
**Space systems — Ground support
equipment for use at launch, landing, or
retrieval sites — General requirements**

*Systèmes spatiaux — Équipements de soutien au sol utilisés sur les sites
de lancement, d'atterrissage ou de récupération — Exigences générales*

STANDARDSISO.COM : Click to view the full PDF of ISO 14625:1999



Contents

1 Scope	1
2 Normative references	1
3 Definitions, symbols and abbreviated terms	2
3.1 Definitions	2
3.2 Symbols and abbreviated terms	3
4 General.....	4
5 Functional designations	4
5.1 General.....	4
5.2 Servicing.....	5
5.3 Checkout and test.....	5
5.4 Handling and transportation.....	5
5.5 Auxiliary.....	5
5.6 Umbilical	5
6 Characteristics	5
6.1 Performance characteristics.....	5
6.1.1 Operability	5
6.1.2 Interfaces	5
6.1.3 Producibility	5
6.2 Physical characteristics.....	5
6.2.1 Limited life.....	5
6.2.2 Useful life.....	6
6.2.3 Protective coating.....	6
6.2.4 Colours	6

© ISO 1999

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

6.2.5 Metric system	6
6.2.6 Redundancy	6
6.3 Reliability	6
6.4 Maintainability	6
6.5 Environmental conditions.....	7
6.5.1 General	7
6.5.2 Natural environment.....	7
6.5.3 Launch-induced environment	7
6.5.4 Controlled interior environment.....	7
6.5.5 Controlled clean environment.....	7
6.5.6 Uncontrolled interior environment	7
6.5.7 Fire/explosion hazard environment	7
6.5.8 Environmental test methods	7
6.5.9 Seismic environment.....	7
6.6 Transportability.....	7
7 Documentation.....	8
7.1 Drawings and specifications	8
7.2 Technical documentation	8
7.3 Operations and maintenance documentation (OMD)	8
8 Supply support	8
9 Personnel and training.....	8
10 Qualification	9
11 Quality assurance.....	9
11.1 General.....	9
11.2 Responsibility for verification	9
11.3 Testing	9
11.3.1 General	9
11.3.2 Load test.....	9
11.3.3 Non-destructive test (NDT)	9
11.3.4 Test reports	9
11.3.5 Instrumentation calibration	10

11.4 Quality conformance verification 10

12 Packaging 10

12.1 Preservation and packaging 10

12.2 Shipping containers 10

12.3 Weight and size 10

12.4 Parts protection 10

12.5 Precision clean parts 10

12.6 Marking 10

12.7 Environmental recording instruments 10

12.8 Transportation and storage 11

13 Design and construction requirements 11

13.1 Structural design 11

13.1.1 Structural steel and other structures 11

13.1.2 Safety factor 11

13.1.3 Critical weld 11

13.2 Mechanical design 11

13.2.1 Pneumatics 11

13.2.2 Cryogenics 11

13.2.3 Hypergols 11

13.2.4 Hydrocarbons 12

13.2.5 Hydraulics 12

13.2.6 Environmental control system (ECS) and coolant servicing systems 12

13.2.7 Life support 12

13.2.8 Lifting devices 12

13.2.9 Springs 12

13.2.10 Umbilical design 12

13.2.11 Torque limits 12

13.2.12 Tethers 12

13.2.13 Jacks 12

13.2.14 Transportation equipment 12

13.2.15 Pressure vessels.....	13
13.3 Electrical/electronic design	13
13.3.1 Electrical control and monitor equipment	13
13.3.2 Pneumatic and hydraulic mechanical components	13
13.3.3 Internal wiring	13
13.3.4 Pyrotechnic systems.....	13
13.3.5 Electrical power	13
13.3.6 Bonding and grounding.....	13
13.3.7 Hazard-proofing.....	13
13.3.8 Lightning protection.....	13
13.3.9 Software.....	13
13.3.10 Firmware.....	13
13.4 Materials, parts and processes	14
13.4.1 Materials	14
13.4.2 Parts	15
13.4.3 Processes.....	17
13.5 Electromagnetic compatibility (EMC).....	19
13.6 Identification markings and labels.....	19
13.6.1 Systems and equipment	19
13.6.2 Load test.....	19
13.6.3 Piping systems	19
13.6.4 Compressed gas cylinders	19
13.6.5 Load capacity.....	19
13.6.6 Test weights	19
13.6.7 Electrical cable assemblies	20
13.6.8 Serial numbers.....	20
13.7 Workmanship.....	20
13.8 Interchangeability	20
13.9 Safety	20
13.10 Human performance.....	20
13.10.1 General	20

13.10.2 Operating characteristics.....	20
13.10.3 Personnel lifting limits	20
13.10.4 Propellant handlers ensemble (PHE) operators	20
13.11 Security.....	21
Annex A (informative) Bibliography	22

STANDARDSISO.COM : Click to view the full PDF of ISO 14625:1999

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 14625 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Annex A of this International Standard is for information only.

