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**Preservation, storage,
handling and transportation
of ESA spacecraft hardware**

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ABSTRACT

The purpose of this specification is to ensure that the physical integrity of ESA spacecraft hardware, including the absence of corrosion and contamination, is maintained throughout all storage, handling and transportation operations.

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1. SCOPE

The purpose of this specification is to ensure that the physical integrity of ESA spacecraft hardware, including the absence of corrosion and contamination, is maintained throughout all storage, handling and transportation operations.

2. GENERAL

2.1 INTRODUCTION

ESA spacecraft hardware and associated equipment hardware shall be handled, stored, packaged and transported in such a manner that all relevant precautions detailed in this specification are complied with.

2.1.1 Electrical Components

For components ordered to SCC specifications, the requirements of ESA/SCC Basic Specification No. 20600 shall apply. However, Tables 1-5 incl. contained within this specification form a useful supplement to the SCC document regarding handling, transportation, storage and other hazards/precautions.

2.1.2 Environmental Factors

The destructive environmental factors that are likely to adversely affect spacecraft during handling, storage, packing and transport are indicated in Table 1. An indication of the levels of acceleration and vibration during various transport modes is given in Table 2 and associated typical limits for equipment are listed in Table 3. However, for critical transport items, it is necessary to determine the safe maximum stress limits by test and/or analysis.

2.1.3 Applicability

These requirements are applicable to storage, handling and transport of flight-standard spacecraft hardware or any other hardware that may contribute to the acquisition of design qualification.

2.1.4 Critical Transport Items

Before handling and transportation of critical transport items the contractor shall prepare a plan for the operations, procedures, maximum stress level and transport equipment to be applied. Critical transport items are those which:

- (a) Exceed the dimensions of normal vehicles when in their transport configuration;
- (b) Exceed the weight-carrying capacity of normal vehicles;
- (c) Are fragile to the extent that any of the following are required:
 - Environmental control during transport or storage;
 - Monitoring and/or maintenance by technical escorts during movement;
 - Development of unique handling, or shock-absorbing techniques to accomplish delivery without damage to the item;
- (d) Are hazardous or dangerous in that:
 - A special permit is required before movement can take place;
 - Toxic or explosive fumes are produced;
 - They contain a rocket motor in an active state;
 - They contain pressurised vessels.

2.2 SAFETY PRECAUTIONS/HAZARDS

The conditions for safety precautions are defined in document ESA PSS-01-40. Particular attention shall be paid to critical transport items, which may contain the following hazards:

- Constituents that produce toxic or explosive fumes;
 - Rocket motors in an active state;
 - Pressurised vessels;
 - Radiating material.
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2.3 IDENTIFICATION OF PACKAGES AND CONTAINERS

The marking and labelling shall include, but not be limited to, details of the following:

- (a) The inner protective bag, wrapping or container shall carry as a minimum the following information:
 - Nomenclature and item number;
 - Serial number;
 - Applicable caution/warning notes;
 - Inspection verification of contents;
 - Expiry date (limited-life items).
- (b) All subsequent protection shall duplicate the above information as required, e.g.:
 - Orientation;
 - Conditions to be established before unpacking;
 - Unpacking instructions (or their location);
 - Lid or other access securing devices;
 - Location of travel documents;
 - Warning of dangerous or toxic contents;
 - Weight and centre of gravity.
- (c) In addition, the words "SPACECRAFT HARDWARE" or "HIGH-REL COMPONENTS" as appropriate and their equivalent in the languages of the items' final destination shall be displayed on all normally visible faces of the outer container.

2.4 DOCUMENTS

2.4.1 Related documents

The following documents are directly related to this specification. The applicability of these documents is defined in the contract.

ESA PSS-01-10	Product Assurance Management and Audit Systems for ESA Spacecraft and Associated Equipment;
ESA PSS-01-20	Quality Assurance of ESA Spacecraft and Associated Equipment;
ESA PSS-01-40	Safety Assurance of ESA Spacecraft and Associated Equipment;
ESA PSS-01-50	Maintainability and Availability Assurance for ESA Spacecraft and Associated Equipment;
ESA PSS-01-70	Material and Process Selection and Quality Control for ESA Spacecraft and Associated Equipment;
ESA PSS-01-201	Contamination and Cleanliness Control;
ESA PSS-01-722	The Control of Limited-Life Materials.

