C and Class D equipment are therefore modified from those specified in MIL-STD-1540 as follows:

a. The thermal design range shall be between the minimum and maximum predicted temperatures. To prevent generating a possible ignition source, the temperature of any part exposed to the atmosphere shall not exceed 178 deg C. Where practicable, each Class C component shall be designed to operate continuously within an ambient temperature range of at least -24 deg C to +61 deg C.

b. The vibration design range shall be the maximum predicted level but not less than 9 g's (rms).

c. The acoustic design range shall be the maximum predicted level but not less than 141 dB overall.

d. The shock spectrum design range shall be the maximum predicted level.

5.5 TRANSPORTABILITY

The space equipment shall be designed for ground transportability and for air transportability. The space equipment to be mounted as an assembly in the STS shall be capable of being transported and handled in both the vertical and horizontal attitude. Attach points for transportation and handling shall be provided on assemblies weighing more than 100 kilograms. The modes of transportation, support, and types of protective covers used shall be chosen to assure that transportation and handling do not impose thermal, vibration, acoustic, or shock environmental conditions which exceed those imposed by operational modes.

SECTION 6

SPACE EQUIPMENT DESIGN REQUIREMENTS

Unless specifically stated otherwise, all requirements apply to Class A, Class B, and Class C. Unless specifically stated otherwise, the requirements for Class C are guidance for Class D.

6.1 SELECTION OF PARTS, MATERIALS, AND PROCESSES

Unless otherwise specified in the contract, the parts, materials, and processes shall be selected and controlled in accordance with documented procedures to satisfy the specified requirements. The selection and control procedures shall emphasize quality and reliability to meet the mission requirements and to minimize total life cycle cost for the applicable system. An additional objective in the selection of parts, materials, and processes shall be to minimize the variety of parts, related tools, and test equipment required in the fabrication, installation, and maintenance of the space equipment. However, identical electrical connectors, identical fittings, or other identical parts shall not be used on space equipment where inadvertent interchange of items or interconnections could cause possible malfunction. The parts, materials, and processes selected shall be of sufficient proven quality to allow the space equipment to meet the functional performance, reliability, and strength as required during its life cycle including all environmental degradation effects. Parts for Class A and Class B equipment shall be in accordance with MIL-STD-1547.

Care shall be exercised in the selection of materials and processes to avoid stress corrosion cracking in highly stressed parts and to preclude failures induced by hydrogen embrittlement. Parts, materials, and processes shall be selected to ensure that any damage or deterioration from the space environment or the outgassing effects in the space environment would not reduce the performance of the space equipment beyond the specified limits.

6.1.1 Material Selection. Materials shall be selected that have demonstrated their suitability for the intended application. Where practicable, fungus inert materials shall be used. Combustible materials or materials that can generate toxic outgassing or toxic products of combustion shall not be used if cost-effective alternatives exist. Materials shall be corrosion resistant or shall be suitably treated to resist corrosion when subjected to the specified environments. Protection of dissimilar metal combinations shall be in accordance with MIL-STD-889. Structural properties of materials for use in space applications shall be taken from MIL-HDBK-5 for metals and from MIL-HDBK-17 for plastics. Properties not listed shall be based upon appropriate material tests. When such data are not available, they shall be determined by approved test methods. A sufficient number of tests to establish values for mechanical properties on a statistical basis shall be performed.

Materials shall be selected for low outgassing in accordance with SP-R-0022 (NASA JSC). The total mass loss shall be less than 1 percent, and the collected volatile condensable material shall be less than 0.1 percent when heated in vacuum to 125 deg C and collected at 23 deg C. The hygroscopic nature of many materials such as composites, electroformed nickel, and anodic coatings for aluminum should be recognized, if they are used, since they emit water in a vacuum and therefore may be unsuitable for some applications.

6.1.2 Finishes. The finishes used shall be such that completed devices shall be resistant to corrosion. The design goal shall be that there would be no destructive corrosion of the completed devices when exposed to moderately humid or mildly corrosive environments that could inadvertently occur while unprotected during manufacture or handling, such as possible industrial environments or sea coast fog that could be expected prior to launch. Destructive corrosion shall be construed as being any type of corrosion which interferes with meeting the specified performance of the device or its associated parts. Protective methods and materials for cleaning, surface treatment, and applications of finishes and protective coating shall be in accordance with MIL-F-7179. Neither cadmium nor zinc coatings shall be used. Chromium plating shall be in accordance with QQ-C-320. Nickel plating shall be in accordance with QQ-N-290. Corrosion protection of magnesium shall be in accordance with MIL-M-3171. Coatings for aluminum and aluminum alloys shall be in accordance with MIL-C-5541 or MIL-A-8625.

6.2 STRUCTURE

6.2.1 General Structural Design. The primary support structure for the space equipment shall possess sufficient strength, rigidity, and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements. It shall survive those conditions in a manner that assures safety and that does not reduce the mission success probability. The primary support structure of the space equipment shall be electrically conductive to establish a single point electrical ground. The structure of equipment to be launched in the STS shall be designed to meet the applicable safety requirements of NHB 1700.7.

6.2.2 Strength Requirements.

6.2.2.1 Yield Load. The structure shall be designed to have sufficient strength to withstand simultaneously the yield loads, applied temperature, and other accompanying environmental phenomena for each design condition without experiencing yielding or detrimental deformation.

6.2.2.2 Ultimate Load. The structure shall be designed to withstand simultaneously the ultimate loads, applied temperature, and other accompanying environmental phenomena without failure.

6.2.3 Stiffness Requirements.

6.2.3.1 Dynamic Properties. The structural dynamic properties of the equipment shall be such that its interaction with the space vehicle control subsystem does not result in unacceptable degradation of performance.

6.2.3.2 Structural Stiffness. Stiffness of the structure and its attachments shall be controlled by the equipment performance requirements and by consideration of the handling, launch, and landing environments. Special stowage provisions shall be used, if required, to prevent excessive dynamic amplification during transient flight events such as launch or landing.

6.2.3.3 Component Stiffness. The fundamental resonant frequency of a component weighing 23 kilograms or less shall be 50 Hertz or greater when mounted on its immediate support structure.

6.2.4 Factors of Safety. The factor of safety of the structure is the ratio of the limit load to the allowable load.

6.2.4.1 Flight Limit Loads. Available options for structural design are listed in Table XII. For all classes of equipment, including Class D, all safety related structural design requirements shall be met. (See 6.12 in this handbook.)

6.2.4.2 Pressure Loads. Factors of safety for pressure loads shall be determined individually for each pressure vessel, based on tests to establish material characteristics and an analysis of life requirements and other environmental exposure. Proof and burst pressure factors shall be established at levels that ensure structural integrity, structural life, and safety throughout all phases. The values listed in Table XIII are to be considered as limiting lower bounds.

TABLE XII. Structural Design Factors of Safety

Design and Test Options	Design Factor of Safety on Limit Loads		
	Yield	Ultimate	
	(FSy)	(FSu) Unmanned Events	(FSu) Manned Events
1. Dedicated Test Article	1.00	1.25	1.40
2. Test One Flight Article	1.25	1.40	1.40
3. Proof Test Each Flight Article	1.10	1.25	1.40
4. No Static Test	1.60	2.00	2.25

6.2.5 Design Load Conditions. The equipment shall be capable of withstanding all design load conditions to which it is exposed in all mission phases, as applicable: ground, prelaunch, erection, post-launch, boost, orbit, reentry, and landing. During the orbit phase, all of the following shall be considered: maneuvering loads, vehicle spin, meteoroid environment, radiation environment, and other environmental factors, such as thermal effects due to internal heating, solar heating, eclipses, and extreme cold due to ambient space environment.

6.3 FLUID SUBSYSTEMS

6.3.1 Pressurized Components. Fluid subsystems and pressurized components shall be in accordance with MIL-STD-1522 and NHB 1700.7 (NASA). For all classes of equipment, including Class D, all safety-related pressurized component design requirements shall be met. (See 6.12 in this handbook.)

6.3.2 Tubing. Tubing shall be stainless steel, where practicable. Tubing joints shall be thermal welded butt joints, where practicable. Tubing design shall incorporate provisions for cleaning and to allow proof testing.

