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Space product assurance

Materials, processes and their data selection

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Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS Executive Secretariat, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

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ECSS-Q-70-71A Rev.1 18 June 2004	First issue Revision 1 Correction of subclause 6.17.6 c. and to implement editorial changes.
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1 Scope

The purpose of this Standard is to define the requirements applicable to materials, processes and their data selection to satisfy the mission performance requirements.

This Standard covers the following:

- selection criteria and rules;
- utilization criteria and rules.

The provisions of this Standard apply to all actors involved at all levels in the production of space systems. These can include manned and unmanned spacecraft, launchers, satellites, payloads, experiments, electrical ground support equipment, mechanical ground support equipment, and their corresponding organizations.

This standard may be tailored for the specific characteristics and constraints of a space project in conformance with ECSS-S-ST-00.

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Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revisions of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system - Glossary of terms
ECSS-Q-ST-20	Space product assurance - Quality assurance
ECSS-Q-ST-70-02	Space product assurance - Thermal vacuum outgassing test for the screening of space materials
ECSS-Q-ST-70-03	Space product assurance - Black-anodizing of metals with inorganic dyes
ECSS-Q-ST-70-04	Space product assurance - Thermal testing for the evaluation of space materials, processes, mechanical parts and assemblies
ECSS-Q-ST-70-07	Space product assurance - Verification and approval of automatic machine wave soldering
ECSS-Q-ST-70-08	Space product assurance - Manual soldering of high-reliability electrical connections
ECSS-Q-ST-70-10	Space product assurance - Qualification of printed circuit boards
ECSS-Q-ST-70-11	Space product assurance - Procurement of printed circuit boards
ECSS-Q-ST-70-18	Space product assurance - Preparation, assembly and mounting of RF coaxial cables
ECSS-Q-ST-70-26	Space product assurance - Crimping of high-reliability electrical connections
ECSS-Q-ST-70-28	Repair and modification of printed circuits board assemblies for space use
ECSS-Q-ST-70-30	Wire wrapping of high-reliability electrical connections
ECSS-Q-ST-70-38	Space product assurance - High-reliability soldering for surface-mount and mixed technology

ECSS-E-ST-32-08	Space engineering - Materials
ESCC 3901	Generic specification - Wires and cables, electrical, 600V, low frequency
ESCC 3902	Generic specification - Cables, coaxial, radio frequency, flexible
ESCC 3903	Generic specification - Solid wires, electrical 350 V, for wire wrapping

3
Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01, ECSS-Q-ST-70, ECSS-Q-ST-70-04, ECSS-Q-ST-70-08, ECSS-QST-70-28 and ECSS-E-ST-32 apply, in particular for the following terms:

A-basis design allowable (A-value)

assembly

B-basis design allowable (B-value)

component

corrosion

lot

material

part

process

relifing

repair

3.2 Terms specific to the present standard

3.2.1. plate

form of material having a thickness of >6 mm

3.2.2. sheet

form of material having a thickness >0,2 mm and <6 mm

3.2.3. foil

form of material having a thickness <0,2 mm

3.2.4. thick coatings

coating with such a thickness that the properties of the substrate do not significantly influence the coating properties.

NOTE A thick homogeneous coating can be as such treated as if it were effectively a bulk material. The thickness is generally above approximately 125 μm

3.2.5. debubbling

removal of bubbles performed by low pressure process between the coating line and the coating stand.

NOTE The pressure can be high enough not to cause boiling. The low-pressure causes the bubbles to expand and thus rise faster.

3.2.6. unstabilized stainless steel

steels from the 300 series which do not contain Titanium of Niobium as a stabilizing element against the formation of iron-carbides

NOTE The iron-carbide formation is also called sensitization and occurs during prolonged heating at temperatures above 370 °C. Iron-carbide formation can also be avoided using lower carbon grades

3.2.7. exfoliation

corrosion that proceeds along planes parallel to the surface, generally at grain boundaries, forming corrosion products that create a wedging stress, giving rise to a layered appearance

NOTE This form of corrosion is associated with a marked directionality of the grain structure. Applied stresses are not necessary for exfoliation to occur. However, in alloys susceptible to stress corrosion cracking, the corrosion product wedging action undoubtedly contributes to the propagation of the exfoliation attack. It is important to note that some alloys not susceptible to stress corrosion cracking can suffer exfoliation corrosion. However, if the grain structure is equiaxed, exfoliation corrosion does not usually occur.

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
ATOX	atomic oxygen
EDM	electro discharge machining
ESMDB	European Space Materials Database
DPL	declared parts list

Abbreviation	Meaning
GOX	gaseous oxygen
KIc	fracture toughness
KIscc	stress-corrosion cracking threshold stress intensity factor
LOX	liquid oxygen
MMPDS	metallic materials properties development and standardization
NDI	non-destructive inspection
PTFE	polytetrafluroethylene
SCC	stress-corrosion cracking
UTS	ultimate tensile strength

3.4 Nomenclature

The following nomenclature applies throughout this document:

a. The word "shall" is used in this Standard to express requirements. All the requirements are expressed with the word "shall".

b. The word "should" is used in this Standard to express recommendations. All the recommendations are expressed with the word "should".

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

c. The words "may" and "need not" are used in this Standard to express positive and negative permissions, respectively. All the positive permissions are expressed with the word "may". All the negative permissions are expressed with the words "need not".

d. The word "can" is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS "may" and "can" have completely different meanings: "may" is normative (permission), and "can" is descriptive.

e. The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

4 Specific requirements

4.1 General

a. This Standard shall be applied together with the ECSS-Q-ST-70.

NOTE Annex A provides information about the European Space Materials Database (ESMDB).

4.2 Material requirements

4.2.1 General requirements

a. Design stresses shall include all residual stresses including those coming from manufacturing and assembly processes.

b. Alloys, heat treatments and coatings which minimize susceptibility to general corrosion, pitting, intergranular and stress corrosion cracking shall be used.

4.2.2 Aluminium and aluminium alloys

a. Wrought heat-treatable products shall be mechanically stress relieved.