STANDARDSISO.COM : Click to view the full PDF of ISO 14625:1999

Introduction

This International Standard is intended to be used during the design of new ground support equipment (GSE) that support space system (launch vehicle or payload) programs or projects. Existing programs and projects may utilize this International Standard to the extent practical in accordance with sound management practices. The edition of this International Standard that was current at the time direction was issued to design, construct, manufacture, or procure the GSE is applicable for the useful life of the hardware. Modifications of existing hardware may be done so the modified hardware complies with the version that is current at the time directions are issued to modify the hardware. When this International Standard is used in procurement, the standard should be reviewed by the program/project office for applicability, and only the sections that apply to the project or program should be included in the procurement documentation.

STANDARDSISO.COM : Click to view the full PDF of ISO 14625:1999

Space systems — Ground support equipment for use at launch, landing, or retrieval sites — General requirements

1 Scope

This International Standard specifies the general characteristics, performance, design, test, safety, reliability, maintainability and quality requirements for ground support equipment (GSE) and systems intended for use at launch, landing, or retrieval-site installations or other locations that are the responsibility of the launch, landing and retrieval site. This International Standard does not specify how to design GSE, but establishes the minimum requirements to provide simple, robust, safe, reliable, maintainable and cost-effective GSE.

This International Standard is applicable to the design of non-flight hardware and software used to support the operations of transporting, receiving, handling, assembly, inspection, test, checkout, service, launch and recovery of space vehicles and payloads at the launch, landing, or retrieval sites. As such, the requirements of this International Standard are optional for hardware used only at the manufacturing, development, or test sites prior to arrival at the launch, landing, or retrieval sites or at the mission control site. However, if such GSE is temporarily used at a launch, landing, or retrieval site, for whatever reason, this GSE shall comply with all the safety-related requirements of this International Standard, as a minimum.

NOTE — In the event of conflict between the documents referenced herein and the contents of this International Standard, the contents of this International Standard supersede except where otherwise noted. The applicable contract or purchase/procurement order takes precedence over the contents of this International Standard in the event of conflicting requirements. Nothing in this International Standard supersedes applicable laws and regulations unless a specific exemption has been obtained.

2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 448:1981, *Gas cylinders for industrial use — Marking for identification of content.*

ISO 898-7:1992, *Mechanical properties of fasteners — Part 7: Torsional test and minimum torques for bolts and screws with nominal diameter 1 mm to 10 mm.*

ISO 1000:1992, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO 1949:1987, *Aircraft — Electrical connectors — Design requirements.*

ISO 1966:1973, *Crimped joints for aircraft electrical cables.*

ISO 2635:1979, *Aircraft — Conductors for general purpose aircraft electrical cables and aerospace applications — Dimensions and characteristics.*

ISO 2964:1985, *Aerospace — Tubing — Outside diameters and thicknesses — Metric dimensions.*

ISO 3010:1988, *Bases for design of structures — Seismic actions on structures.*

- ISO 6346:1995, *Freight containers — Coding, identification and marking.*
- IEC 60034 (all parts), *Rotating electrical machines.*
- IEC 60038:1983, *IEC standard voltages.*
- IEC 60079 (all parts), *Electrical apparatus for explosive gas atmospheres.*
- IEC 60096 (all parts), *Radio frequency cables.*
- IEC 60169 (all parts), *Radio frequency connectors.*
- IEC 60189 (all parts), *Low frequency cables and wires with PVC insulation and PVC sheath.*
- IEC 60227 (all parts), *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V.*
- IEC 60245 (all parts), *Rubber insulated cables of rated voltages up to and including 450/750 V.*
- IEC 60297 (all parts), *Dimensions of mechanical structures of the 482.6 mm (19 in) series.*
- IEC 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes.*
- IEC 60326 (all parts), *Printed boards.*
- IEC 60364 (all parts), *Electrical installations of buildings.*
- IEC 60364-5-54:1980, *Electrical installations of buildings — Part 5: Selection and erection of electrical equipment — Chapter 54: Earthing arrangements and protective conductors.*
- IEC 60794 (all parts), *Optical fiber cables.*
- IEC 60874 (all parts), *Connectors for optical fibers and cables.*
- IEC 60884 (all parts), *Plugs and socket-outlets for household and similar purposes.*
- IEC 60947 (all parts), *Low-voltage switchgear and control gear.*
- IEC 61000 (all parts), *Electromagnetic compatibility (EMC).*
- IEC 61024 (all parts), *Protection of structures against lightning.*
- IEC 61086 (all parts), *Specification for coatings for loaded printed wire boards (conformal coatings).*
- ISO/IEC Guide 25:1990, *General requirements for the competence of calibration and testing laboratories.*

3 Definitions, symbols and abbreviated terms

3.1 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1.1

cognizant authority

organization that is recognized as having expertise in one or more technical disciplines

EXAMPLES ISO, IEC, etc.

3.1.2
commercial-off-the-shelf
COTS

equipment, including hardware and associated software/procedures, that is commercially available from current industry inventory

3.1.3
critical weld

weld whose single failure during any operating condition could result in injury to personnel or damage to property or flight hardware

3.1.4
flight hardware lifting device

structural or mechanical items between the crane hook and the flight vehicle interface that are used to lift the flight hardware

EXAMPLES sling, cable, shackle, beam, etc.