TABLE XIII. Pressurized Components Factors of Safety

Component c/	Design Ultimate	Acceptance (Proof)	Qualification
Solid Rocket Motor Cases b/	1.25	1.10 a/	1.25 a/
Pneumatic Vessels b/	2.00	1.50 a/	2.00 a/
Lines, Fittings, and Hoses			
Less than 3.81 cm dia. d/	4.00	2.00 a/	4.00 a/
3.81 cm dia. and larger d/	1.50	1.10 a/	1.50 a/
Other Pressurized Components	2.50	2.00 a/	2.50 a/

Notes:

a/ No yielding permitted at acceptance (proof) test pressure, and no rupture at qualification pressure.

b/ Factors of safety shown are minimum values applicable to metallic pressure vessels for which ductile fracture mode is predicted via a combination of stress and fracture mechanics analyses. Design of metallic pressure vessels for which brittle fracture mode is predicted by these analyses shall be in accordance with fracture mechanics methodology wherein the proof factor as well as the design ultimate factor of safety shall be established to provide a minimum of four times the specified service life against mission requirements. In addition, a fracture control program shall be established to prevent structural failure due to the initiation or propagation of flaws or crack-like defects during fabrication, testing, and service life.

c/ All pressure vessels, sealed containers, lines, fittings, and other pressurized components of equipment to be launched in the STS shall be designed to meet the applicable safety requirements of NHB 1700.7 (NASA) and SAMTO HB S-100 (designated by NASA as KHB 1700.7).

d/ 3.81 cm diameter is equivalent to 1.5 inches diameter.

6.3.3 Separable Fittings. Separable fittings shall have redundant sealing surfaces, such as double "O" rings, and be of the "parallel loaded" type. "Parallel loaded" means that the fitting contains a compressed element which exerts outward pressure on the other elements of the fitting such that both seals are maintained even if relaxation occurs. Separable fittings shall have provisions for locking. Separable fittings should be accessible for leak tests and for torque checks. Separable fittings should not be designed or assembled with lubricants or fluids that could cause contamination or could mask leakage of a poor assembly.

6.4 MOVING MECHANICAL ASSEMBLIES

Deployment mechanisms, sensor mechanisms, pointing mechanisms, drive mechanisms, despin mechanisms, separation mechanisms, and other moving mechanical assemblies on Class A and Class B space equipment shall be in accordance with DOD-A-83577. Class C and Class D equipment should use DOD-A-83577 as a guide.

6.5 EXPLOSIVE ORDNANCE

Explosive ordnance to be installed on Class A and Class B space equipment shall be in accordance with DOD-E-83578. Class C and Class D equipment should use DOD-A-83578 as a guide. For all classes of equipment, including Class D, all safety-related explosive ordnance design requirements shall be met. (See 6.12 in this handbook.)

6.6 WIRING

The electrical wiring harnesses between space components shall be in accordance with DOD-W-83576.

6.7 ELECTRONIC COMPONENTS

Electronic components for Class A and Class B space applications shall be in accordance with DOD-E-8983. Parts for Class A and Class B equipment shall be in accordance with MIL-STD-1547. Class C equipment should be designed using DOD-A-8983 and MIL-STD-1547 as guides.

6.8 SOLAR ARRAYS

Solar arrays for Class A and Class B space applications shall be in accordance with MIL-S-83576. Class C equipment should be designed using MIL-S-83576 as a guide.

6.9 NAMEPLATES AND PRODUCT MARKING

For Class A, Class B, and Class C space applications, each vehicle, experiment, component, and interchangeable subassembly shall be identified by a nameplate. The nameplate identification may be attached to, etched in, or marked directly on the item. The nameplate shall utilize suitable letter size and contrasting colors, contrasting surface finishes, or other techniques to provide identification that is readily legible. The nameplate shall be capable of withstanding cleaning procedures and environmental exposures anticipated during the service life of the item without becoming illegible. Metal foil nameplates may be applied if they can be placed in an area where they cannot interfere with proper operation should they inadvertently become detached. Metal stamping shall not be used. Where practicable, identification nameplates on components and subassemblies shall be in locations which permit observation of the marking at the next higher level of assembly. Nameplates shall contain, as a minimum, the following:

a. Item identification number

b. Serial number

c. Lot number

d. Manufacturer

e. Nomenclature

The marking of any two or more items intended for space applications with the same item number or identification shall indicate that they may be capable of being changed, one for another, without alteration of the items themselves or of adjoining equipment if the items also meet the specified flight accreditation requirements.

6.9.1 Data Cards. When size limitations, cost, or other considerations preclude marking all applicable information on an item, the nameplate may simply provide a reference key to cards or documents where the omitted nameplate information may be found. A copy of the referenced nameplate information or card shall accompany the item or assembly containing the item during ground tests and ground operations.

6.9.2 "NOT FOR FLIGHT" Marking. Items which by intent or by material disposition are not suitable for use in flight, and which could be accidentally substituted for flight or flight spare hardware, shall be red tagged or stripped with red paint, or both, to prevent such substitution. The red tag shall be conspicuous and marked "NOT FOR FLIGHT." The red paint shall be material compatible and the stripes unmistakable.

6.10 ELECTROMAGNETIC COMPATIBILITY

Class A and Class B space equipment shall be designed for electromagnetic compatibility in accordance with MIL-STD-1541. For Shuttle launched equipment, the requirements of JSC 07700, Vol. XIV also apply. Although Ground Support Equipment (GSE) need not meet the flight electromagnetic compatibility requirements, it is necessary that GSE not be a source of interference to, or be affected by, flight hardware. GSE which is to be used at the launch site, particularly that for Shuttle launched equipment, must also meet the emission requirements imposed by the launch site.

Emissions of Class C and Class D equipment shall be controlled in accordance with MIL-STD-1541 requirements and, for Shuttle launched equipment, in accordance with the requirements of JSC 07700, Vol. XIV.

6.11 INTERCHANGEABILITY

To the extent practicable, the design of the space equipment shall make provisions for the factory replacement of components and subassemblies and for the prelaunch installation or replacement of explosive ordnance devices, and batteries.

6.12 GENERAL SAFETY REQUIREMENTS

6.12.1 General. The design for all classes of equipment shall be such that hazards to personnel, to the system, and to the associated equipment are either eliminated or controlled throughout all phases of the system life cycle. The safety requirements shall be in accordance with MIL-STD-1574.

6.12.2 Space Transportation System Payloads. For all payloads which are to be launched by the Space Transportation System (STS), the safety requirements shall also be in accordance with Chapter 2 of NHB 1700.7 (NASA). For these payloads, it is required that the payload must tolerate a minimum number of failures and/or operator errors determined by the consequence of any hazardous functions. For catastrophic hazards or hazards that would result in personnel injury, loss of the orbiter or STS facilities and equipment, the hazard needs to be controlled such that no combination of two failures, operator errors, or radio frequency signals would unleash the hazard. For critical hazards or hazards that would result in damage to STS equipment or in the use of contingency or emergency procedures, the hazard needs to be controlled such that no single failure, or operator error, would unleash the hazard. Hazardous functions are thereby controlled with either two or three inhibits, depending on whether the hazard is critical or catastrophic.

In addition, Chapter 2 of NHB 1700.7 (NASA) defines safety requirements for space equipment structural design, stress corrosion, pressure vessels, sealed containers, hazardous materials, pyrotechnics, destruct subsystems, radiation, electrical subsystems, flammable atmospheres, and reflown hardware.

6.12.3 Ground Equipment. The safety requirements for ground equipment shall be in accordance with SAMTO HB S-100 (designated by NASA as KHB 1700.7).

6.13 HUMAN PERFORMANCE/HUMAN ENGINEERING

Throughout the design and development of the equipment, the applicable criteria in MIL-STD-1472 shall be judiciously applied to obtain effective, compatible, and safe man-equipment interactions. Provisions such as tabs, collars, and different thread sizes shall be employed to prevent incorrect assembly which may impair the intended functions.

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SECTION 7

COMPUTER RESOURCE REQUIREMENTS

Unless specifically stated otherwise, all requirements apply to Class A, Class B, and Class C. Unless specifically stated otherwise, the requirements for Class C are guidance for Class D.

7.1 COMPUTER RESOURCES FOR SPACE EQUIPMENT.

The computer resources are those required to function on-line or off-line during one or more phases or modes of the service life of the space equipment. These computer resources shall be capable of performing the required real time computational functions in the space equipment and in the associated ground equipment. These real time functions include data processing, communications, display, and control functions. In addition, the equipment computer resources shall perform the required nonreal time data processing and support functions.