NOTE For example in TX5X or TX5XX tempers

b. Wrought alloys 5456, 5083 and 5086 shall be used only in controlled tempers for resistance to SCC and exfoliation.

NOTE Examples of controlled tempers are H111, H112, H116, H117, H323, H343

c. Long-term manned structures, shall not use aluminium alloys 2024-T6, 7079-T6 and 7178-T6 in structural applications.

d. Black Anodising shall not be used on 2000 and 7000 series of Aluminium Alloys in conformance with requirements from the clause 5 of ECSS-Q-ST-70-03.

e. Long-term manned structures, shall not use aluminium alloys 5083-H32, 5083-H38, 5086-H34, 5086-H38, 5456-H32 and 5456-H38 in applications where the temperature exceeds 66 °C.

4.2.3 Copper and copper alloys

a. For electronic assemblies applications and wirings, materials and processes shall conform to the requirements from clause 5 to clause 15 of ECSS-Q-ST-70-08 and from clause 5 to clause 16 ECSS-Q-ST-70-38.

b. Copper coatings shall not be used on external surfaces exposed to atomic oxygen in the low Earth orbit.

4.2.4 Nickel and nickel alloys

a. The effect of alloying element depletion at the surface of superalloys in high-temperature oxidizing environments shall be evaluated when sheet is used.

NOTE A slight amount of depletion can involve a considerable proportion of the effective cross section of the material.

b. Any foreign material which can contain sulphur, shall be removed prior to heat treatment or high temperature service.

NOTE 1 Nickel and high nickel content alloys are susceptible to sulphur embrittlement.

NOTE 2 Sulphur can be contained for example in oils, grease, and cutting lubricants as well as in air

4.2.5 Titanium and Titanium alloys

a. Hydrogen, Oxygen and Nitrogen uptake shall be avoided in all phases of the parts manufacturing or use.

NOTE 1 The uptake of hydrogen during processes (with possible generation of hydrides) can occur for example on processes such as welding, cleaning and heat treatment.

NOTE 2 The uptake of oxygen during processes (with possible generation of alpha cases) can occur for example during heat treatment, welding and Electro Discharge Machining.

b. Titanium alloys whose hardenability is limited by section size shall not be used in dimensions which exceed their limits.

c. Structural applications using titanium shall be designed to avoid fretting.

d. For manned structures, titanium shall not be used with LOX or GOX at a pressure exceeding 34,5 kPa.

e. For manned structures, titanium shall not be used with air where the oxygen partial pressure exceeds 34,5 kPa.

f. The use of cleaning fluids and other chemicals that are detrimental to the performance of titanium or titanium alloy parts shall not come in contact with these metals.

4.2.6 Steels

a. All high-strength heat treated parts which are acid cleaned, plated or exposed to other hydrogen-producing processes shall be subjected to a baking process.

NOTE High-strength heat treated parts are > 1225 MPa UTS.

b. Tempers of precipitation hardening steels that are susceptible to stress corrosion and hydrogen embrittlement shall not be used.

c. Designs using precipitation hardening steels shall ensure the following:

1. controlled processing procedures are used, and
2. processing and procurement records are maintained for the reference.

4.2.7 Stainless steels

a. Unstabilized austenitic steels shall not be used at temperatures above 370 °C.

b. When using 400-series stainless steels the risk for hydrogen embrittlement, corrosion and stress corrosion cracking shall be controlled.

4.2.8 Filler metals: welding, brazing, soldering

a. The selection of alloys to be welded and the selection of process techniques shall be in conformance with national or international aerospace specifications and standards.

b. The fusion zone and the unmelted heat affected zone of a weld shall be accessible for inspection.

c. All welds used for structural applications shall undergo 100 % radiographic inspection in conformance with approved specifications.

d. All welds used for structural applications shall undergo a NDI program that shall be submitted for customer approval.

NOTE ECSS-E-ST-32-01 contains additional Requirements specific to welds used for Potential Fracture Critical Items applications.

e. The suitability of the equipment, processes, welding supplies and supplementary treatments selected by the supplier shall be demonstrated through qualification testing of welded specimens representing the materials and joint configuration of production parts.

f. The selection of brazing alloys and brazing techniques shall be in conformance with national or international aerospace specifications and standards.

g. Design shall include the effect of the brazing process on the strength of the parent metal.

NOTE Base metal is the example of the parent metal.

h. Subsequent fusion welding in the vicinity of brazed or soldered joints or other operations with high temperatures that affect the brazed or soldered joint shall not be performed.

i. Soldered joints shall not be used for structural applications .

j. Solders, process materials and procedures for electrical and electronic assembly shall conform to the requirements from clause 5 to clause 15 of ECSS-Q-ST-70-08 and from clause 5 to clause 16 of ECSS-Q-ST-70-38.

4.2.9 Miscellaneous metallic materials

a. The supplier shall demonstrate that the selected Magnesium alloys are protected against corrosion effects with respect to the applicable environment.

b. Hazards related to Magnesium alloys flammability during manufacturing shall be prevented.

c. The supplier shall demonstrate that the selected Magnesium alloys are used in applications where risks of ignition are prevented.

NOTE Examples of risk areas are those subjected to wear, abuse, foreign object damage, abrasion, erosion or at any location where fluid or moisture entrapment is possible.

d. Alloys containing Beryllium higher than 4 % by weight shall not be used.

e. The design of parts made of beryllium alloys shall include the material's low impact resistance, notch sensitivity, its anisotropy and sensitivity to surface finish requirements.

f. The application of refractory alloys shall be subjected to approval by the customer.

NOTE Limited amount of data for structural assessment are available on these materials.

g. Silver and osmium coatings shall not be used on external surfaces of space systems exposed to atomic oxygen in low Earth orbit.

h. Platings with open porosity shall be sealed.

i. The selection of a superalloy for a given application shall be based on tests of the material in simulated in-service environments.

j. Foreign material which contains sulphur shall be removed from superalloys prior to heat treatment or high-temperature service.

NOTE Examples of materials that can contain sulphur are: oils, grease and cutting lubricants

k. The effect of alloying element depletion in superalloys at the surface in a high-temperature oxidizing environment shall be evaluated when sheet is used.