2.4.2 Referenced Documents

For **information purposes only**, Annex 'A' lists other documents which may be used to supplement the text of this specification.

3. DETAILS

3.1 STORAGE CONTROL

The contractor shall provide and control secure storage areas for items that are not in work. Storage areas shall be clearly marked "SPACECRAFT HARDWARE", have adequate areas for receiving, inventory and issue of stored items and be provided with documented operation procedures for the control and implementation of all storage functions. Controls shall be maintained over the acceptance into and withdrawal from the storage area; this shall include access limited to authorised personnel only. Records shall be maintained to provide traceability for all items within the storage area. These records shall include identification, location, date of receipt, storage life and conditions and details of any maintenance, tests or inspections required during storage. The records shall be employed to control the use of materials and ensure that the older materials in stock are used before new supplies.

Limited-Life materials, suspended limited-life materials, non-conforming items awaiting MRB disposition, components, test samples, data etc., and all other items which require to be stored separately for health or safety reasons shall be placed in segregated areas within the storage area. Each segregated area within the stores shall be clearly identified and labelled. The document ESA PSS-01-722 defines the controls for limited-life items.

Items shall be stored in such a manner as to preclude stress and prevent damage to their preservative treatment or protection. Provision shall be made for the prevention of deterioration of items whilst in storage through the maintenance and control of environments, i.e. the temperature, humidity and contamination levels shall be controlled within the ranges that are appropriate to the preservation or packaging method applied to the stored compartments or bins with suitable separators.

3.2 PACKAGING SELECTION AND CONTROL

3.2.1 General

The contractor shall control packing operations to ensure that the materials, procedures and instructions used provide for the protection of items at all times while at the contractor's plant, and ensure as far as possible their safe transit/delivery to end user, in particular, critical transport items.

Packaging materials shall not add any hazard to the item (i.e. electrostatic discharge) and shall not contaminate any surface, optical item, mechanism, liquid or gaseous supply lines that will not be processed or cleaned before integration into a complete spacecraft. Only space-qualified adhesive tapes are to be used on or within the immediate wrappings. **No PVC or other highly plasticised polymers shall be employed.**

All electrical connections, coaxial connectors, fluid or gaseous unions and mechanical interface provisions shall be protected with firmly secured closures or other devices of suitable material and in clean condition

Inspections shall be performed as necessary to ensure that items meet the specified packaging requirements and that no damage has occurred, and quality conformance inspection/tests shall be performed as part of the acceptance of the packaging items/containers.

3.2.2 Packing for Transportation

- a) **Inner Protection.** Items which require a high degree of protection from water vapour shall include an active
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dessicant within the waterproof/vapourproof container. Dessicant packs shall include a humidity indicator, preferably visible without removing any external protection.

- b) **Mechanical protection.** The inner container of a package containing spacecraft hardware shall be cushioned to a degree determined by the induced environment. The outer container used shall afford mechanical protection for the item and support for any cushioning required. Tie-down points and handles at suitable points shall be incorporated. Some suggested containers are listed in Tables 4 and 5.

3.2.3 Specially Designed Protective Equipment

Spacecraft hardware that is defined as fragile (critical transport items) or in need of special protection for other reasons shall be protected by specially designed protective equipment.

The equipment shall incorporate any environmental control, shock-absorbing, monitoring and warning features required to ensure that transport and storage by the project-approved method and route are accomplished without stress, damage, contamination, corrosion or change in performance of the transported item.

The equipment shall be designed to include casters, jacking systems or other mechanisms to facilitate handling before, during or after movement.

Specially designed protected equipment shall be identified early as as possible in the design stage of spacecraft development.

The drawings and specification of containers, trolleys, skids or rigs shall be prepared in accordance with appropriate project specifications, format, content, control at the EQ (equipment specification) level.

3.3 TRANSPORT

3.3.1 General

All relevant and necessary precautions shall be taken during transportation especially for critical transport items. The contractor shall provide transportation containers that incorporate in their design provisions for the attenuation of mechanical and environmental elements to a level that the item can withstand without damage.