The following requirements for computer resources apply to Class A equipment. For Class B and Class C equipment, the following requirements for computer resources apply only to major elements of the computer resources. Unless defined otherwise by the program office or by the contract, major elements of computer resources are computer hardware or software costing more than $100,000 each. For Class B and Class C computer resources elements that are less than a major element, and for all Class D computer resources, the requirements shall be interpreted as guidance information.

7.1.1 Computational Equipment. The computational equipment includes processing units; special purpose computational devices; main storage; peripheral data storage; input and output units such as printers, graphic displays, and video display devices; and other associated devices. To the extent practicable, the associated ground equipment computational capability shall be provided by commercially available general purpose computer equipment.

7.1.1.1 Computer Instruction Performance Rate. Within its operating environment, each processing unit shall perform instructions at a rate which is at least twice that required by all other requirements specified. This increased capability is to allow for contingency growth in peak real time functional capability beyond the specific requirements identified.

7.1.1.2 Data Channel Capacity. The maximum input data rate capability and the maximum output data rate capability, when operating with the application computer programs, shall be at least twice that required by the worst case data rate.

7.1.1.3 Main Storage (Primary Memory). The capacity of the main storage (primary memory) in each computer in the space equipment shall be at least 150 percent of the basic capacity required by the other requirements specified. This 50 percent spare capacity is to allow for contingency growth beyond the initial specific requirements.

7.1.1.4 Automatic Initialization and Startup. Each computer shall have facilities to establish support capabilities in response to a single control action. These facilities shall provide for the automatic loading, initialization, and starting of both the operating system and the application computer programs.

7.1.2 Operating Systems Used in Computers. Where practicable, the operating system for each computer shall be in broad use and shall have a demonstrable record of reliable performance. Operating systems which require development shall be developed in accordance with the standards, conventions, and development requirements for application programs contained herein. Where applicable, the operating systems shall provide the scheduling, task switching (on a priority basis), input/output control, data management, and memory management capabilities required to support the real time computational and control functions of the computational components. The operating system shall be capable of exploiting the growth requirements specified for the computational equipment without necessitating any modifications. Program peculiar changes, modifications, additions, or enhancements to vendor supplied and maintained operating systems shall require approval by the contracting officer prior to incorporation and implementation.

7.1.3 Application Computer Programs.

7.1.3.1 Programming Language. Where practicable, application computer programs for space equipment shall be written in Ada per MIL-STD-1815 or in JOVIAL J73 per MIL-STD-1589. Assembly language shall be used only where its use is necessary for the satisfaction of system performance requirements or where its use is cost effective over the life of the system. The term "assembly language" includes the use of microcode and microprogramming.

7.1.3.2 Computer Program Structure. The computer program structure shall consist of Computer Program Configuration Items (CPCIs) at the highest level. A top-level CPCI may consist of one or more lower level CPCIs, of one or more Computer Program Components, or a combination of both. The lowest level CPCI may consist of one or more Computer Program Components. Each Computer Program Component consists of one or more lower level Computer Program Modules.

7.1.3.3 Structure of Modules. Computer Program Modules shall each be organized into two parts: an interface part and an implementation part.

a. The interface part shall characterize the capabilities the module makes available to other modules or to other interfacing system items such as devices or human operators. The interface part shall not exceed 50 lines of source code (excluding comments).

b. The implementation part of each module shall define how the operations specified in the interface are to be provided. The implementation part shall not exceed 100 lines of source code (excluding comments).

7.1.3.4 Hierarchical Program Design. Computer programs shall be designed in a hierarchical manner, and the levels of the hierarchy shall correspond to the levels of abstraction of the tasks performed by the program. A level of abstraction is characterized by:

a. The types of data objects defined to exist on that level

b. The operations defined to be performed to those data objects

Each level of the program shall be complete in itself. Provisions for incorporating existing modules into the hierarchy shall be made so as to maximize the reuse of previously developed computer programs.

7.1.3.5 Standardized Control Structures. Only closed control structures shall be used in the construction of program modules. Closed control structures are structures that have a single entry point and a single exit point. For example, closed control structures include: (a) a simple sequence, (b) a conditional selection, and (c) an iteration.

7.1.3.6 Strong Typing. Explicit declarations shall be provided of the characteristics attributed to computer program elements. No computer program element with a particular collection of declared characteristics shall be treated as if it had some other characteristics.

7.1.3.7 Encapsulation of Representations. Every computer program element which is used to represent some concept other than itself shall be treated as encapsulated within the declaration of the concept represented. Encapsulated means that external to the encapsulating declaration, no operation shall be applied directly to the internal elements. For example, either an array or a linked list may be the element used to represent a concept such as a collection. In that case, the array or linked list would be treated as declared within the declaration for the collection, and no external array or list operations would be allowed, only collection operations.

7.1.3.8 Program Coding Conventions. All computer programs shall conform to the following coding conventions:

a. The structure of the source code shall reflect the design of the program.

b. Each line of source code shall contain no more than three statements, i.e., no more than three semicolons in Ada or JOVIAL. Each statement in a line with multiple statements shall have no more than three operations.

c. To the extent practicable, names used in computer programs shall be consistent with those used in the system design.

d. The code shall be written such that no code is modified during execution.

7.1.3.9 Program Comments. Comments shall be incorporated throughout each computer program to self-document the organization and logic of the program. Computer programs shall adhere to the following commenting standards:

a. Banners. A banner shall be the first item in each computer program listing. The banner for a CPCI listing shall state the CPCI title, the titles of all subtier CPCIs if any, and the titles of all subtier Computer Program Components. The banner for a Computer Program Component listing shall state the title for the parent CPCI, the component title, and the title of all modules in the component. The banner for each of the two parts of a module listing shall state the title for the parent CPCI, the title for the parent component, the title for the parent modules (if any), the title of the module, and whether the part is the interface or the implementation part of the module.

b. Headers. A header consisting of a consecutive block of comments shall follow the banner in each source code listing to facilitate the understanding and readability of the listing. The header shall provide a prose abstract of the declarations and processing activities to assist in understanding the program code.

c. Special Comments. Special comments shall be included within the source code listing to assist in reading particularly subtle or confusing code. Special comments may supplement header comments, but they shall not replace the header comments. A special comment shall be included for every logic branch and join point to characterize the intended operation of the program to that point.

7.1.3.10 Message Generation. The ground equipment computer programs shall generate error and diagnostic messages on line to facilitate real-time fault isolation required to maintain the system in operational status. In addition, these ground equipment computer programs shall generate off-line error and diagnostic messages for the logging of fault messages onto system files for those categories of faults which require isolation and correction but can be addressed off line and do not degrade operational performance. The required processing time to identify and generate error and diagnostic messages shall not degrade the performance of the system. Messages shall conform to the following:

a. With the exception of lengthy diagnostic procedures for use following an abnormal condition, processor message and advisory formats shall not require additional interpretation by the operator. For example, table lookups and references to documentation shall not be required.

b. Every message and advisory shall include a unique description of the condition which prompted it.

c. On-line error messages shall contain, as a minimum, the following information:

(1) Time error was detected
(2) Textual description of error condition
(3) Required operator action where applicable

d. Off-line error messages shall contain, as a minimum, the following information:

(1) Time error was detected
(2) Textual description of error condition
(3) Required operator action where applicable
(4) Identification of triggering module
(5) Identification of source program operation being performed at the time of the error
(6) Computer program or system execution status following the error

7.1.3.11 <u>Character Set Standards</u>. Character sets shall conform to standards in FIPS PUB 1 (ANSI-STD X 3.4-1968).

7.1.3.12 <u>Growth</u>. The application computer programs shall satisfy their performance requirements without the implementation of any of the growth provisions identified herein for computational equipment. However, the application programs shall be designed to be capable of easily exploiting any of the identified growth provisions, such as added memory, which may be implemented.

7.1.4 <u>Firmware</u>. Computer programs and data stored in a class of storage that cannot be dynamically modified by the computer during processing shall be considered firmware. Requirements on firmware shall be the same as those on application computer programs.