3.1.5
ground support equipment
GSE

non-flight systems, equipment, or devices necessary to support the operations of transporting, receiving, handling, assembly, inspection, test, checkout, servicing, launch and recovery of a space system at launch, landing, or retrieval sites

3.1.6
safety critical

any condition, event, operation, process, equipment, or system with a potential for personnel injury, fatality, or damage to or loss of equipment or property

3.1.7
safety factor

ratio of ultimate strength, breaking strength, or yield strength to the material design limit stress

3.1.8
safe working load

assigned load as shown on the identification tag, that is the maximum load the device or equipment shall operationally handle and maintain

3.1.9
sneak circuit

unexpected path or logic flow within a system that, under certain conditions, can initiate an undesired function or inhibit a desired function

NOTE — Sneak circuits are not the result of hardware failure but are latent conditions inadvertently designed into the hardware or coded into the software and triggered by timing or human error.

3.2 Symbols and abbreviated terms

A-50	aerozine-50
CFC	chlorofluorocarbon
CIL	critical items list
COTS	commercial off-the-shelf
ECS	environmental control system
EEE	electrical, electronic and electromechanical
EMC	electromagnetic compatibility

EMI	electromagnetic interference
FMECA	failure mode, effects and criticality analysis
GSE	ground support equipment
ICD	interface control document
LH ₂	liquid hydrogen
LHe	liquid helium
LN ₂	liquid nitrogen
LOX or LO ₂	liquid oxygen
MMH	monomethylhydrazine
NDT	non-destructive test
NH ₃	ammonia
N ₂ H ₄	hydrazine
N ₂ O ₄	nitrogen tetroxide
OMD	operations and maintenance documentation
PCB	polychlorobiphenyl
PHE	propellant handlers ensemble
RF	radio frequency
SCAPE	self-contained atmospheric protective ensemble
SCC	stress corrosion cracking
SI	international system of units
UDMH	unsymmetrical dimethylhydrazine

4 General

The general design requirements and criteria described in this International Standard are the minimum requirements necessary to meet the needs and expectations of internal customers (e.g. safety, reliability, maintainability, quality, supportability, etc.) in a cost-effective manner. In order to meet customer expectations, GSE may need requirements that are more stringent than those specified herein. In such cases, requirements that exceed the provisions described in this International Standard shall be determined by the responsible design organization in consultation with its customers (e.g. users, operators, etc.).

5 Functional designations

5.1 General

GSE covered by this document shall be classified according to one of the functional designations given in 5.2 to 5.6. Under each functional designation, GSE can be classified by criticality, whereby the GSE

- either physically or functionally interfaces with flight hardware/software;
- is classified as safety critical; and/or
- generates data used in determining flight worthiness/certification.

The GSE is assessed as safety critical if loss of the GSE or improper performance could result in loss of life, loss of flight hardware, or damage to flight hardware. The GSE defined herein shall be subject to the configuration control requirements specified in the approved program configuration management plan.

5.2 Servicing

Servicing GSE is equipment used to supply electrical power or fluids to the flight hardware and/or associated GSE. Typical functions of servicing GSE are those functions of storage, transfer, flushing, purging, pressurizing, conditioning, vapour disposal and decontamination of propellants and other fluids required by the flight hardware.

5.3 Checkout and test

Checkout and test GSE is equipment used in the test and checkout of flight hardware and/or associated GSE. Typical functions of checkout and test GSE are the functions of stimuli monitoring and evaluation.

5.4 Handling and transportation

Handling and transportation GSE is equipment used for the movement and support of flight hardware and/or associated GSE. Typical types of equipment used in the handling and transportation category are slings, dollies, trailers, shipping containers, support stands, jacks, hoists, strongbacks and special handling mechanisms.

5.5 Auxiliary

Auxiliary GSE is equipment used to align, access, protect and calibrate flight hardware. Auxiliary GSE includes, but is not limited to, protective devices, access stands and platforms, and alignment or calibration hardware.

5.6 Umbilical

Umbilical GSE is equipment used to interface directly with flight hardware for transfer of fluids, electrical power, or electronic signals to and from the flight vehicle element.

6 Characteristics

6.1 Performance characteristics

6.1.1 Operability

GSE shall support the flight hardware operational requirements and shall be designed to ensure that it does not degrade or contaminate associated flight or ground systems, subsystems, or experiments during use, checkout, servicing, or handling.

6.1.2 Interfaces

GSE shall meet the requirements of all interfaces with new or existing flight and facility hardware or software. Future system compatibility shall be in accordance with identified interfaces. GSE hardware shall meet the requirements of the applicable interface control document (ICD).

6.1.3 Producibility

GSE hardware shall provide for ease of production, manufacture, construction and inspection. Special care shall be taken to avoid imposing close manufacturing tolerances unless required by design and performance.

6.2 Physical characteristics

6.2.1 Limited life

Use of items with a life of less than the useful life of the system or equipment for which the items are intended shall be avoided whenever possible. Items with limited life shall be identified. Identified limited-life items shall be

controlled from the date of manufacture through operational use, including storage. Provisions will be made for replacement or refurbishment of these items after a specified age or operating time/cycle. Status of limited-life cycle items and waivers on limited-life items shall be maintained. Elapsed time or cycle indicators shall be employed to accumulate operational time or cycles if critical.