4.2.10 Optical materials

a. The supplier shall demonstrate that the performances of the selected optical glasses or coatings are not degraded below the acceptable levels by ionizing radiation, particle, UV radiation and ATOX for the intended application.

b. Use of glasses for the structural applications shall be in conformance with requirements 4.2.21a, 4.2.21b and 4.2.21c.

c. The use of organic glasses shall assess radiation resistance aspects.

d. An assembly incorporating optical materials shall account for the difference in thermal expansion coefficients between the optical material and its mounting.

4.2.11 Adhesives, coatings, varnishes

a. The surfaces on which the adhesives, coatings or varnishes are applied shall be clean and dry prior to their application.

b. Structural adhesive bonds in honeycomb panels shall attach the facings rigidly to the core to allow loads to be transmitted from one face to another.

c. Adhesives, coatings and varnishes shall be physically and chemically compatible with the component parts of the finished assembly.

NOTE This includes for example the adherends for adhesives, substrates and any other parts, such as materials used in the insulation or bodies of electronic components for coatings.

d. Adhesives, coatings and varnishes shall be capable of accommodating dimensional changes resulting from temperature excursions without causing damage to the adhesive bond, or to other parts of the assembly.

NOTE Electronic PCBs are example of other parts of the assembly

e. The supplier shall demonstrate that the mismatch of thermal expansion coefficients between adherends and adhesive or between substrates and coatings is within the design requirements.

f. When acceptability of the mismatch of thermal expansion coefficients between adherends and adhesive is verified by test, the relevant procedure shall conform to the requirements of clause 5 of ECSS-Q-ST-70-04.

g. When acceptability of the mismatch of thermal expansion coefficients between substrates and coatings is verified by test, the relevant procedure shall conform to the requirements of clause 5 of ECSS-Q-ST-70-04.

h. Applications of thick coatings that can result in damage to the coated items shall be evaluated by testing.

NOTE Resulting damage can be for example: high residual stresses, high temperatures during cure.

i. The selection of alkyd-, polyester- or polysulphide-type coatings shall not be used.

j. Any compound that contains or releases corrosive media that can attack adjacent parts of the assembly shall be evaluated for its potential risk.

NOTE Examples of corrosive media are: acetic acid, ammonia, amines, hydrochloric and other acids.

k. The supplier shall verify that the curing is efficient in the whole surface of the bonded area when adhesives need atmospheric moisture as part of the curing process.

NOTE This verification is even more important in case of non-porous or large surfaces.

l. The supplier shall demonstrate that solvents contained in coatings and varnishes have been removed prior to curing.

NOTE Thinner is example of solvent.

m. Adhesives, coatings and varnishes that are sensitive to moisture contamination shall only be used in controlled-humidity environments.

n. Where void free application is used on coatings and varnishes the supplier shall apply a debubbling process, defined in a dedicated procedure in conformance with Annex E from the ECSS-Q-ST-20.

4.2.12 Adhesive tapes

a. Tapes containing polyvinylchloride shall not be used in space segment elements or ground segment equipment undergoing vacuum.

b. All release agents present on the surface of tapes shall be removed.

c. The adherent surface or surfaces on which the tape is applied shall be clean and dry prior to its application.

d. When an adhesive tape is applied to painted surfaces, the supplier shall verify that the paint is not degraded when the adhesive tape is removed.

e. An even pressure shall be used on the tape during its application.

f. Controls shall be performed to ensure that the tape is not damaged during its application.

g. Perforated tapes should be used to enable the correct evacuation of trapped air bubbles underneath the adhesive tape.

h. When perforated tapes are not used, the process of tape application and removal of bubbles shall be documented.

i. The exposure to the space environment shall not impair the function of the tape.

j. Surfaces that have had tapes removed for reworking or for temporary reasons shall be cleaned after the tape is removed.

k. Removed tapes shall not be reused.

NOTE Adhesives, in particular silicone ones, can leave a residue which prevents adhesion of other systems onto that surface.

l. The supplier shall demonstrate that the selected Velcro-type tape does not release hooks or felt during assembly or disassembly.

m. Conductive adhesive tapes shall be tested to ensure that the specified conductivity and adhesion are maintained at temperature extremes.

4.2.13 Paints and inks

a. The surfaces on which paints or inks are applied shall be clean and dry prior to their application.

b. Contamination of painted surfaces shall be prevented.

NOTE For non-moisture curing paints, environmental control applies

c. Painted surfaces shall be protected from mechanical damage.

NOTE Examples of mechanical damage: scratches and chips

d. Electrical properties of paints shall comply with the requirements from the Clause 6 of ECSS-E-ST-20-06.

NOTE The requirements to be compliant with, are relevant to Surface Materials.

4.2.14 Lubricants

a. The selection of the lubricant shall avoid the contamination of the lubricated part.

b. Lubricants shall only be applied to clean surfaces.

c. Lubricated items shall be protected from contamination.

NOTE Examples of contamination are: dust and dirt.

d. When oils and greases are directly exposed to space environment, the supplier shall demonstrate that the selected grade complies with the mission requirements.

e. Graphite alone shall not be used as lubricant under vacuum.

NOTE Under vacuum conditions graphite is not a lubricant but an abrasive. It can be used in combination with other lubricating materials such as silver or MoS_2.

f. The long-term performance of lubricants shall be assessed during their selection for long-term deployed systems.

g. Lubricants containing chloro-fluoro compositions shall not be used with aluminium or magnesium if shear stresses are imposed.

4.2.15 Potting compounds, sealants, foams

a. Polysulphide potting material shall not be used.

b. Non-metallic foams with an open-cell structure shall not be used.

NOTE Open-cell foams are difficult to keep clean

c. The supplier shall assess the effect of shrinkage or the production of exothermic temperatures during curing before use.

d. Surface treatments shall be used in conformance with approved process procedures on components and assemblies to ensure adhesion between the component and the potting compound or sealant.