7.1.5 <u>Computer Resource Utilization Monitoring</u>. The ground equipment computer resources shall provide a capability which can be exercised under operator control to monitor, record, display, and print the utilization of the various computer resources. The computer resource utilization that shall be measurable and recordable during real-time operations includes:

a. Job timing, i.e., overall utilization of the central processing unit

b. Task timing, i.e., the seconds used by each program in the central processing unit

c. Computer main storage (primary memory) utilization

d. Peripheral data storage (secondary memory) utilization

e. A trace of the program execution sequence

The time interval between recording samples shall be variable, and the types of data collected shall be options; both shall be under operator control.

7.2 <u>COMPUTER PROGRAM MAINTENANCE RESOURCES</u>

For Class A space equipment, computer program maintenance resources are required to support software development and to validate changes throughout the development and operational use of the software.

For other classes of space equipment, the requirements for computer program maintenance resources are intended for compliance only if delivery of the computer program maintenance resources are required by the contract. Delivery requirements may not mean a physical transfer, but may be a paper transfer at the time it is determined that the contractor has established the computer program maintenance resources needed to support possible changes to the software required during on-orbit operations. The need for computer program maintenance resources is dependent both on the complexity of the software and the time that on-orbit operational support of the space equipment is required. For an on-going operational space program, the need is clear. For one of a kind space equipment where there may be a need only to support development and changes through the first launch and any contingency backup launches, the need may not be as clear. For Class B or Class C (and for most Class D) space equipment, delivery of the computer program maintenance resources may not be required by the contract. The requirements for computer program maintenance resources should, however, be helpful for any major software development and should be used as guidance even if not required contractually.

7.2.1 Computational Equipment for Computer Program Maintenance. The computational equipment for computer program maintenance is that computational equipment required during the service life to develop and test changes to the computer programs used in the space equipment and in any related training equipment. To the extent practicable, this computational equipment for computer program maintenance shall be identical to the computational equipment used for computer program development. In other words, the computer program development equipment would normally transition to the computer program maintenance facility. The computer program maintenance equipment shall be capable of accommodating the growth requirements of the computational equipment without necessitating major hardware modifications.

7.2.2 Computer Programs for Computer Program Maintenance Computers. The operating system for each computer used in the maintenance of computer programs shall be capable of exploiting the growth requirements specified for the computational equipment without necessitating any major modifications. Maintenance of the computer programs shall be supported by utility programs and other computer programs running with the operating system(s) and computer(s) specifically identified for computer program maintenance. The operating system(s) and computer programs used for computer program maintenance shall provide as a minimum the following interactive capabilities:

a. Editing

b. Compilation which produces relocatable object code

c. If applicable, assembly which produces relocatable object code

d. Linking type loader

e. Generation, maintenance, and initialization of storage media for programs and data

f. Diagnostics to support fault isolation

g. Debugging tools

h. Program library facilities for both source and object code

i. Configuration control capability.

To the extent practicable, the operating system(s), other computer programs, and firmware to be used for computer program maintenance during the service life shall be the same as that used for computer program development.

7.2.3 Computer Resource Utilization Monitoring. The computer resources used for computer program maintenance shall provide a capability to monitor, record, display, and print the simulated utilization of the computer resources in the space equipment under simulated flight conditions. The intent of this capability is to provide a means for making measurements that would assure that adequate growth margins can be maintained as changes are incorporated during the service life of the space equipment.

7.2.4 Additional Growth Capability. The computer resources used for computer program maintenance shall be capable of accommodating the specified growth requirements of the computer resources of the space equipment without necessitating any major modifications.

7.2.5 Tools for Computer Program Maintenance. Tools required for the initial development of the space equipment computer programs and firmware shall be organized into a library and facility for subsequent reuse in testing and validating changes to the computer programs. These tools include configuration-controlled masters of the released computer programs and firmware, the associated documentation, as well as the test drivers, simulated data, and other special purpose devices. For example, if a Microprocessor Development System (MDS) was used to develop firmware, the MDS and the associated computer programs and documentation shall be controlled and retained as part of the computer program maintenance resources to support possible change activity during the operational service life of the system.

SECTION 8

MANUFACTURING

Unless specifically stated otherwise, all requirements apply to Class A, Class B, and Class C. Unless specifically stated otherwise, the requirements for Class C are guidance for Class D.

8.1 PROCESSES AND CONTROLS.

Acceptance and flight certification of space equipment is primarily based on an evaluation of data from the manufacturing process. The manufacturing process for Class A, Class B, and Class C equipment shall be accomplished in accordance with documented procedures and process controls which assure the reliability and quality required for the mission. These manufacturing procedures and process controls shall be documented to give visibility to the procedures and specifications by which all processes, operations, inspections, and tests are to be accomplished by the supplier. This internal contractor documentation shall include the name of each part or component, each material required, the point it enters the manufacturing flow, and the controlling specification or drawing. The documentation shall indicate required tooling, facilities, and test equipment; the manufacturing check points; the quality assurance verification points; and the verification procedures corresponding to each applicable process or material listed. The specifications, procedures, drawings, and supporting documentation shall reflect the specific revisions in effect at the time the items were produced. These flow charts and the referenced specifications, procedures, drawings, and supporting documentation become the manufacturing process control baseline and shall be retained by the supplier for reference. It is recognized that many factors may warrant making changes to this documented baseline; however, all changes to the baseline processes used, or the baseline documents used, shall be recorded by the supplier following establishment of the manufacturing baseline or following the manufacture of the first item or lot of items. These changes provide the basis for flight accreditation of the items manufactured or of subsequent flight items.

The manufacturing process and control documents shall provide a supplier-controlled baseline that assures that any subsequent failure or discrepancy analysis that may be required can identify the specific manufacturing materials and processes that were used for each item. In that way, changes can be incorporated to a known baseline item to correct the problems.

8.2 ASSEMBLY LOTS

To the extent practicable, parts for use in space equipment shall be grouped together in individual assembly lots during the various stages of their manufacture to assure that all devices assembled during the same time period use the same materials, tools, methods, and controls. Parts and devices for space equipment that cannot be adequately tested after assembly without destruction of the item, such as explosive ordnance devices, some propulsion components, and complex electronics, shall have lot controls implemented during their manufacture to assure a uniform quality and reliability level of the entire lot. Each lot shall be manufactured, tested, and stored as a single batch. Sequential lot numbers that indicate the date of manufacture shall be assigned to each lot. (Typically, use three digits for the day of the year and two digits for the year.)

8.3 CONTAMINATION

8.3.1 Fabrication and handling. Fabrication and handling of space equipment shall be accomplished in a clean environment. Attention shall be given to avoiding nonparticulate (chemical) as well as particulate air contamination. To avoid safety and contamination problems, the use of liquids shall be minimized in areas where initiators, explosive bolts, or any loaded explosive devices are exposed.

8.3.2 Device Cleanliness. The particulate cleanliness of internal moving subassemblies shall be maintained to at least level 500 as defined in MIL-STD-1246. External surfaces shall be visibly clean.

8.3.3 Outgassing. Items that might otherwise produce deleterious outgassing while on orbit shall be baked for a sufficient time to drive out all but an acceptable level of outgassing products prior to installation in the experiment or space vehicle. (See 6.1.1 in this handbook.) Analytical contamination models shall be used to evaluate performance impacts of outgassing on adjacent critical equipment.

8.4 ELECTROSTATIC DISCHARGE

Appropriate provisions stated in DOD-HDBK-263 shall be used to avoid and to protect against the effects of static electricity generation and discharge in areas containing electrostatic sensitive devices such as microcircuits, initiators, explosive bolts, or any loaded explosive device (also see 9.2 in this handbook). Both equipment and personnel shall be grounded.

8.5 CRAFTSMANSHIP

Space equipment shall be manufactured, processed, tested, and handled such that the finished items are of sufficient quality to ensure reliable operation, safety, and service life. The items shall be free of defects that would interfere with operational use such as excessive scratches, nicks, burrs, loose material, contamination, and corrosion.

8.6 MECHANICAL INTERFACES

Where practicable, a common interface drill template shall be used to assure correct mechanical mating, particularly for interfaces external to the equipment.

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SECTION 9

STORAGE AND HANDLING PROVISIONS

Unless specifically stated otherwise, all requirements apply to Class A, Class B, and Class C. Unless specifically stated otherwise, the requirements for Class C are guidance for Class D.

9.1 HANDLING AND STORAGE IN-PLANT PRIOR TO ACCEPTANCE

Environmental conditions for Class A and Class B equipment during processing, and during storage prior to shipment, shall be within the following limits:

a. Temperature: 21 deg C ± 20 deg C

b. Humidity: 50 percent ± 40 percent

Cleanliness shall be maintained during processing using appropriate protective containers or covers.