6.2.2 Useful life

GSE shall be designed for a useful life appropriate to its mission. When a useful life is not identified by program or mission requirements, a goal of 10 years may be used. During this period, normal preventive maintenance, repair, modification, or calibration may be accomplished to maintain specified performance.

6.2.3 Protective coating

Protective coating of hardware shall be appropriate to the condition, use and environment to which the GSE will be exposed during its life cycle. The coating shall minimize corrosion and should indicate its use (see 6.2.4).

6.2.4 Colours

The colours given in table 1 should be used for the type of GSE indicated.

Table 1 — Colours for GSE

Colour	GSE type
Grey or blue	Consoles and panels
Grey or orange	Structural steel
Red	Remove before flight, safety and protective equipment
White	Transportation containers
Black	Panel lettering
Yellow or white	Handling and transportation equipment

6.2.5 Metric system

New GSE shall use the metric system in accordance with ISO 1000.

6.2.6 Redundancy

Redundant systems, subsystems, or components shall be physically separated or otherwise protected to ensure that failure of one will not prevent the other from performing the function.

6.3 Reliability

GSE shall be designed to meet system availability and/or dependability requirements. GSE shall be designed to minimize the probability of system failure and reduce the severity of the failure effect of the system. As a minimum, GSE shall be designed to be fail-safe, except for structure and pressure vessels in the rupture mode. The quality management system of the supplier shall provide appropriate procedures and instructions to perform and document analyses like the failure mode, effects and criticality analysis (FMECA)/critical items List (CIL), reliability diagrams, and, in particular cases, sneak circuit analysis or equivalent.

6.4 Maintainability

GSE shall be designed to minimize the complexity and duration of maintenance, the maintenance resources required to keep the system operational, and maintenance downtime. High-failure-rate items should be identified for accessibility concerns. Human engineering criteria shall be used to provide accessibility to failed items (see 13.10). Fault detection and isolation should be considered based on criticality and cost of failures.

6.5 Environmental conditions

6.5.1 General

GSE shall be designed to meet natural and induced environments to which it will be subjected during its life cycle. The manager of the geographical location where the GSE is to be located shall provide an environmental document that defines the natural and induced environmental conditions.

6.5.2 Natural environment

GSE used or stored in an exterior environment shall be designed to function properly at its respective geographical location after exposure to the natural environment as tailored to reflect program-defined risk and exposure times.

6.5.3 Launch-induced environment

GSE designed to function during or after exposure to the launch-induced environment shall be designed to withstand the environment defined in program-induced environmental requirements documents.

6.5.4 Controlled interior environment

GSE designed to function within a controlled interior environment shall be designed to the following temperature and humidity requirements:

- a) temperature: + 15 °C to + 27 °C with extremes of an uncontrolled temperature of + 10 °C to + 40 °C for a maximum of 1 h;
- b) humidity: nominal 55 %, with a range of 40 % to 70 % within the above defined temperature range (15 °C to 27 °C).

6.5.5 Controlled clean environment

GSE used in a controlled clean environment shall be designed to be operated and maintained at a cleanliness level compatible with the intended use.

6.5.6 Uncontrolled interior environment

GSE used in an uncontrolled interior environment shall be designed to meet the most severe exterior environmental conditions for temperature and humidity anticipated at the respective geographical locations.

6.5.7 Fire/explosion hazard environment

GSE operated in locations where fire or explosion hazards may exist due to flammable gases or vapours, flammable liquids, liquid, gas, or solid propellants, etc., shall be hazard-proofed to prevent such hazardous conditions in accordance with the requirements specified in this International Standard.

6.5.8 Environmental test methods

Environmental methods and conditions required for GSE life cycle testing and qualification may be in accordance with accepted national or international aerospace industrial practices, as applicable.

6.5.9 Seismic environment

If GSE may be subjected to a seismic environment, hardware shall be designed to resist the effects of a seismic event using the appropriate criteria and guidelines given in ISO 3010 or in accordance with a national standard.

6.6 Transportability

GSE design shall take into consideration the mobility and transportability constraints imposed by the deployment and maintenance concepts, handling equipment and planned modes of transportation (i.e. road, rail, sea, or air). If necessary, GSE shall be capable of being partially dismantled or packed in order to meet the maximum size

envelopes of the transportation method to be used (see 12.3). Maximum compatibility with existing procedures, facilities and equipment, including material handling equipment, shall be a design goal.

GSE to be transported by personnel shall be provided with such handling provisions (e.g. handles, hand holds, etc.) necessary to meet operational transportability requirements. GSE that exceeds personnel lifting limits shall be provided with material handling provisions (e.g. sling, lift points, castors, skid, etc.) necessary to meet the operational requirements for installation/removal, maintenance and use.

7 Documentation

7.1 Drawings and specifications

Drawings and specifications required for the fabrication, construction, installation, modification, test, operation, maintenance, or utilization of GSE shall be prepared in accordance with accepted national or international drawing practices, as applicable.

7.2 Technical documentation

Technical documentation (e.g. manuals, reports, etc.) shall be prepared in accordance with accepted national or international aerospace industrial practices, as applicable.