NOTE Examples of surface treatments: etching and priming

e. The supplier shall assess if pre-coating shall be used to ensure proper adhesion between the part and the potting compound or sealant and reduce residual stresses created during curing.

f. Where void free potting application is used, the supplier shall apply a debubbling process, defined in a dedicated procedure in conformance with Annex E from the ECSS-Q-ST-20.

g. Foams with fully closed-cell structure shall not be debubbled.

h. All filler materials used in potting compounds shall be dry, as defined by the supplier in a dedicated specification.

i. The supplier shall demonstrate that the cure procedures are performed such that the temperatures and pressures created during curing process do not damage the potting compound or the parts being potted.

j. All potting, coating and sealing materials used successively shall be evaluated for compatibility.

NOTE Some chemical or atmospheric constituents can affect those of another material.

k. Catalysts and hardeners shall be evaluated for their compatibility with any metals present in the assembly.

4.2.16 Reinforced plastics including PCBs

a. The design and verification of fibre-reinforced composite materials used for structural applications shall conform to the requirements from clause 4 of ECSS-E-ST-32-08.

b. Composite materials made with polyester containing styrene shall not be used.

c. The individual stages of all processing of reinforced plastics shall be controlled and monitored in conformance with approved quality control and inspection procedures.

NOTE These can include, for example, correct lay-up of plies, no or low void content, absence of defects, absence of contamination, results of test coupons and non-destructive evaluation.

d. Natural reinforcing materials shall not be used for electronic composite laminates.

NOTE 1 Cotton and paper are examples of natural reinforcing materials

NOTE 2 PCBs are example of electronic composite laminates

e. Qualification of electronic PCBs shall conform to the requirements from clause 5 to clause 9 of ECSS-Q-ST-70-10.

f. Procurement of electronic PCBs shall be in conformance with requirements from clause 5 to clause 7 of ECSS-Q-ST-70-11.

4.2.17 Rubbers and elastomers

a. Designs using rubber and elastomeric materials shall be evaluated for:

1. "set" under stress,
2. effects of cyclic stress,
3. environmental resistance, and
4. chemical resistance.

b. Polysulphide materials shall not be used in the space environment.

c. Chlorinated materials shall not be used in space environments.

d. Silicone materials shall not be used in pressurized systems requiring low gas permeability.

e. Rubbers and elastomers containing plasticisers or extending oils shall not be used under vacuum.

f. The leaching of filler materials shall be evaluated with respect to their potential hazard to associated equipment.

g. Material depolymerization due to vacuum exposure shall be evaluated.

h. Rubbers or elastomers releasing corrosive media shall be evaluated for its potential risk.

i. Materials that liberate acetic acid shall be evaluated before use.

j. Rubbers and elastomers used in long-term, manned structures shall be evaluated for their long-term resistance to the following:

1. ageing,
2. low temperature,
3. ozone,
4. heat-ageing,
5. polymer reversion,

6. working fluids,
7. lubricants and operating media and,
8. any application- or mission-specific requirements.

k. The cure date of rubbers and elastomers shall be recorded.

l. The cured date of rubbers and elastomers should be indicated on the part.

m. For rubbers and elastomers, environmental exposure shall be assessed.

NOTE Examples of environmental exposure are: flammability requirements, electrical requirements, normal use temperature, abnormal use temperature excursions, chemical exposure and humidity levels.

4.2.18 Thermoplastics

a. Structural designs using thermoplastic composite materials shall conform to the requirements of clause 4 of ECSS-E-ST-32-08

b. For polymer-based materials, a clear definition of all the design constraints shall be established.

NOTE 1 Examples of polymer-based materials are thermosetting and thermoplastic.

NOTE 2 Examples of design constraints are: short-term loading, long-term loading, cyclic loading, impact loading, design life and critical dimensional tolerances.

c. Thermoplastics shall be evaluated for the effects of service conditions.

d. A structural design analysis shall be performed on all parts incorporating polymer-based materials, including the visco-elastic nature of the chosen material.

e. For polymer-based materials prototypes shall be produced and tested to qualify the design.

NOTE Examples of polymer-based materials are thermosetting and thermoplastic.

f. For polymer-based materials, environmental exposure shall be assessed.

NOTE Examples of environmental exposure are: flammability requirements, electrical requirements, normal use temperature, abnormal use temperature excursions, chemical exposure and humidity levels.

g. The supplier shall demonstrate that the anisotropic characteristics of plastic films are assessed during design.

h. The supplier shall demonstrate how the processing methods of thermoplastics accounts for their softening temperature.

i. PTFE shall not be used in applications requiring creep resistance.

j. Thermoplastics that retain residual stresses after processing shall be subject to an approved thermal stress-relief process.

k. The release of additives in plastics under vacuum shall be evaluated for their effect on the material performance and contamination risk.

l. Materials that absorb and release water shall be evaluated with respect to the effect on the performance of the material and for contamination risk.

m. Cellulose and acetate materials in the form of films shall not be used in space applications.

n. Polyamide films shall be evaluated for moisture-related effects.

o. Polyvinyl acetate shall not be used in space applications.

p. Polyvinyl butyrate shall not be used in space applications.

q. Multi-layer systems shall be vented to eliminate internal overpressure.

r. Multi-layer systems shall be baked to an approved process prior to integration into the space segment elements.

4.2.19 Thermoset plastics or PCBs

a. Structural design of components using thermosetting resins shall conform to the requirements of clause 4 of ECSS-E-ST-32-08.

NOTE Examples of thermoset plastics are fibre reinforced composites.

b. Thermosetting plastics shall be evaluated for the effects of service conditions.

c. Curing processes shall be evaluated by means of a preliminary test programme using thermal-analysis equipment.

d. Resins used in PCBs for space hardware shall be qualified in conformance with requirements from clause 5 to clause 9 of ECSS-Q-ST-70-10.

e. Polyester resins shall not be used for space applications.

4.2.20 Material aspects of wires and cables

a. General requirements for wires and cables shall be in conformance with requirements from ESCC Generic Specifications 3901, 3902 and 3903.

b. Electrical wires and cables shall be procured in conformance with the requirements of ESCC Generic Specification 3901.