9.2 STORAGE AND TRANSPORTATION SUBSEQUENT TO ACCEPTANCE

Electrostatic sensitive items, such as most electronic assemblies and components containing explosives, for Class A and Class B equipment shall be stored and transported in sealed packages using antistatic wrapping material. The antistatic wrapping material used should not produce nonvolatile residues. The antistatic wrapping material shall be grounded through a resistor prior to removal. The grounding resistor shall have a value between 100,000 ohms and 1 megohm.

Storage, handling, and transportation conditions to which items are to be subjected prior to flight shall be controlled to acceptable limits. Cleanliness shall be maintained during storage and transportation using appropriate protective containers or covers. Temperature and humidity conditions and transportation shock exposure shall be monitored subsequent to manufacture, and the measured levels shall be evaluated against the acceptance test limits.

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SECTION 10

QUALITY ASSURANCE PROVISIONS

Unless specifically stated otherwise, all requirements apply to Class A, Class B, and Class C. Unless specifically stated otherwise, the requirements for Class C are guidance for Class D.

10.1 PARTS, MATERIALS, AND PROCESS CONTROLS

Parts, materials, and process controls are to be applied during manufacture and assembly of all items to ensure that reliable equipment is fabricated. All parts and materials shall be adequately controlled and inspected prior to assembly. During fabrication of space equipment, the tools and processes, as well as parts and materials, shall be adequately controlled and inspected to assure compliance with the approved manufacturing processes and controls. Quality assurance requirements included in specifications referenced in Sections 5 through 9 of this handbook are considered incorporated as requirements of this section and should be met for the applicable classes of equipment.

10.1.1 Records. Records documenting the accreditation status of the space equipment shall be maintained following assignment of serial numbers. Each space item shall have inspection records and test records maintained by serial number to provide traceability from system usage to assembly lot data for the devices. Complete records shall be maintained for the space items and shall be available for review during the service life of the system. The records shall indicate all relevant test data, all rework or modifications, and all installation and removals for whatever reason.

10.1.2 Manufacturing Screens. Each critical subassembly, each component, each experiment, and each vehicle shall be subjected to in-process manufacturing and assembly screens to assure compliance with the specified requirements to the extent practicable. Compliance with the documented process controls, documented screening requirements, required hardware configuration, and general workmanship requirements shall be verified. At each level of assembly, each completed unit shall be subjected to visual inspection to assure that it is free of obvious defects and is within specified physical limits.

10.1.3 Nonconforming Material. Nonconforming material, components, or assemblies that do not meet the established tolerance limits set for the acceptance limits in the in-process screens shall be rejected for use. Any rejected material, component, or assembly may be reworked and rescreened in accordance with established procedures if system reliability is not jeopardized. Nonconforming material or assembled units in each lot may be reworked and rescreened in accordance with established procedures if the rework is not so extensive as to jeopardize the lot identity of the material or assembled unit. If the reworked material or assembled unit subsequently passes the in-process screens, it can again be considered part of the lot. Reassignment of assembled units to a different lot shall not be made. Nonconforming material or assembled units that do not satisfy these rework criteria shall be considered scrap.

10.2 DESIGN VERIFICATION TESTS

Design verification tests shall be performed to demonstrate compliance of new designs or of modified designs with the specified performance. Test units shall be sufficiently similar to the final units as to not jeopardize the validity of the test results.

10.2.1 Verification of Nonoperating Constraints. The effects of nonoperational environments on the space equipment may be determined by nonoperating development tests. These tests would be used to identify fabrication, storage, handling, transportation, installation, and launch preparation constraints or controls that may be necessary. Note that approval of the contracting officer is required, if it is necessary to provide special nonoperating environmental controls other than those specified herein.

10.2.2 Development Tests. Typically, breadboard or prototype hardware is used for development tests. When cost effective, flight hardware may be utilized for the development test program. The development tests are performed as required to yield information necessary to determine:

- Design feasibility
- Adequacy of basic design approaches
- Functional parameters
- Thermal and structural data with particular emphasis on deployment, separation, latching mechanisms, clearances, structural dynamic characteristics, and math model verification
- Mass properties
- Packaging and fabrication techniques
- Stabilization performance
- EMC including TEMPEST
- Safety
- Cleanliness requirements and contamination compatibility

10.2.2.1 Modal Survey. Modal survey tests are required for large equipment (see MIL-STD-1540). The flight hardware, or dynamically simulated hardware, including attachment and support hardware is the test article. All natural modes of vibration at frequencies below 50 Hz shall be determined.

10.2.2.2 Static Loads. A static loads test as specified in MIL-STD-1540 shall be performed on each vehicle or experiment.

10.2.2.3 Thermal Balance. The flight vehicle or experiment shall be subjected to a thermal balance test as specified in Paragraph 6.2.8 of MIL-STD-1540. The test shall include both maximum and minimum power dissipation modes. If heat pipes are included, the attitude of the equipment shall be such as to not bias the test measurements. A thermal math model shall be used to correlate pretest temperature predictions with the test data from the thermal balance test. As a goal, correlation of test results to the thermal model predictions shall be within ± 3 deg C. The correlated thermal math model is then used to make final temperature predictions for all mission phases and, hence, verify the thermal margins required by MIL-STD-1540.

10.2.2.4 Magnetic Mapping. If applicable, a magnetic mapping on the assembled vehicle or experiment shall be conducted to provide remnent, stray, and induced magnetic field data.

10.2.2.5 Current Margin. Electrical current margins on all electroexplosive device ordnance circuits shall be demonstrated. The test shall verify that no less than the minimum recommended firing current (twice all-fire) would be delivered to the electroexplosive devices under worst conditions of minimum voltage and maximum circuit and electroexplosive device resistance. The test shall also verify that the maximum current delivered to the electroexplosive device does not exceed its maximum qualified firing current under worst conditions of maximum voltage and minimum circuit and electroexplosive device resistance.

10.2.2.6 Mechanism Motion Test. The erection, deployment, latching, and jettison features shall be tested to demonstrate adequate functioning under worst case environments.

10.2.2.7 Shock. Equipment susceptible to shock shall be evaluated for bench handling (nonoperating) and while operating for possible pyroshock effects.

10.2.2.8 Crash Safety (Nonoperating). Although analysis is usually adequate for Shuttle missions, a demonstration may be used to show that the equipment design complies with the crash safety criteria: i.e., the equipment and its mounting attachments shall not become detached, create a hazard to personnel or to the Shuttle Orbiter, or prevent egress from a crashed vehicle. Operating performance is not required during or after this test, so a nonoperating mass simulator may be used. Compliance to the fracture control plan is required.

10.2.2.9 Outgassing. Outgassing evaluation tests are required for materials, components, and subsystems whose outgassing properties are not known. (See 6.1.1 in this handbook.)

10.3 LOT CERTIFICATION TESTING REQUIREMENTS.

Space parts, materials, and components that cannot be adequately tested after assembly, and must rely upon the process controls and in-process screening to assure satisfactory performance and reliability, shall have appropriate lot certification tests imposed prior to assembly. Lot certification testing is that testing performed to demonstrate confidence that a lot of parts, materials, or components that have passed the in-process screening also meets the other quality and performance requirements. All items submitted for lot certification shall have been manufactured using the same supplier-documented processes and controls. Certification of a lot is achieved by the satisfactory completion without failure of the applicable tests. Note that lot certification testing should be performed by the supplier and need not be repeated by the user.

10.4 QUALIFICATION AND ACCEPTANCE TESTS

Qualification and acceptance tests are intended to demonstrate, to the extent it is practicable, that devices manufactured in accordance with the approved processes and controls meet the specified design requirements.

10.4.1 Component Qualification and Acceptance Tests. For Class A components, the first article manufactured of each type shall be acceptance tested and then qualification tested in accordance with MIL-STD-1540. In addition, for STS usage, it should be demonstrated that the component can operate in an explosive atmosphere. The component should not create an explosion in an explosive atmosphere; it should contain any explosion occurring inside the component; and the temperature of the component case and of all internal parts exposed to the atmosphere shall not exceed 178 deg C. Upon completion of the qualification test program, the Class A qualification article is usually used as a development test article for extended margin evaluation tests and life tests. However, the qualification article test history may be reviewed for excessive test time and potential fatigue-type failures to determine if the unit can be refurbished and used in the qualification vehicle or experiment or as a flight spare in a redundant flight set, but it should not otherwise be planned for flight. Subsequent Class A flight components after the first unit of each type shall be acceptance tested in accordance with MIL-STD-1540.