7.3 Operations and maintenance documentation (OMD)

Operations and maintenance documentation (i.e. schematics, diagrams, operation and maintenance manuals, lists, etc.) shall be developed to the extent necessary to permit operations and maintenance personnel to fully utilize, operate, troubleshoot and otherwise maintain the GSE within their charge.

8 Supply support

GSE design shall accommodate the supply support system for the identification and acquisition of sufficient spare parts, components, materials and items to support construction, fabrication, installation, activation, tests, verification and operation activities that occur during the life cycle of the equipment or system.

9 Personnel and training

GSE design shall minimize the personnel and training requirements for the operation and maintenance of hardware and software. Hardware and software design shall keep the number and skill levels of personnel to a minimum. OMD shall be utilized as the source documentation in training courses. All GSE shall be designed assuming operations and maintenance will be performed by appropriately trained and skilled personnel, unless otherwise directed.

GSE shall be designed for simplicity of use, redundancy and controls that are self-explanatory. The design shall provide for appropriate safety and warning devices to alert personnel of impending or existing hazards and shall ensure that normal operations/failures will not adversely affect personnel safety or the safety of the system or equipment. The design shall limit the number of controls and the data provided to the absolute minimum possible so only those functions needed by an unskilled and untrained operator are available. The design shall provide ease of operation so unskilled and untrained operators do not require training for normal or emergency conditions. Design features shall ensure ease of operation, safety and economy. The resultant design shall optimize compatibility between equipment and human performance without requiring personnel training. The training necessary for operation and maintenance of GSE should be included in the training systems for the equipment that the GSE supports.

10 Qualification

Critical systems, subsystems and other components that have significant failure impact shall be qualified in accordance with the provisions of the approved program/project verification plan.

11 Quality assurance

11.1 General

A supplier of GSE shall have a quality management system established which incorporates appropriate design rules and technical quality requirements. The design shall also include special quality-related requirements, such as special processes, special testing, and any other necessary special requirements that produce a quality product. Quality requirements will be defined in program/project quality and technical requirements documents, specifications, contractual requirements and other specified documentation.

11.2 Responsibility for verification

The concept of quality assurance places primary responsibility for quality of delivered products, materials, or services on the supplier. The supplier is also responsible for the verification/quality of subcontractor products. However, where assembly of the system or equipment is at a customer facility, responsibility for verification may be split between the customer and the supplier. Accordingly, the supplier's responsibility for inspection shall be clearly stated in the contract documentation and the customer's role, either as a partner or monitor, shall be specified. A typical statement of responsibility is given in the following example.

EXAMPLE

“Responsibility for verification: Unless otherwise specified in the contract or order, the supplier is responsible for the performance of all verification requirements specified herein. Except as otherwise specified, the supplier may use its own facilities or any commercial laboratory acceptable to the customer. The customer reserves the right to perform any of the verifications set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to prescribed requirements.”

11.3 Testing

11.3.1 General

Testing shall be specified by the engineering documentation and will normally be limited to end-item acceptance testing to verify compliance with the applicable specifications and the ability of the end item to perform its functions.

11.3.2 Load test

A load test shall be performed on hardware whenever there is reason to question its safety for the intended use. The minimum static test load shall be 125 % of the design or working load. Lifting devices and equipment shall be load tested in accordance with accepted national or international aerospace industry practice, as applicable. The static test load for flight hardware lifting devices shall be 200 % of the design or working load. An alternative to the 200 % static load test shall be a 150 % minimum static load test and a 110 % minimum dynamic test of the design or working load. Non-flight hardware lifting devices shall use a minimum static test load of 125 % of the design or working load.

11.3.3 Non-destructive test (NDT)

All NDT's of base materials shall be performed in accordance with accepted national or international aerospace industry practice, as applicable.

11.3.4 Test reports

Test reports shall be prepared in accordance with accepted national or international aerospace industry practice, as applicable.

11.3.5 Instrumentation calibration

Calibration of measuring instruments shall be established and maintained in accordance with ISO/IEC Guide 25.

11.4 Quality conformance verification

A verification program shall be specified in the contract documentation. This program shall ensure that examinations and tests are performed to verify all requirements of this International Standard have been achieved. This quality conformance verification program shall include:

- tests and analyses of the performance and reliability requirements;
- measurement or comparison of specified physical characteristics;
- verification, with specific criteria, of workmanship;
- test and inspection methods for ensuring compliance, including environmental conditions for performance.

12 Packaging

12.1 Preservation and packaging

Hardware shall be preserved and packaged in accordance with accepted national or international aerospace industry practice, as applicable.

12.2 Shipping containers

Shipping containers shall be compatible with on-site transportation, handling and storage methods. For convenient handling and stacking, containers having a gross weight of more than the maximum weight allowed by human engineering shall be provided with integral skids or pallets for shipment. The recommended minimum skid or pallet thickness is 100 mm. Attach points shall be provided where applicable for crane hoists and tiedowns.

12.3 Weight and size

The weight and cubic displacement of packaging and packing shall be held to a minimum consistent with the requirement of the item and the method of transportation. Oversized hardware shall be designed so the configuration (i.e. item) may be disassembled as required and packaged for shipment.