NOTE Electrical wires and cables are 600 V, low frequency.

c. Coaxial, radiofrequency, flexible cables shall be procured in conformance with the requirements ESCC Generic specification 3902.

d. The materials for coaxial cable assembly shall be selected in conformance with requirements from clause 5 of ECSS-Q-ST-70-18.

e. For wires with insulating material made of PTFE or other non-treated fluorocarbons, the supplier shall demonstrate that workmanship avoids cold flow.

NOTE 1 Examples of good practices are controlled bend radii, no contact with sharp objects, wire fixation rules.

NOTE 2 The use of irradiated ETFE-Ethylenetetrafluroethylene (TEFZEL) wires with improved characteristics against cold flow is preferred.

4.2.21 Ceramics and other non-metallic materials

a. Ceramics and glasses, except as fibres, shall not be used in a structural applications without the prior approval of the customer.

b. Engineering data used to justify the selection and demonstrate the strength of ceramics and glasses for structural uses shall be subject to review and approval by the customer.

c. All applications using composite materials based on ceramic, carbon and glass compositions shall be reviewed and approved by the customer.

d. Products containing asbestos shall not be used.

4.3 Process requirements

4.3.1 Adhesive bonding

a. The supplier shall demonstrate the ability to reproduce the required bonding quality

b. Process conditions and environments shall be specified and controlled during all stages of adhesive bonding.

NOTE Adhesive bonding stages include preparation, application, curing or drying, inspection or testing and storage.

c. Surfaces to be bonded shall be cleaned and prepared by a surface treatment process.

NOTE Examples of treatment process are abrasion or chemical etching, release film or peel ply removed before bonding.

d. Prepared surfaces shall be protected from contaminants.

e. Prepared surfaces shall be stored in controlled environment.

f. During the bonding process, the adhesive cure cycle shall be controlled.

NOTE For guidelines on structural adhesive bonding see ECSS-E-HB-32-21.

g. The supplier shall demonstrate that the bonded primary structural joints show cohesive failure modes in shear testing.

NOTE 1 Good toughness and peel strength are applicable characteristics for structural adhesives.

NOTE 2 An insert system consists of a removable threaded fastener and a fixture that is embedded into the honeycomb structure using a potting compound. The general processing steps for installing inserts include:

- machining the honeycomb panel, normally using specific tools
- potting the insert
- curing the potting material.

NOTE 3 For guidelines on the use of inserts see ECSS-E-HB-32-22.

4.3.2 Composite manufacture

a. Process conditions and environments shall be specified and controlled during all stages of composite manufacture.

NOTE 1 Manufacturing stages include for example: storage or de-storage and handling of raw materials, preparation, application, curing, machining, inspection or testing and storage of finished parts.

NOTE 2 See ECSS-E-HB-32-20 for information on composite manufacture.

b. Tooling materials shall be selected to ensure thermal-expansion matching between the composite over the processing temperatures.

NOTE The rigidity of the tooling is also an important parameter.

4.3.3 Encapsulation and moulding and varnishing

a. Process conditions and environments shall be specified and controlled during all stages of encapsulation, moulding and varnishing.

NOTE Stages of encapsulation moulding and varnishing include for example preparation, application, curing or drying, inspection or testing and storage.

b. In electronic assemblies, when potting is used for encapsulation it shall allow rework or repair.

c. In electronic assemblies conformal coating shall be used on populated boards.

4.3.4 Painting and coating

a. Processes developed for all types of paints shall be implemented and controlled in conformance with requirements from clause 4 of ECSS-Q-ST-70-31.

b. Process conditions and environments shall be specified and controlled during all stages of painting, coating.

NOTE Stages of painting, coating include for example preparation, application, curing or drying, inspection or testing and storage.

c. Pre-treatment processes for the surfaces to be painted shall be selected and controlled to ensure adhesion of the paint to the substrate.

NOTE Pre-treatment processes include for example cleaning, abrasion and priming.

4.3.5 Cleaning

a. All cleaning agents and processes shall be included in the cleaning associated procedures referenced in the DPL in conformance with DRD from the Annex C of the ECSS-Q-ST-70.

b. Selection and use of solvents shall be controlled to ensure that they do not degrade the base material or that of adjacent parts.

NOTE For example, polymer materials adjacent to metals.

c. Cleaning processes shall not degrade the base material, any applied surface coating or finishes, or adjacent parts.

NOTE 1 Surface coatings include for example paint and varnish

NOTE 2 Labels can also be damaged by cleaning.

NOTE 3 Cleaning processes including for example submerging in solvent baths and use of ultrasonic cleaning can induce damage.

d. Cleaning processes shall be used to remove all chemical residues produced during manufacture and assembly.

NOTE This include for example cutting oils and dye-penetrants.

4.3.6 Welding and brazing

a. Selection of welding techniques used in aerospace engineering shall be performed on the base of assessment of the following:

1. parent metals to be joined,
2. effect of the welding process on material properties in the fusion zone, heat affected zone and parent metal,
3. filler material.

NOTE In the aerospace industry the following welding techniques are used:

- tungsten inert gas (TIG);
- metal inert gas (MIG);
- plasma-arc welding;
- electron beam welding (EB);
- resistance welding (induction, spot, seam);
- diffusion welding;
- laser welding; and
- friction stir welding.

b. The selection of alloys to be welded and the selection of process techniques shall be in conformance with national or international aerospace specifications and standards.

c. Welding processes shall be selected to provide:

1. the weld quality specified in the selected standard,
2. the minimum weld energy input, and
3. protection from contamination.

d. The suitability of the equipment, the welding process documentation including process variants, the filler material and any supplementary treatments shall be demonstrated through qualification testing of welded specimens representing the materials and the joint configuration of production parts.

e. Each operator shall be trained and certified along with the applicable welding equipment and related procedure for specific welding tasks.

f. In long-term, manned structures, alloyed titanium shall be welded using alloy weld filler wire and not commercially pure filler wire.

g. Welded assemblies of corrosion resistant steels shall be heat treated after welding, except for stabilized steels or low carbon grades.

h. Equipment and procedures used for welding shall be certified for their capability to produce welds and weld repairs.

i. The weld repair process and inspection shall be performed only under nonconformance review board approval.

j. The weld repair process and inspection shall be qualified to the same level of assurance as the primary process specification drawing requirement using the same inspection technique that found the original defect and by all other methods of examination that were originally specified for the affected part.

k. The result weld repair process qualification and inspection shall be subject to review by the customer.

l. Brazing processes shall be evaluated regarding the effect on the parent metal.

m. The supplier shall demonstrate that in case the subsequent fusion welding is applied, it is not affecting any brazed joints in the vicinity.

n. Brazing operations shall be carried out by trained operators, working with documented and approved brazing procedures.