The design of specially built transport containers shall permit safe packing and unpacking and shall be such as to ensure that neither the containers nor the equipment they contain shall suffer functional damage due to handling or static electrical discharge.

The containers and any auxiliary equipment shall incorporate any environmental controls, shock-absorbing monitoring and warning features required to ensure that transport methods and routes are accomplished without stress, damage, contamination, corrosion or change in performance of the transported item, i.e.

- items that require strict control of the induced inertial forces shall be accompanied by a shock recorder equipped to measure acceleration in three mutually perpendicular axes.
 - items sensitive to humidity shall be packed together with a humidity indicator, preferably visible without removal of the external protection of the package or container.
-

These requirements shall be avoided whenever possible but in any case shall be identified during the design phase of the spacecraft concerned.

3.3.2 Critical Transport Items

For the transport of critical transport items outside the premises of ESA, the manufacturer or user shall follow a pre-planned route, and vehicles to be used during the transportation shall be specified.

3.3.3 Specially Designed Transport Equipment

Spacecraft hardware that poses handling or transport problems, i.e. critical transport items, may require special modification of existing transport vehicles or the design of unique transportation systems.

3.4 HANDLING

The general requirements for handling equipment are given in ESA PSS-01-20 and ESA PSS-01-40. In addition, design considerations shall include factors encountered in hoisting, handling, and airdrop. Shock results from the application of lifting force are considered to be vertical for 10 to 40 milliseconds duration and may be incidental to any mode of transportation.

Lifting rings or eyes shall be so located as to insure a stable lifting configuration. Slings, handling fixtures, eyes and other support equipment to be used with hoisting equipment, employed in lifting hazardous items shall be periodically proof-load tested and shall have some means of ensuring that pins, devices, catches etc. that may be readily disassembled cannot be inadvertently exchanged with similar pieces that were not part of the whole assembly when it was last proof tested.

4. QUALITY ASSURANCE

4.1 GENERAL

The appropriate quality assurance requirements shall be applied. However, particular attention shall be paid to the avoidance of damage to spacecraft hardware during handling, storage, preservation, packaging, marking and labelling, transportation and shipping as detailed in this specification.

The means utilised for preservation, storage, handling and transportation of ESA spacecraft hardware shall be in compliance with the ESA product assurance policy outlined in this or other applicable PA documents as defined in the contract.

All contractors/establishments performing preservation, handling, packaging or transport operations or organising these activities with respect to ESA spacecraft hardware shall fulfil ESA requirements.