12.4 Parts protection

There shall be an efficient, reliable and economical system for the protection of all parts during shipping, handling and storage. There shall be standardization of parts protection procedures, methods, materials and devices, such as carts, boxes, containers, or transportation vehicles necessary to prevent damage to parts.

12.5 Precision clean parts

Precision clean parts shall be packaged in such a manner to preserve the cleaning level of the part until used.

12.6 Marking

Containers shall be marked in such a manner so as to easily identify the contents of the container without opening it in accordance with ISO 6346.

12.7 Environmental recording instruments

Shipment of hardware that is sensitive to the environment shall include instruments which record the environment with respect to time. Proof of adequate packaging shall be demonstrated if the use of a recording instrument is required but is not feasible in a single-item shipment of a small item.

12.8 Transportation and storage

The packaging shall protect the hardware during transportation and storage.

13 Design and construction requirements

13.1 Structural design

13.1.1 Structural steel and other structures

The design of structural steel, aluminium, concrete and other GSE structures (e.g. access platforms, support stands, etc.) shall be in accordance with accepted national or international aerospace industrial practices and the requirements of this International Standard.

13.1.2 Safety factor

A minimum safety factor of 2 against yield or permanent deformation and 3 against ultimate failure or collapse shall be used. The safety factor for flight hardware lifting devices shall be 3 against yield or permanent deformation and 5 against ultimate failure or collapse.

13.1.3 Critical weld

Critical welds shall be avoided wherever possible. Critical welds shall be identified by the responsible design organization on the design drawings by placing a flag note in the tail of the critical weld symbol.

The required appropriate non-destructive testing for critical welds shall also be identified by the responsible design organization in the general notes on the design drawings.

13.2 Mechanical design

13.2.1 Pneumatics

The design of pneumatic (i.e. gaseous nitrogen, helium, oxygen, hydrogen, breathing air and special oxygen/nitrogen mixtures) servicing systems and equipment shall be in accordance with accepted national or international aerospace industrial practices, as applicable. Vacuum systems or compressed air systems shall be designed in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.2 Cryogenics

The design of cryogenic [i.e. liquid hydrogen (LH₂), liquid oxygen (LO₂), liquid helium (LHe) and liquid nitrogen (LN₂)] servicing systems shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.3 Hypergols

The design of the following hypergolic fuel servicing systems and equipment shall be in accordance with the provisions of the national regulations applicable at the launch, landing, or retrieval site.

- monomethylhydrazine (MMH),
- nitrogen tetroxide (N₂O₄),
- hydrazine (N₂H₄),
- aerazine-50 (A-50),
- unsymmetrical dimethylhydrazine (UDMH).

13.2.4 Hydrocarbons

The design of hydrocarbon fuel (i.e. JP-4, JP-5, RP-1, etc.) servicing and storage systems and equipment shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.5 Hydraulics

The design of hydraulic servicing systems and equipment shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.6 Environmental control system (ECS) and coolant servicing systems

The design of ECS and coolant servicing systems and equipment used to condition and control the environment within selected space vehicle, spacecraft, or experiment compartments shall be in accordance with accepted national or international aerospace industrial practices, as applicable. Environments in which personnel may be exposed shall be maintained in a condition in accordance with the safety objectives of the launch site.

13.2.7 Life support

The design of life support systems and equipment used or worn by personnel involved in toxic material operations, emergency rescue operations, and all activities where the possibility of exposure to hazardous atmosphere exists shall be in accordance with accepted national or international aerospace industrial safety practices, as applicable.

13.2.8 Lifting devices

The design of lifting devices (e.g. cranes, crane bridges, hoists, etc.) shall be in accordance with national or international standards, as applicable. When lifting flight hardware, a liftability analysis shall be performed to certify the stability of the lift prior to completion of the final design.

13.2.9 Springs

Spring design shall be in accordance with accepted national or international aerospace industrial practices. See the *Handbook of Spring Design* (see annex A) for suggested methods and practices.

13.2.10 Umbilical design

The design of flight-to-ground umbilicals shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.11 Torque limits

Threaded fasteners that require torquing shall use the torque limit criteria specified in ISO 898-7, as a minimum. For threaded fasteners of diameters greater than 10 mm, torquing requirements shall be determined by accepted design methods.

13.2.12 Tethers

Equipment used in areas where the dropping of hardware could result in injury to personnel or damage to flight hardware shall be tethered.

13.2.13 Jacks

The design of jacks shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.14 Transportation equipment

Transporters and other motorized GSE used for transportation of flight elements shall be designed to system specifications compiled from appropriate sections of industry and military specifications applicable to the characteristics of the desired end item. Transportation equipment shall ensure that loads imparted to flight hardware are equal to or less than 80 % of the design flight loads.

13.2.15 Pressure vessels

All pressure vessels for use in GSE shall be designed, constructed, tested and certified in accordance with accepted national or international aerospace industrial practices, as applicable.

13.3 Electrical/electronic design

13.3.1 Electrical control and monitor equipment

The design of electrical control and monitor systems and equipment shall be in accordance with accepted national or international aerospace electronic industry practices, as applicable.