4.3.7 Crimping and stripping and wire wrapping

a. Fabrication processes and controls used in crimping of electrical terminations, terminal lugs, splices and two-piece shield termination rings shall conform to the requirements from clause 5 of ECSS-Q-ST-70-26.

b. Fabrication processes and controls used in wire wrapped electrical connections shall conform to the requirements from the clause 5 of ECSS-Q-ST-70-30.

4.3.8 Soldering

a. Soldered joints shall not be used for structural applications without the prior approval of the customer.

b. Fabrication processes and controls used in soldering of electrical connections shall conform to the requirements from clause 5 of ECSS-Q-ST-70-07, from clause 5 to clause 15 of ECSS-Q-ST-70-08 and from clause 5 to clause 16 of ECSS-Q-ST-70-38.

c. Repair processes and controls used in soldering of electrical connections shall conform to the requirements of clause 5 of ECSS-Q-ST-70-28.

d. The supplier shall demonstrate that when subsequent fusion welding or brazing is applied, it is not affecting any soldered joints in the vicinity.

4.3.9 Surface treatments

4.3.9.1 General

a. All surface treatments process specifications shall include the qualified thickness range.

b. Processes and materials shall not degrade the substrate and result in loss of performance or integrity.

c. The supplier shall demonstrate that the surface is free from defects and it is not stained or discoloured.

d. CTE mismatches between coatings and substrates shall be assessed.

NOTE 1 Surfaces of materials are often treated for the following reasons:

- To improve properties, e.g. nitriding, carburising and shot-peening.
- To increase resistance to an environment, e.g. corrosion, moisture- and diffusion barriers, high-temperature and ATOX.
- To provide particular characteristics, e.g. thermo-optical properties.

NOTE 2 Some surface treatments are also included in other processes, for example preparation prior to painting and adhesive bonding to improve adhesion. These can include a proprietary "chemical" process such as anodizing or alodining or the application of a primer.

4.3.9.2 Anodizing

a. The supplier shall demonstrate that when anodizing processes are applied to thin foils, the perforation is prevented.

b. The supplier shall demonstrate that when anodizing processes are applied to thin foils the complete removal of process chemicals in complex parts is ensured.

NOTE Thin foils include for example honeycomb cores

c. Anodized layers shall be sealed and be continuous when used as the final surface finish of a part.

d. Anodized surfaces for pre-treatment of painting shall not be sealed.

e. Process conditions shall be implemented and controlled.

NOTE 1 Process conditions include for example bath constituents, temperature and time

NOTE 2 Anodizing is an electrolytic process for thickening and stabilizing the inherent oxide films on metal substrates. Anodizing is widely used on aluminium alloys and can be applied to magnesium and titanium. The anodized layer is electrically non-conductive.

NOTE 3 Not all grades of an alloy can be anodized successfully.

NOTE 4 Depending on the precise process, anodizing can produce:

- hard anodized wear resistant and durable surfaces;
- coloured surfaces (either functional or decorative), e.g. black for optical properties;
- pre-treatment process prior to adhesive bonding or painting.

NOTE 5 Specifications for aerospace anodizing processes are available (often of American origin), but bath constituents and process conditions tend to vary between organizations.

4.3.9.3 Chemical conversion

a. Chemical conversion layers shall be continuous when used as the final surface finish of a part.

b. Control of process conditions shall be implemented and controlled.

NOTE 1 Process conditions include for example bath constituents, temperature and time.

NOTE 2 Chemical conversion processes involve the absorption of a protective metal oxide film into an existing oxide film. The resulting surface finish can be electrically conductive or non-conductive.

NOTE 3 Non-metal oxide films may sometimes be used.

NOTE 4 Chemical conversion processes include:

- Chromating (mixed metal-chromium oxide film), providing good corrosion resistance and pre-treatment for subsequently applied organic coatings. For example, alodine and iridite are non-electrolytic, immersion-type processes that are used on aluminium surfaces. These coatings have a thickness of less than 1 µm and are electrically conductive.
- Phosphating, used as a pre-treatment prior to painting on ferrous materials.

4.3.10 Plating

a. Process conditions and environments shall be specified and controlled during all stages of plating.

NOTE Plating stages include for example preparation, application, inspection or testing, and storage.

b. Platings with open porosity shall not be used.

NOTE 1 Porous platings fail to provide adequate corrosion protection and can act as sources of contamination.

NOTE 2 Plated layers of less than 1 µm thickness tend to be porous.

c. An approved post-plating baking process shall be applied to materials with known or suspected susceptibility to hydrogen embrittlement.

d. Plating of terminals used in electronic assemblies, shall satisfy the requirements from clause 5 to clause 15 of ECSS-Q-ST-70-08.

e. In electronic assemblies, processes used for the removal of gold plating shall satisfy the requirements from clause 7.2.3.2 of ECSS-Q-ST-70-08.

f. All platings shall be blister tested by baking during a minimum of 30 minutes at a maximum temperature seen in production or qualification phases.

4.3.11 Machining

a. Machining shall not be performed on martensitic steel hardened to ≥1225 MPa UTS.

NOTE 1 Machining include for example drilling or grinding.

NOTE 2 Numerous different machining operations are used for aerospace materials. International or national aerospace standards and specifications are normally applied.

NOTE 3 Special tools and processes are applied to the machining of composites (laminates and honeycomb panels) to prevent damage to the materials (e.g. delamination, break-out on the backface and distortion of the core) that degrade the material integrity.