4.2 TESTING/ACCEPTANCE OF PACKAGES, TRANSPORT CONTAINERS AND HANDLING EQUIPMENT

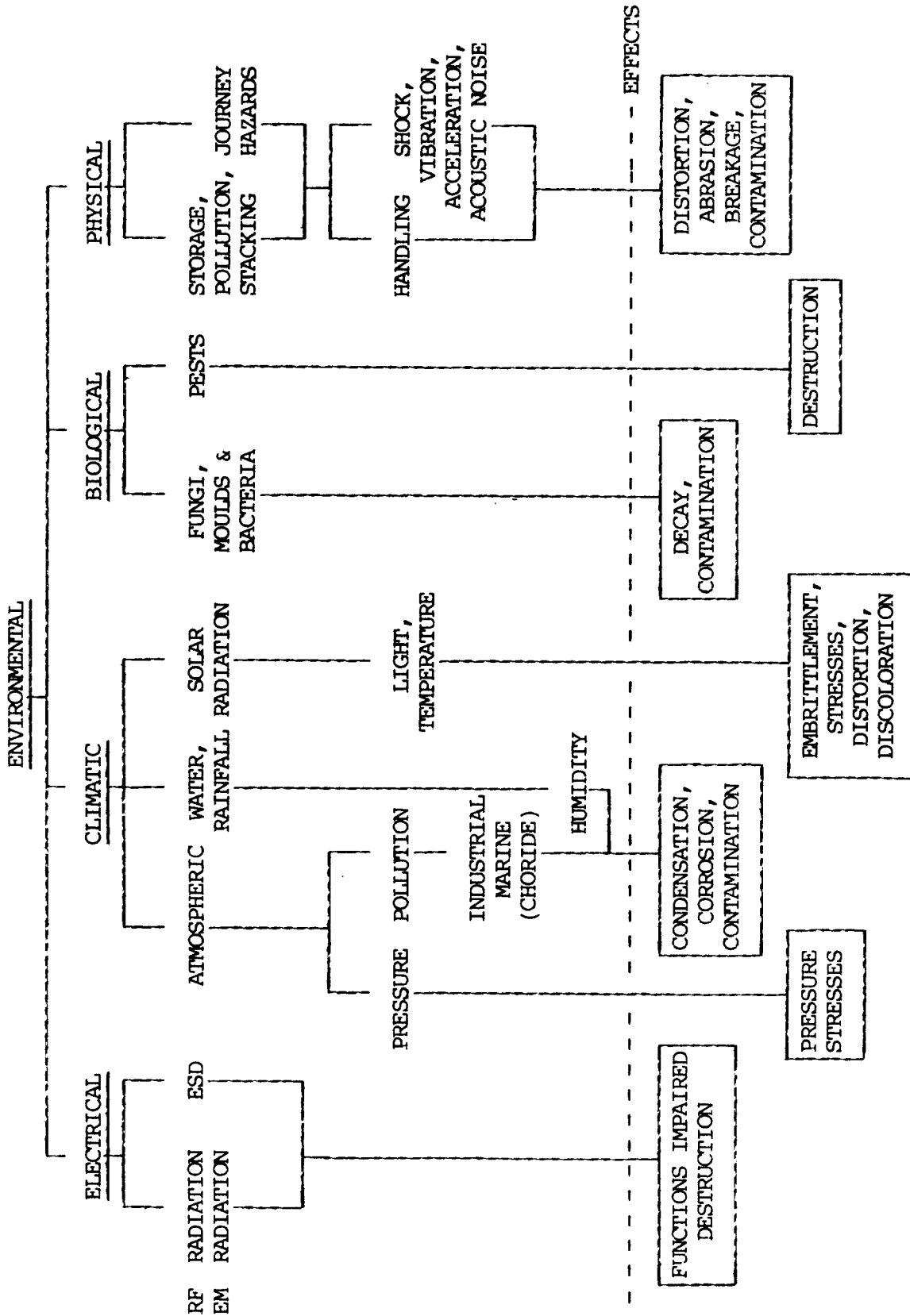
The following constraints shall apply:-

- a) Where the method of transport, handling or storage proposed for an item requires the use of a unique design of protection, packaging or transport equipment, then that design of protection, or packaging shall be tested to ascertain its effectiveness.
 - b) Tests for effectiveness of protection against natural and induced environments shall be conducted on the same test specimen.
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- c) The contents of a test specimen shall be representative of the spacecraft hardware to be protected, in the following parameters;
- size and shape
 - weight
 - centre of gravity and moment of inertia.
- d) The test environment shall be monitored and be representative of the known levels of natural and induced environments.
- e) "Test journeys" via the proposed route and method may be acceptable as tests, providing at least two consecutive return journeys are completed with satisfactory test results.
- f) The number and level of accelerations imparted to the contents of the test specimen shall be recorded in 3 mutually perpendicular axes, and any ingress of moisture or contamination shall be noted.
- g) When containers are required to provide a pressure control for the item, the container shall be tested to determine the pressure-control capability. Where necessary, a test adapter should be fitted for leak tests.
- h) Mobile specially designed protective equipment shall be tested to verify that the induced forces reaching the item do not exceed design limits. Both the item and vehicle shall be equipped with suitable monitoring and measuring instruments.

i) Additional tests may be imposed by the contract, the spacecraft hardware specification or the approved test plan.

j) Functional tests shall be conducted for all end items to verify the conformance of the hardware to applicable requirements and ensure safe operations and protection of flight hardware during handling, transportation and storage.