13.3.2 Pneumatic and hydraulic mechanical components

The electrical design for pneumatic and hydraulic mechanical components shall be in accordance with accepted national or international aerospace fluid component industry practices, as applicable.

13.3.3 Internal wiring

The design of internal wiring used for electrical interconnection of components or parts within electronic GSE shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.3.4 Pyrotechnic systems

The design of pyrotechnic systems and equipment shall be in accordance with the national regulations applicable at the launch, landing, or retrieval site.

13.3.5 Electrical power

The design of electrical power for systems and equipment shall be in accordance with IEC 60364. Standard voltages shall be in accordance with IEC 60038. Adapters or other electrical devices may be required to ensure GSE compatibility between different power systems.

13.3.6 Bonding and grounding

Bonding and grounding shall be provided in accordance with IEC 60364-5-54.

13.3.7 Hazard-proofing

Electrically energized equipment that is operated in a hazardous environment shall be hazard-proofed equipment and wiring or shall be intrinsically safe in accordance with IEC 60079.

13.3.8 Lightning protection

Lightning protection for GSE at the launch pad, hazardous processing facilities and other hazardous areas shall be designed in accordance with IEC 61024.

13.3.9 Software

Software incorporated in the design of GSE shall follow the recommendations of accepted national or international aerospace industrial practices, as applicable.

13.3.10 Firmware

Firmware incorporated in the design of GSE shall meet the requirements of accepted national or international aerospace industrial practices, as applicable.

13.4 Materials, parts and processes

13.4.1 Materials

13.4.1.1 General

Recovered or recycled materials may be used instead of virgin materials except in those cases where virgin materials are deemed necessary to ensure adequate performance. For establishing properties, national or international industrial standards, as applicable, shall be used for metal. Applications for materials shall be limited to those materials that are adequately described by controlling specifications or standards of a cognizant authority. Any additional qualifying tests and inspections shall be indicated in the engineering documentation. Control documents may be created for proposed materials that lack such documentation.

13.4.1.2 Hydrogen embrittlement

Materials subject to hydrogen embrittlement shall not be used in applications where the material could be exposed to hydrogen. These materials include, but are not limited to, titanium, maraging steels, stainless steels and precipitation-hardening stainless steels. Low-strength carbon and stainless steels are preferred construction materials.

13.4.1.3 Stress corrosion

Materials shall be selected from alloys that are resistant to stress corrosion cracking (SCC), unless the GSE is used and stored in a controlled interior environment as specified in this International Standard.

13.4.1.4 Dissimilar metals

Dissimilar metals shall not be used in direct contact with each other for applications where the operational environment may cause corrosion. Separation by use of barrier tape, protective coatings, or other methods of isolation shall be used in these applications.

13.4.1.5 Toxic materials or formulations

Toxic materials or formulations shall not be specified in GSE design. Toxic products and formulations shall not be generated by a system or equipment. Typical examples of such toxic materials are mercury in liquid or vapour form, polychlorobiphenyls (PCB's), lead-based paints, chlorofluorocarbons (CFC's) and asbestos. Toxic fluids such as N_2H_4 , N_2O_4 , MMH, UDMH and ammonia (NH_3) may only be used when specifically required by a flight vehicle system requirement. The use of such toxic fluids shall comply with the applicable safety regulations. A material's hazardous analysis shall be performed to determine if the GSE design involves any materials or by-products that may be considered hazardous.

13.4.1.6 Flammability, odour and off-gassing

13.4.1.6.1 General

Materials used in hardware designed for use in direct contact with the flight vehicle element or in close proximity shall be qualified for flammability, odour and off-gassing in accordance with accepted national or international aerospace material standards, as applicable.

13.4.1.6.2 Oxygen service

Only materials that are compatible with oxygen shall be selected for use in liquid or gaseous oxygen and liquid or gaseous air systems.

13.4.1.6.3 Type J fluid service

Only materials that are compatible with type J fluids (i.e. hydrogen, hypergols, etc.) shall be used in these systems.

13.4.1.7 Heat and blast protection

Coating materials used for heat and blast protection of hardware shall be compatible with the space system propellants, shall not create debris and shall protect the hardware to which it is applied with a minimum of repair after launch.

13.4.1.8 Potting and moulding compound

Potting and moulding compound for electrical connectors shall be compatible with the space system propellants and shall provide a hermetic seal, isolation and insulation of electrical current, and structural support for the connector.

13.4.1.9 Fungus resistance

Materials susceptible to the growth of fungi shall be avoided. When these materials cannot be avoided, the material shall be treated to resist fungus.

13.4.1.10 Liquid locking compounds

Single component liquid locking compounds that are anaerobic (remain liquid when exposed to oxygen) shall not be used without prior project/program approval.

13.4.2 Parts

13.4.2.1 Use of commercial parts

Commercial off-the-shelf (COTS) equipment, parts, items, software, or components shall be used to the maximum extent possible when

- a) they satisfy the hardware function;
- b) they will not degrade the safety or reliability of the flight or ground system; and
- c) they provide a cost savings that will exceed possible cost increases due to unique maintenance or logistics requirements, modifications, or an increase in the complexity of the interfacing equipment.