NOTE 4 For guidelines on machining composites, see ECSS-E-HB-32-20.

b. When machining is not avoided, carbide-tipped tooling and other techniques necessary to avoid formation of untempered martensite shall be used.

c. The use of EDM machining processes may lead to the formation of re-cast layer on the materials surfaces that has detrimental effects on the fatigue performances.

d. The consequences of the effects specified in the requirement 4.3.11c shall be assessed and reflected in any machining specification.

e. Safety equipment shall be provided for operators processing beryllium and beryllium-copper alloys.

f. The collection and disposal of dust and debris produced during the processing of beryllium and beryllium-copper alloys shall conform to national or international specifications.

4.3.12 Forming

4.3.12.1 Overview

Although forming processes are applied to metallic-, polymer-based and ceramic-type materials, this applies only to metal forming. Metal forming processes generally form two main groups:

- "Warm" or "hot": rolling, forming, various forging techniques.
- "Cold":
  - primary forming by various sheet metal techniques, e.g. deep drawing and bending, or
  - finishing operations, e.g. cold forging and cold rolling.

Specialized techniques used in the manufacture of certain spacecraft parts include:

- superplastic forming, e.g. panel sections and tanks;
- "gatorising": forging with superplastic materials, e.g. integral turbine blades or discs;
- explosive forming, e.g. tanks and sections.

Process selection is influenced by the material to be formed, its specific composition and mechanical properties plus the requirements of the finished formed part, e.g. shape, size, strength and appearance.

4.3.12.2 Forging

a. Forging techniques shall be used that produce an internal grain-flow pattern such that the direction of flow is parallel to principal stresses.

b. Evaluation of flow patterns, including test data shall be submitted as part of the approval procedure for forged components.

NOTE The mechanical properties are optimum in the direction of material flow during forging.

4.3.12.3 Sheet metal forming

a. Forming processes shall respect the minimum bend radii for the specific alloy and condition.

NOTE Example of condition is heat-treatment or temper

b. Annealing processes shall be selected to avoid degradation of the material.

c. Hot forming temperatures and soak times shall be selected to avoid segregation effects at grain boundaries or liquation of low melting point alloy constituents, either during heating the material or as a result of localized "over-heating" during forming.

NOTE 1 All forming processes for sheet metals involve plastic deformation of the material. Processing techniques are either conducted "cold", or "warm or hot".

NOTE 2 The amount of deformation possible without fracture is linked to the material ductility.

d. For materials which harden as a result of cold working normally, an annealing process shall be applied to achieve the final shape without cracking or fracture.

NOTE 1 High-strength materials are difficult to form to complex shapes by cold forming, and can be done "warm or hot".

NOTE 2 Forming is often followed by a final heat-treatment to restore the mechanical properties of the finished part.

4.3.12.4 Superplastic forming

a. Superplastic forming processes shall only be applied to specific grades of materials designed to behave superplastically:

1. microstructure: 1 μm to 5 μm grain size and stable at process temperature,
2. plastic deformation in the range of 100 % to 1500 % typically, without fracture,
3. heated to at least 50 % of the melting temperature (in K),
4. relatively low forming stresses,
5. low deformation rate.

NOTE 1 Commercial superplastic alloys include those based on aluminium, titanium, copper, nickel, stainless- and carbonsteels.

NOTE 2 Depending on the metal alloy, super plastic forming can be combined with diffusion bonding to create finished parts, such as struts, cylinders and integrally stiffened panels.

NOTE 3 See ECSS-E-HB-32-20 for superplastic forming processes.

4.3.12.5 Explosive forming

a. Safety procedures shall be applied for the storage and handling of explosives.

NOTE 1 Explosive forming is a rapid process for producing small quantities of large, fairly simply-shaped parts. It is applied to materials retaining acceptable ductility at high plastic deformation rates.

NOTE 2 Explosive forming is also used as a cladding process and for joining dissimilar metals that cannot be joined effectively by any other means.

4.3.13 Heat treatment

a. Heat treatment of metals and alloys shall conform to national or international specifications for aerospace applications.

b. Heat treatment procedures that are not included in any national or international specifications shall be approved by the customer prior to their use.

c. Processes shall be selected and controlled to avoid the dezincification of brasses.

4.3.14 Marking

a. Marking of spacecraft piece parts for identification purposes shall not result in the degradation of any mechanical or surface characteristics.

b. Solvents in inks shall not attack substrates.

c. Inks shall have outgassing properties in conformance with the requirements from clause 5 of ECSS-Q-ST-70-02.

d. Engraving of painted, plated or coated parts shall not be performed.

e. Stamping resulting in stress-raisers shall not be performed.

4.3.15 Miscellaneous processes

4.3.15.1 Overview

Bolts offer the greatest strength for mechanical fastened joints, providing that they are not over-tightened and no damage occurs during assembly. For guidelines on the design of bolted joints, see ECSS-E-HB-32-23.

Riveted joints are permanent and are normally sealed against the environment. Disassembly can only be done by drilling out the rivets. Consequently, riveted joints cannot be used where access is used, or expected, to internal or adjacent parts of the structure. For guidelines on riveted joints in composites, see ECSS-E-HB-32-20.

4.3.15.2 Casting

a. Quality control and inspection procedures of all process related factors influencing the performance and integrity of castings shall be implemented and controlled to all of them.

NOTE Process-related factors influencing the performance and integrity of castings include for example gas bubbles, inclusions and porosity, shrinkage.

4.3.15.3 Rigid, flexible and rigid-flex printed circuit boards

a. Procurement and qualification of rigid, flexible and rigid-flex printed circuit boards used for fabrication processes and controls shall conform

to the requirements from clause 5 to clause 9 of ECSS-Q-ST-70-10 and from clause 5 to clause 7 of ECSS-Q-ST-70-11.

4.3.15.4 Printed circuit assemblies

a. Fabrication processes and controls used in staking and conformal coating of printed circuit boards and electronic assemblies shall conform to the requirements of from clause 5 to clause 15 of ECSS-Q-ST-70-08, from clause 5 of ECSS-Q-ST-70-07 and from clause 5 to clause 16 of ECSS-Q-ST-70-38.

b. The repair and modification of printed circuit boards assemblies shall conform to the requirements from clause 4 of ECSS-Q-ST-70-28.