TYPICAL ENVIRONMENTAL FACTORS AND THEIR EFFECTS
TABLE 1

TABLE 2

GUIDANCE TO VARIOUS TYPES OF JOURNEY HAZARDS

Transport Mode	Location/Condition Type of Vehicle	Maximum Acceleration at highest frequency (g)	Shock Pulse length or Frequency	Vibration (V) Bump (B)
Air	Fuselage	4-8	3-500 Hz	V
		2	5-500 Hz	V
	Landing Turbulence	1-4	2-300 Hz	V
		10	100 Hz	B
		0-7	Not known	V
Road (Lorry)	Test Track	3-13	5-80 ms	B
	Normal lorry	1	5-200 Hz	V
	Bad road	5	5-15 Hz	V
	High speed	3	1-5 Hz	V
	Springs Bottoming	10	20 ms	B
Rail	Wagon	1-3	1-3 Hz	V
	Track Bumps	3-5	10-50 ms	B
	Shunting (Side Impacts)	20	Not known	B
Sea	Machinery and Propellers	11	1-20 Hz	V
	Amidship	4-5	1-20 Hz	V
	Deck	11	0-100 Hz	V
	Bow slams- normal	0-5	10 ms	B
	Bow slams-abnormal	6	10 ms	B

TABLE 3

TYPICAL MAX. ACCELERATIONS FOR SOME EQUIPMENT TYPES

Classification	Typical max. acceleration (g)	Typical Examples
Fragile electronic/ mechanical equipment	20-40	Gyroscopic instruments Delicate radar and electronic items, etc.
Laboratory equipment/ instrumentation generally	40-60	Caged gyroscopic flight instruments
Instrumentation	60-80	General electronic assemblies Fuel gauges Pressure gauges
Mechanical equipment	80-110	Motors
Robust mechanical equipment	110-150	Storage batteries

TABLE 4
CONTAINER TYPES

No.	Container type (standard)	Some relevant specifications (UK)
1	Kraft lined chipboard rigid box	BS 1133 Section 7
2	Kraft lined chipboard case	BS 1133 Section 7
3	Corrugated-board case (double-faced board)	BS 1133 Section 7
4	Fireboard packing cases	BS 1133 Section 7, CH 7.5
5	Plywood drums	BS 1133 Section 8
6	Metal containers	BS 1133 Section 10
7	Corrugated-board case (double-board)	BS 1133 Section 7
8	Corrugated-board case (triple-wall)	
9	Metal-edged plywood	BS 1133 Section 8
10	Battened plywood	BS 1133 Section 8
11	Framed plywood	BS 1133 Section 8
12	Softwood	BS 1133 Section 8
13	Softwood, large, framed	BS 1133 Section 8
	Container type (special)	
1S	Pallet bases with covers	BS 1133 Sections 1 - 22
2S	Reinforced plastic	
3S	Moulded plastic (unreinforced)	
4S	Vulcanised fibreboard and treated fibreboard	
5S	Moulded plywood	
6S	Plywood metal reinforced	
7S	Metal containers	
8S	Laminated materials e.g. alum/balsa, alum/rigid foamed plastic	

TABLE 5

SUGGESTED SUITABLE CONTAINER TYPES

Gross package weight and type of cargo	Expendable and/or limited reusable	Reusable
Up to 5 kg	1,2,3,4	2s,3s,4s,7s
Up to 10 kg	2,3,4,5,7,9	2s,3s,4s,5s,7s,8s
Up to 20 kg	5,7,8,9,10,12	2s,4s,5s,6s,7s,8s
Up to 40 kg	6,7,8,9,10,12	2s,5s,6s,7s,8s
Up to 125 kg	8,10,12,13	2s,6s,7s,8s
Up to 250 kg	8,10,12,13	2s,6s,7s,8s
Up to 250 kg classified as difficult loads	11,13	2s,6s,7s,8s
Up to 500 kg	11,13	2s,6s,7s,8s
Cargo suitable for attaching by bolting or other means to a pallet base	1s	1s

ANNEX 'A'

REFERENCED DOCUMENTS

- MIL-P-116, Preservation Methods
- MIL-B-121, Barrier Material, Greaseproofed, Waterproofed,
Flexible
- MIL-B-131, Barrier Material, Water-vapourproof, Flexible,
Heat-sealable
- MIL-B-794, Parts and Equipment, Procedures for Packaging of
- MIL-P-9024 Packaging, Handling, and Transportability in
System/Equipment Acquisition
- ESA/SCC 3060 Basic Specification, Preservation Packaging and
Despatch of SCC Electronic Components
- BS 1133 Section 1 to 22 British Standard Specification
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