In all cases, exact materials of construction and applicable specifications shall be determined for evaluation of material compatibility requirements. Any additional qualifying tests and inspections shall be indicated in the engineering documentation. Control documents may be created for proposed parts that lack such documentation.

13.4.2.2 Electrical, electronic and electromechanical (EEE) parts

EEE parts shall be selected in accordance with accepted national or international aerospace industrial practices, as applicable. Only EEE parts commensurate with the criticality of the application and the life cycle of the hardware shall be used. Determination of the EEE grade shall be based on the specific circuit function and its associated criticality.

13.4.2.3 Tubing and fittings

Tube fittings used in high-pressure fluid systems shall be in accordance with accepted national or international aerospace industrial practices, as applicable. Tubing shall be in accordance with ISO 2964.

13.4.2.4 Fluid system components

Fluid system components used in the design of liquid or gas systems shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority. Control documents may be created for proposed fluid components that lack such documentation. Fluid components shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware, or loss of mission is a direct concern, fluid components shall be selected from items of the highest practical quality.

13.4.2.5 Electrical power receptacles and plugs

Electrical power receptacles and plugs for GSE shall conform to the IEC 60309 or IEC 60884. The wiring of receptacles and plugs should be verified to ensure compatibility with the GSE's intended destination.

13.4.2.6 Electrical power cable

Alternating current (a.c.) power cable shall conform to the IEC 60227 or IEC 60245, where the presence of PVC or rubber is not detrimental to the intended use of the GSE. Power cables for use in environmental chambers or environmentally hazardous areas shall use appropriate aircraft or vacuum-approved cable types.

13.4.2.7 Electrical cable

Flexible multi-conductor jacketed electrical cable shall be in accordance with accepted national or international aerospace electrical industry practices, as applicable.

13.4.2.8 Instrumentation and communication cable

Instrumentation and communication cable shall be in accordance with IEC 60189, where the presence of PVC or rubber is not detrimental to the intended use of the GSE. Power cables for use in environmental chambers or environmentally hazardous areas shall use appropriate aircraft or vacuum-approved cable types.

13.4.2.9 Fibre-optic cable

Fibre-optic cable shall be in accordance with IEC 60794.

13.4.2.10 Electrical hook-up wire

Electrical hook-up wire shall be in accordance with ISO 2635.

13.4.2.11 Radio-frequency (RF) cables

Radio-frequency cables shall be in accordance with IEC 60096.

13.4.2.12 Connectors

13.4.2.12.1 Multi-conductor connectors

Electrical multi-conductor connectors for electrical control and monitor systems and equipment shall comply with ISO 1949.

13.4.2.12.2 Radio frequency (RF) connectors

RF connectors shall be selected from IEC 60169.

13.4.2.12.3 Fibre-optic connectors

Fibre-optic connectors shall be in accordance with IEC 60874.

13.4.2.12.4 Protective covers or caps

Protective covers or caps shall be specified for all electrical connector plugs and receptacles when they are not connected. Protective covers or caps shall

- a) be moisture-proof;
- b) protect sealings, surfaces, threads and pins against damage;
- c) be resistant to abrasion, chipping, or flaking;
- d) comply with cleanliness requirements for plugs and receptacles on which they are used;

- e) be made of material that is compatible with the connector materials;
- f) be connected to the cable with suitable lanyard, chain, or hinge;
- g) be non-static producing.

13.4.2.13 Sensors and transducers

Sensors and transducers used in the design of electrical control and monitor systems shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority. Control documents may be created for proposed sensors and transducers that lack such documentation. Sensors and transducers shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware, or loss of mission is a direct concern, sensors and transducers shall be selected from items of the highest practical quality.

13.4.2.14 Exterior electrical enclosures

Electrical enclosures used in exterior applications shall be designed to protect the electrical/electronic devices, apparatus and wiring contained within the enclosure from the effects of the natural and induced environment and to prevent any potential hazardous conditions.

13.4.2.15 Rack, panels and modular enclosures

Electronic racks, panels and modular enclosures used in interior applications shall be in accordance with IEC 60297.

13.4.2.16 Printed boards

GSE printed boards shall be designed, fabricated and qualified in accordance with IEC 60326.

13.4.2.17 Motors

Motors used in GSE shall be in accordance with IEC 60034. Starters and controllers shall be in accordance with accepted national or international aerospace industrial practices for industrial control devices specified in IEC 60947.

13.4.2.18 Threaded fasteners

Threaded fasteners shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority. Control documents may be created for proposed fasteners that lack such documentation. Fasteners shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware, or loss of mission is a direct concern, fasteners shall be selected from items of the highest practicable quality. These critical fasteners shall have lot traceability from the manufacturer to the warehouse storage or shall have acceptance testing (chemical and physical properties, where applicable) of fasteners by lot or be proof-loaded prior to use. Other applications shall give primary consideration to reduced cost and schedule requirements.

13.4.3 Processes

13.4.3.1 Welding

Welding shall be in accordance with the accepted national or international aerospace industrial practices, as applicable.

13.4.3.2 Brazing

Brazing of steel, copper, aluminium, nickel and magnesium alloys and induction brazing shall be in accordance with accepted national or international aerospace industrial practices, as applicable to non-flight equipment.