4.3.15.5 Wire and cable assemblies

a. The processes to be used for coaxial cable assembly shall be selected in conformance with clause 5 of ECSS-Q-ST-70-18.

NOTE Silver-plated copper strands are the preferred conductors. These are suitable for soldering and crimping.

The general requirements for wires and cables assemblies are described by the ESCC standards.

b. If Nickel plated copper strands are used the supplier shall demonstrate that solderability after ageing is as described by the generic specification.

NOTE Nickel is magnetic and cannot be used for all applications.

c. Tin-plated finishes electroplated other than pure tin-coated wires shall be either re-flowed or excluded.

d. Silver-plated wires shall be procured in conformance with requirements from the ESCC Generic Specification 3901.

e. The individual wire specification of silver-plated wires should be consulted for other requirements such as accelerated ageing, cut-through resistance and flammability.

f. The following shall be assembled or installed in conformance with the requirements from clause 5 to clause 15 of ECSS-Q-ST-70-08:

1. electrical connectors;
2. interconnecting cables, harness and wiring;
3. solder splice.

g. Solder sleeves shall not be used in flight hardware due to their retention of solder flux and inspection difficulties.

4.3.15.6 Fibre optic assemblies

a. Fabrication processes and controls shall be established for terminations, joining fibre optic cable assemblies and their installation and submitted to the customer for approval.

NOTE ECSS-Q-TM-70-51 contains guidelines referring to the assembly of fibre optic.

4.3.16 Inspection procedures

a. All NDI processes shall be selected according to aerospace national or international standards suitable for the intended use of the hardware to be inspected, and be submitted to the customer for customer approval.

NOTE Many different inspection procedures are employed for spacecraft materials and processes are numerous and varied. They are used at all stages of the manufacturing process and form part of the overall quality assurance plan.

b. Inspection procedures shall contain the material, the part, the classification of defects and establish their acceptance and rejection criteria.

NOTE 1 The ability to inspect a part is a critical part of the design development.

NOTE 2 Some inspection procedures can be relatively straightforward, for example visual inspection by unaided eye; whereas others are complex and need equipment that is regularly maintained and calibrated to recognized, approved standards, for example eddy current and ultrasonic.

c. Acceptance and rejection criteria shall be defined according to aerospace national or international standards or qualification testing.

d. Inspection equipment shall be regularly maintained and calibrated in conformance with the clause 5.2.6 from ECSS-Q-ST-20.

Annex A (informative) Information about the European Space Materials Database (ESMDB)

A.1 Overview

European Space Materials Database (ESMDB) provides free distribution of knowledge in the field of Materials technologies via a shared database.

A dedicated Steering Board is created for the regular update of the ESMDB. This Board is in charge for selection and validation process of candidate materials and relevant tools. Material property data obtained from tests by material producers, government agencies, and members of the aerospace industry are submitted to ESMDB Steering board for review and analysis.

A.2 Database access

Database access is controlled by ESMDB Steering Board Chairman who is responsible for the username and password control.

A.3 Database structure

The database contains a version identifier and includes the following categories, sub-dived into detailed properties:

1. Product
   - (a) Material name
   - (b) Product datasheets
   - (c) Safety datasheets
   - (d) General information
   - (e) precautions
   - (f) chemical composition
   - (g) CAS registry ID
   - (h) manufacturer
2. Experience and availability
   - (a) development status

(b) cost range
(c) lot reproducibility
(d) equivalent designations
(e) space experience

3. General properties
   (a) atomic weight
   (b) crystal structure
   (c) magnetic properties
   (d) curie temperature
   (e) pot life
   (f) shelf life
4. Elastic properties
   (a) Tensile, shear, bulk modulus
   (b) poisson ratio
   (c) acoustic impedance
5. Mechanical properties
   (a) UTS
   (b) proof stress
   (c) shear strength
   (d) elongation
   (e) fatigue limit
   (f) KIc or KIscc
6. Electrical properties
7. Thermal properties
8. Properties relevant to space use
9. Fracture surface, microsections
10. Fluid system compatibility
11. Special recommendations
12. Criticality, obsolescence, regulations

A.4 Database quality ratings

The properties of the database can have associated the following quality ratings:

a. Design data
   1. These design properties are presented as A- and B- or S-basis room temperature values.

2. A- and B- or S-basis definitions are found in MMPDS.

b. Limited laboratory testing

1. These properties are obtained from a certified source.

c. Manufacturer's data

1. The name of the manufacturer is an important part of the property.

d. Typical data

1. A typical property value is an average value and has no statistical assurance associated with it.

Bibliography

ECSS-S-ST-00	ECSS system - Description, implementation and general requirements
ECSS-Q-ST-70	Space product assurance - Materials, mechanical parts and processes
ECSS-Q-ST-70-01	Space product assurance - Cleanliness and contamination and control
ECSS-Q-ST-70-06	Space product assurance - Particle and UV radiation testing of space materials
ECSS-Q-ST-70-20	Space product assurance - Determination of the susceptibility of silver-plated copper wire and cable to "red-plague" corrosion
ECSS-Q-ST-70-21	Space product assurance - Flammability testing for the screening of space materials
ECSS-Q-ST-70-22	Space product assurance - Control of limited shelf-life materials
ECSS-Q-ST-70-29	Space product assurance - Determination of offgassing products from materials and assembled articles to be used in a manned space vehicle crew compartment
ECSS-Q-ST-70-36	Space product assurance - Material selection for controlling stress-corrosion cracking
ECSS-Q-ST-70-37	Space product assurance - Determination of the susceptibility of metals to stress-corrosion cracking
ECSS-Q-TM-70-51	Space product assurance - Termination of optical fibres
ECSS-E-HB-32-20	Space engineering - Structural material handbook
ECSS-E-HB-32-21	Space engineering - Adhesive bonding handbook
ECSS-E-HB-32-22	Space engineering - Insert design handbook
ECSS-E-HB-32-23	Space engineering - Threaded fasteners handbook