For Class B components, qualification tests slightly modified from the MIL-STD-1540 baseline are required for the first article manufactured of each type. These are called protoflight tests, and they also serve as the acceptance tests for that item. The required Class B component protoflight tests are the component qualification tests specified in MIL-STD-1540 (6.4 in MIL-STD-1540) with the following changes:

a. The environmental design margins have been modified for Class B from those defined in MIL-STD-1540, so the qualification test levels are reduced. (See 5.4 in this handbook.)

b. For the component vibration qualification test (6.4.5 in MIL-STD-1540), the test level shall not be less than 9 g's (rms).

c. For the component acoustic qualification test (6.4.6 in MIL-STD-1540), the test level shall not be less than 141 dB overall.

d. For the component pressure test, only proof pressure tests per 6.4.10.3 a and 6.4.10.3 b in MIL-STD-1540 shall be conducted.

e. The component burn-in acceptance test (7.3.9 in MIL-STD-1540) shall be substituted for the component qualification life test (6.4 in MIL-STD-1540).

f. For STS usage, it should be demonstrated that the component can operate in an explosive atmosphere. The component should not create an explosion in an explosive atmosphere; it should contain any explosion occurring inside the component; and the temperature of the component case and of all internal parts exposed to the atmosphere shall not exceed 178 deg C.

Following these Class B qualification tests, the qualification article may be used as a flight article and installed into the flight vehicle or experiment, or used as a flight spare, without further testing. Subsequent Class B flight components after the first unit of each type, if any, shall be acceptance tested in accordance with MIL-STD-1540.

The environmental design margins for Class C components are zero, so qualification test levels and acceptance test levels are the same. Therefore, Class C components only require acceptance testing in accordance with MIL-STD-1540. In addition, for STS usage, it should be demonstrated that the component can operate in an explosive atmosphere (see above).

The environmental design margins for Class D components are zero, so qualification test levels and acceptance test levels are the same; however, testing of Class D components is optional.

10.4.2 <u>Software Qualification and Acceptance Tests</u>. Qualification and acceptance of software shall be based on functional testing of the computer programs, data, and firmware in the space equipment computers, using representative test cases generated to simulate the range of operational requirements. Software for Class A space equipment requires an independent verification and validation.

10.4.3 <u>Experiment or Vehicle Level Qualification and Acceptance Tests</u>. A large space vehicle typically includes several physically distinct segments such as a host vehicle segment, an experiment or payload segment, and an injection stage. The size limitations of most environmental facilities generally preclude testing of all segments combined. In that case, each major segment is tested as though it were a space vehicle being delivered by the contractor involved. Space experiments can therefore usually be acceptance tested and qualification tested as though they were a separate space vehicle.

For Class A space experiments or vehicles, the first article manufactured shall be acceptance tested and then qualification tested in accordance with the vehicle level tests of MIL-STD-1540. Upon completion of the qualification test program, the Class A qualification article is usually used as a development test article for evaluation tests. However, the qualification article test history may be reviewed for excessive test time and potential fatigue-type failures to determine if the unit can be refurbished and used as a flight spare. If such flight use is planned, and if subsequent to qualification testing there are significant modifications incorporated in the qualification test article, or numerous components are refurbished or replaced with new components, the equipment shall be retested to the vehicle level acceptance test baseline of MIL-STD-1540 (7.1 in MIL-STD-1540) prior to flight certification.

Subsequent Class A space experiments or vehicles, after the first qualification unit, shall be acceptance tested in accordance with the space vehicle level acceptance test baseline of MIL-STD-1540.

For Class B space experiments or vehicles, the flight article may be the only article fabricated, and qualification tests slightly modified from the MIL-STD-1540 space vehicle level qualification test baseline are required for the first article. These are called protoflight tests, and they also serve as the acceptance tests for the item, so the space vehicle level acceptance tests required by MIL-STD-1540 are waived. For protoflight tests, only the vehicle level qualification test baseline of MIL-STD-1540 (6.2 in MIL-STD-1540) is required for Class B space experiments or vehicles, with the following changes:

a. The environmental design margins have been modified for Class B from those defined in MIL-STD-1540, so the qualification test levels are reduced. (See 5.4.1 in this handbook.)

b. For the space vehicle acoustic qualification test (6.2.3 in MIL-STD-1540), the test level shall be 3 dB greater than the maximum predicted level but not less than 141 dB overall. The duration of the test shall be the same as for the space vehicle acoustic acceptance test (7.1.3.3 in MIL-STD-1540).

c. For the space vehicle vibration qualification test (6.2.4 in MIL-STD-1540), the test levels shall produce vibration responses in the equipment which are 3 dB greater than the maximum predicted level. The duration of the test shall be the same as for the space vehicle vibration acceptance test (7.1.4.3 in MIL-STD-1540).

d. For the space vehicle thermal vacuum qualification test (6.2.7 in MIL-STD-1540), the number of hot-cold cycles shall be four and the temperature extremes shall be 5 deg C beyond the minimum and maximum predicted temperatures.

e. If the optional space vehicle thermal cycling test (6.2.9 in MIL-STD-1540) is adopted as baseline, the minimum space vehicle temperature range shall be 60 deg C. The test should include 15 percent more thermal cycles than specified for the space vehicle thermal cycling acceptance test (7.1.8.3 in MIL-STD-1540).

f. Tests shall be conducted to verify the adequacy of the limit and ultimate loads for structural devices, such as separation nuts and bolts.

g. The safety requirements of NHB 1700.7 (NASA) shall be verified for Shuttle-launched equipment.

h. Electrical and electronic equipment shall be tested to the requirements of MIL-STD-1541, and for Shuttle-launched equipment, to the requirements of JSC 07700, Vol. XIV.

Subsequent flight units of Class B space equipment after the first unit shall be acceptance tested in accordance with the space vehicle level acceptance test baseline of MIL-STD-1540 (7.1 in MIL-STD-1540).

Class C and Class D space equipment only require acceptance testing in accordance with the space vehicle level acceptance test baseline of MIL-STD-1540 (7.1 in MIL-STD-1540). However, the EMC test (7.1.2 in MIL-STD-1540) is required; it is not optional.

10.5 RETEST.

Retest guidelines shall be in accordance with MIL-STD-1540.

10.6 REUSABLE FLIGHT HARDWARE TESTS.

Some equipment, or portions of the equipment, may be intended for reuse on subsequent missions. Reusable equipment would be subjected to repeated exposure to test, launch, flight, and recovery environments throughout its life. Qualification testing of reusable hardware shall be conducted at environmental levels and durations that provide a sufficiently high margin to assure equipment integrity after the required repeated environmental exposures. Methodology for avoiding fatigue failures is presented in MIL-HDBK-340.

10.7 QUALIFICATION OF EXISTING DESIGNS.

Requalification is required for items that incorporate extensive changes in design, manufacturing processing, environmental levels, or performance requirements. However, methodology presented in MIL-HDBK-340 may be used to show that existing designs, or items previously qualified for other applications, have adequately demonstrated compliance to all qualification requirements for the new designs. Deficiencies in meeting some requirements may be fulfilled by supplementing existing data with new test data. However, qualification by similarity shall be permitted only with the concurrence of the contracting officer. Waiver of qualification or requalification requirements requires the approval of the contracting officer.

10.8 SERVICE LIFE VERIFICATION TESTS

Service life verification tests are defined as those tests conducted on limited life devices to demonstrate that flight devices would perform satisfactorily during their specified service life. Explosive ordnance devices and other components whose performance may degrade with time shall have life certification or extensions based upon passing either an aging surveillance test or an accelerated aging test as described in the applicable subtier specifications such as DOD-E-83578 for explosive ordnance.

10.9 PRELAUNCH VALIDATION TESTS

Prelaunch validation tests shall be conducted on space equipment in accordance with the applicable requirements of MIL-STD-1540. These integrated system tests include all tests designed to verify system performance.

10.9.1 Functional Integration. End to end integration tests shall be conducted to assure an orderly buildup and verify proper subsystem operation.

10.9.2 Alignment Checks. Alignment checks shall be conducted as required to verify alignments of specific equipment.

10.9.3 Integrated System Tests. Integrated system tests are system-level functional tests done in accordance with the applicable paragraphs of MIL-STD-1540. Integrated system tests provide baseline performance data and follow-up comparison data to verify factory tests and assure that no degradation results from the individual environmental tests, transportation, storage, and preceding flights shall include a "typical" flight simulation encompassing prelaunch, launch, and orbital modes of operation.

10.9.4 Mass Properties. Actual weight and center of gravity (cg) measurements are required at the component and at each higher level of assembly to verify predictions and to ensure that the equipment meets final weight and cg requirements.

10.9.5 High Pressure. Tests of all pressure subsystems of the integrated equipment shall be performed in accordance with MIL-STD-1540 (Paragraph 6.2.6), NHB 1700.7 (NASA), and SAMTO HB S-100 (designated by NASA as KHB 1700.7).

10.9.6 Certification for Flight. Upon completion of the integrated system tests, the test history of the integrated equipment shall be reviewed to determine its acceptability for flight. The concept of product flight accreditation is used to assure that the critical components satisfy all requirements that have been found necessary for successful space missions. Note that items furnished by other government agencies (GFE) may require additional testing or controls to satisfy the flight accreditation requirements. Flight accreditation is a process in which the status of each item is under continuing evaluation from program inception to final accreditation for flight. The extent of reviews required is dependent upon the specific qualification and production status of the experiment to be flown and the suitability of its as-qualified design for the intended mission application. Unless specifically excluded, flight accreditation should incorporate all technical assessment activity from inception of the program through manufacturing, qualification, transportation, handling, storage, and post-delivery operations leading to final installation and checkout prior to flight. The assessment activity involves incremental reviews and culminates in documentation that all accreditation requirements have been met. After completion of the final review for each item, the acceptability or nonacceptability for flight is documented.

Items are considered to be flight accredited if the items satisfy all of the following conditions or the conditions have been waived by the contracting officer:

a. The items have passed the specified design verification tests.

b. The items have passed the qualification or protoflight test requirements.

c. The items are from a lot that passed the specified lot certification tests. Government furnished items are not exempt from this requirement. If prior lot certification testing has not met the requirements contained herein, testing should be conducted to demonstrate compliance.

d. The items have been transported and stored within the specified environmental limits for the device.

e. The items are from a lot that has an adequate service life for the scheduled operational use.

SECTION 11

NOTES

11.1 TAILORING

The material presented in the handbook is intended as a baseline that should be tailored to the needs of each program. To assist in this, the requirements are stated in ways that are self-tailoring to each application, where possible. Note that the program characteristics imposed by the statement of work and data delivery requirements (referenced in the acquisition contract) determine to a large extent the program class. The equipment characteristics imposed by the program peculiar specifications (also referenced in the acquisition contract) determine to a large extent the equipment class. There is no requirement that the experiment class, the vehicle class, and the program class be the same. That could be the case, but almost any mix can be visualized to meet unique program requirements.

Some of the information included in the handbook is for general guidance. Nevertheless, all requirements of this handbook should be evaluated for each application, and those that seem inappropriate should be identified. Contractors are encouraged to report to the contracting officer, for program office review and consideration, any identified requirements believed excessive or conflicting. However, contractors are reminded that deviations from contractually imposed requirements can be granted only by the contracting officer. In the case of differences between requirements in this handbook and contract requirements, the contract requirements take precedence.

11.2 CLASSIFICATION PROCESS

11.2.1 Discussion The classifications of space programs, space vehicles, and space experiments are program management decision that are based on compromises between minimum risk and minimum cost that are determined to be appropriate by the government. The classification decisions may seem somewhat arbitrary because they are not only based on the program factors and goals, but on a consideration of failure contingencies made possible by the mix of other space programs that exist or will exist in the same time frame, and on other less tangible factors such as the maturity of the hardware, program office, or contractors involved. The tradeoff analysis for making these determinations includes consideration of such factors as the national priority of the program, the associated national prestige at risk, the complexity of the space vehicle or space experiment being acquired, the allowable program schedule, the allowable weight, on-orbit life, criticality of the launch time, retrievability, on-orbit repairability, plans for ongoing production, the system life cycle cost, the allowable program risk, and the contingency plans associated with possible flight failure.

The major factor considered in establishing the program class, the vehicle class, the experiment class, and the quantity of items to be manufactured is the contingency plan to be used in the event, unlikely as it might be, that a hard failure occurs early after launch, and all data are lost. The proper contingency plan depends on the purpose of the program. If the planned program is simply a technology demonstration, a reflight contingency plan using the same type of item might not be the best plan because of other parallel programs, or because it could be estimated that technology advances would occur in the time that would have elapsed such that a different technology demonstration would be needed. If the planned space equipment is retrievable, or if in-orbit maintenance is possible, the contingency plans would involve those actions. Follow-on flights, if they are part of the planned program, would be an integral part of the contingency plans, and more than one vehicle or experiment would be required. At the national level, if a hard failure is really acceptable without a contingency plan, it will surely be suggested that consideration be given to spending the time and money on a program for something that is really needed.

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. It is helpful to distinguish between the "hardware class," as reflected in the equipment specification requirements, and the "program class," as reflected in the acquisition contracts. In all cases, the hardware and software must be be designed to survive and function in the anticipated space environments. In every case, the requirement is also for high reliability, because a flight failure in space is seldom cost effective. In the hardware classifications, as one progresses from Class A to Class D, the hardware may have lower design margins, less compliance to technical standards, and less stringent testing requirements imposed. As a result, the related costs decrease, the related confidence margins decrease, and the risks increase. In the program management classifications, as one progresses from Class A to Class D, the program management constraints, data delivery requirements, and spares requirements imposed by the government decrease. As a result, the related management costs decrease, the government visibility decreases, and the risks increase. A program for a certain class of hardware that is managed as a Class B program should have lower acquisition costs, and higher risk, than if it were managed as a Class A program. A program managed as a Class C program should have lower acquisition costs, and higher risk, than if it were managed as a Class B program. A Class D program would have the lowest acquisition costs and the highest risk. The correct program decisions regarding the classification of space equipment acquisition programs (as reflected in the contracts), and of the space equipment itself (as reflected in the equipment specification requirements), are major management steps towards reducing the acquisition costs. If the correct decisions are made, they can also be major steps in reducing the program life cycle cost. Reducing initial acquisition costs may not be a successful means of reducing the program life cycle cost. If it were always successful, all programs and equipment would be Class D.

In all space experiment programs there are extensive pressures to reduce costs and schedules. Some actions are equally effective in reducing costs, regardless of the class of the space equipment or the class of the space program. For example, an effective way to reduce acquisition costs may be to allow the use of a standard item, rather than reduce the weight by a redesign. This is not always feasible; but in those cases where it is, it would be equally effective independent of class considerations. Other actions, such as those to eliminate management requirements and data reporting requirements, cannot be applied to the same extent to all program classes, but they are actions that are applied to Class D programs, to some extent to Class C programs, and to a lesser extent to Class B programs. Other ways to reduce costs are to reduce the amount of hardware fabricated and the number of people involved in the program. Although many actions can be taken to greatly decrease cost, the fundamental design and manufacturing requirements must be met for proper operation in space and for mission success. Therefore, the most effective actions are not to eliminate essential designers or manufacturing personnel, or to reduce design and manufacturing requirements, but to eliminate some of the management reviews, data reporting requirements, and testing requirements. The price paid by a space experiment program in taking these actions is a tradeoff between cost savings and an increase in the risk of failure. The actions that involve program management are not addressed in this technical handbook, except to a limited extent in the matrices of Section 4 and to some extent in this section.

11.2.2 Experiment or Vehicle Classification Criteria

A space experiment may be a lower level of assembly of a space vehicle, a payload that performs its mission while attached to an orbiting 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 or a space vehicle is an arbitrary decision of little consequence, since the requirements and classification criteria should be the same. Correlation of the technical requirements (experiment or vehicle specification requirements) with the Class definitions identifies the class of experiment or vehicle being acquired.

11.2.2.1 Class A Experiment or Vehicle - High Priority, Minimum Risk. Class A space experiments are equipment for which a minimum risk approach is clearly dictated by prohibitively high cost of the consequences of failure, or by an unacceptable combination of costs and intangible factors associated with failure. Success-critical single failure points are not permitted if avoidable by functional or block redundancy. Unavoidable single failure points must be justified based on risk analysis and measures implemented to minimize risk. Design margins are conservative. Full compliance to technical standards is generally required. A formal qualification program is required using initial components. Flight acceptance testing is required on subsequent components. A formal experiment qualification program is also required using dedicated qualification equipment. Subsequent flight experiments would be acceptance tested. Class A space experiments are typically complex, high-priority, high-cost, long-life equipment. For Spacelab or Orbiter attached instruments, Class A is likely to be appropriate only for equipment or instruments which are expected to be critical to the success of an entire Spacelab or Orbiter mission.

The criteria for a Class A space vehicle is the same as for a Class A space experiment. However, qualification tests planned for the space vehicle need not repeat tests conducted at the subtier space experiment level. A decision can be made to either conduct separate tests on the experiment and on the host vehicle or to combine the experiment with the vehicle for a single qualification test. The most cost-effective overall qualification program should be implemented. The typical Class A space vehicle is a large upper-stage vehicle with the highest complexity such as a large upper-stage vehicle carrying several high priority Class A experiments. Class A is typified by high priority free-flyer space vehicles that will not be accessible by the Space Transportation System (STS) after deployment.

11.2.2.2 Class B Experiment or Vehicle - Medium Risk with Cost-saving Compromises. Class B space experiments can be characterized by an approach where reasonable compromises between minimum risk and minimum cost are appropriate due to the capability to recover from in-flight failure by some means that is at least marginally acceptable, even though it involves significantly high costs or highly undesirable intangible factors. Success-critical single failure points are acceptable based on cost and risk tradeoff analysis, and measures implemented to minimize the risks. Single string design approaches are acceptable; however, payloads or experiments with multiple information sources should provide redundant functions to preserve the capability for partial success. Design margins are limited. Full compliance to technical standards is generally required. The first unit of each type of component is given combined qualification and acceptance tests (protoflight tests). Subsequent components are given an acceptance test. Typically, a single Class B space experiment is constructed, and it is given combined qualification and acceptance tests (protoflight tests) prior to launch. The testing is more extensive than functional or environmental screening tests, but less extensive than a formal qualification test for Class A.

The criteria for a Class B space vehicle is the same as for a Class B space experiment. It would be designed to preserve the capability for partial success should one or more experiments fail. However, the combined qualification and acceptance tests (protoflight tests) planned for the space vehicle need not repeat tests conducted at the subtier space experiment level. A decision can be made to either conduct separate tests on the experiment and on the host vehicle or to combine the experiment with the vehicle for a single protoflight test. The most cost-effective overall test program should be implemented. The typical Class B space vehicle is a one of a kind, free-flyer vehicle which carries several independent, high priority experiments. It would be designed to preserve the capability for partial success should one or more equipments fail. The typical Class B space vehicle is a directly deployed free-flyer space vehicle which after deployment will not be accessible by the STS and may or may not be retrievable.

11.2.2.3 Class C Experiment or Vehicle - Economically Reflyable or Repeatable. Class C space experiments are equipment where compromises between minimum risk and minimum cost can be driven toward the minimum acquisition cost extreme. This is acceptable if the risk of failure remains low and the launch costs are low enough so that reflight or repeat flight is cost effective as a routine backup in the event of an in-flight failure. Also, there should be a relatively small impact of a failure except for the cost of repair and reflight, which is estimable with reasonable confidence and is directly tradeable with in-flight reliability enhancement costs. Therefore, a decision criterion of minimum total expected cost is appropriate and practical. For Class C, retrievability or in-orbit maintenance is usually possible. Success-critical single failure points are acceptable. Design margins are zero. Only limited compliance to technical standards is required. Each component is given an acceptance test. Typically, a single experiment is constructed, and it is given an acceptance test prior to launch. The testing is typically limited to functional, environmental screening, safety, and interface compatibility tests.

The criteria for a Class C space vehicle is the same as for a Class C space experiment. However, the acceptance tests planned for the space vehicle need not repeat tests conducted at the subtier space experiment level. A decision can be made to either conduct separate tests on the experiment and on the host vehicle or to combine the experiment with the vehicle for a single test. The most cost-effective overall test program should be implemented. Class C space equipment and Class C space vehicles are typified by Orbiter attached experiments, or any equipment planned for in-orbit maintenance.

11.2.2.4 Class D Experiment or Vehicle - Minimum Acquisition Cost. Class D space experiments or vehicles can be characterized as having objectives worth achieving by a minimum-cost attempt. Class D covers medium to low priority space experiments or vehicles where contractor maturity can be utilized to the maximum extent. Most technical parameters including margins would be established by the contractor. Single failure points are acceptable, and formal verification requirements are limited to those necessary for safety and compatibility. Typically, a single unit is constructed, and it is given an acceptance test prior to launch. Class D experiments or vehicles are usually small and simple. Class D is typified by an STS Orbiter "Get Away Special" or other last minute carry-on payloads.

11.2.3 Program Classification Criteria

Acquisition management of space vehicles and experiments is usually at the system program level. The management is the responsibility of the System Program Office (SPO). The SPO establishes schedules, budgets, interface agreements, management controls, technical controls, reviews, acquisition strategies, acquisition contracts, and other plans, tools, and resources required for a successful program. Correlation of these SPO actions with the Class definitions might identify the classification or program class for the total program managed by that SPO. Correlation of the management requirements, item deliveries, data deliveries, and other nonproduct requirements in each contract with the class definitions always identifies the classification or program class of each acquisition.

11.2.3.1 Class A Program - High Priority, Minimum Risk. Class A is assigned to programs where every feasible step must be taken to assure success. Class A programs are programs with the highest national priority, with the highest associated national prestige at risk, with the longest allowable program schedule, and with the lowest feasible program risk. Class A programs are structured with extensive checks and balances and with detailed reviews of every step. Formal reviews are held every month. Full compliance to management standards is generally required. Extensive data delivery requirements are typical. A complete set of component flight spares is required. A complete qualification vehicle independent of the flight hardware is usually required, and the refurbished qualification vehicle is used in the contingency plan associated with possible flight failure. The typical Class A space program would usually have ongoing production or operational requirements.

11.2.3.2 Class B Program - Medium Risk with Cost-saving Compromises. Class B space programs can be characterized by an approach where reasonable compromises between minimum risk and minimum cost are appropriate. Provisions for a contingency backup launch are typically not part of a Class B program but should be considered in the initial program planning. Class B is assigned to programs where the added fabrication and testing costs associated with a complete qualification vehicle independent of the flight hardware are not desired. Program schedules are reduced, with formal reviews only every two months. Component flight spares are limited.

11.2.3.3 Class C Program - Economically Reflyable or Repeatable. Class C space programs are programs where compromises between minimum risk and minimum cost can be driven toward the minimum acquisition cost extreme. Class C programs cover medium priority space programs usually where reflight or repeat flight is cost effective as a routine backup in the event of an in-flight failure. Program schedules are shorter, with informal reviews only every three months. Component flight spares are limited. Because Class C space programs run a greater risk of failure than Class B, contingency backup launch plans should be a factor in deciding to implement a Class C program, even though the contingency plans might not be a part of the initial acquisition contract.

11.2.3.4 Class D Program - Minimum Acquisition Cost. Class D programs are minimum-cost programs that are contractor managed with little government review. Class D covers medium to low priority space programs where contractor maturity can be utilized to the maximum extent. Program schedules are short. Component flight spares are not required. Class D programs can be characterized as programs that have objectives worth achieving by a low-cost attempt. Because Class D space programs run a greater risk of failure than Class C, contingency backup launch plans should be a factor in deciding to implement a Class D program, even though the contingency plans might not be a part of the initial acquisition contract.

Custodians
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Preparing Activity
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(Project No. 1810-F030)

Document 0787e/Arch 0057e
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(TO DETACH THIS FORM, CUT ALONG THIS LINE.)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER DOD-HDBK-343 (USAF)	2. DOCUMENT TITLE Design, Construction and Testing Requirements for One of a Kind Space Equipment
3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)* ☐ VENDOR ☐ USER ☐ MANUFACTURER ☐ OTHER *(Specify)*: ______
b. ADDRESS *(Street, City, State, ZIP Code)*	

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

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