Chapter 4: Payload general design requirements

CHANGE TRACEABILITY Chapter 4

Here below are listed the changes between issue N-2 and issue N-1:

N°§	PUID	Change Status	Reason of Change	Change Reference
§4.1.2.2	**[PL - 4.1.2 -6]**	New in		PUM.6.2.EJ.08
§4.2.1.1	**[PL - 4.2.1 - 2 a]**	Modified in	STR cable added	CIIS.4.1.JC.1_1
§4.2.2.4	**[PL - 4.2.2 - 5 a]**	Modified in	Vertical handling	PUM.6.1.CG.31_27
§4.2.2.4		New in	Nota added	PUM.6.1.CG.31_27
§4.2.2.4		New in	Figure 4.2-3 added	PUM.6.1.EJ.25
§4.4.3.2	**[PL - 4.4.3 - 7 a]**	Modified in	AWG limitation	PUM.6.1.EJ.15
§4.6.1.5.2		Modified in	X Co-coordinate modified	PUM.6.1.EJ.33
§4.7	**[PL - 4.5.7 -1]**	Deleted in	Replaced by PL-4.7-1	PUM.6.1.CG.31_23
§4.7	**[PL - 4.7 -1]**	New in	New numbering+ additional sentence	PUM.6.1.CG.31_23
§4.7	**[PL - 4.5.7 -2]**	Deleted in	Replaced by PL-4.7-2	PUM.6.1.CG.31_23
§4.7	**[PL - 4.7 -2]**	New in	New numbering	PUM.6.1.CG.31_23

Here below are listed the changes from the previous issue N-1:

N°§	PUID	Change Status	Reason of Change	Change Reference
§4.1.4.1	**[PL - 4.1.4 - 2 a]**	Modified in	To be documented in IDS/ICD	PUM.6.2.EJ.08
§4.1.4.1	**[PL - 4.1.4 - 3 a]**	Modified in	To be documented in IDS/ICD	PUM.6.2.EJ.08
§4.1.8.4		New in	New Section: Storage requirements	PUM.6.2.EJ.09
§4.1.8.4	**[PL - 4.1.8 -4]**	New in	Storage requirements	PUM.6.2.EJ.09
§4.1.8.4	**[PL - 4.1.8 -5]**	New in	Storage requirements	PUM.6.2.EJ.09
§4.2.5.2		Modified in	Safety factors for characterized materials added	PUM.6.2.EJ.11
§4.2.5.2	**[PL - 4.2.5 - 4 a]**	Modified in	Criteria added	PUM.6.2.EJ.12
§4.4.2.1	**[PL - 4.4.2 -21]**	New in	Sneak circuits and unintentional alctrical paths to be precluded	PUM.6.2.EJ.30
§4.4.2.7.4	**[PL - 4.4.2 -20]**	New in	Connectors with electroexplosive devices	PUM.6.2.EJ.30
§4.7	**[PL - 4.7 -3]**	New in	Warnings and precautions in PL AIT instructions	PUM.6.2.EJ.14

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Section	Sentence	Planned Resolution
§4.2.2.2	The Payload Grounding Point shall be located as close as possible to the –Zs –Ys attachment foot and this location shall be identified in the payload ICD. This Grounding Point shall consist in a ground stud as shown in Figure 4.2-0 (TBC values are typical values which shall be defined by the Payload Supplier depending on payload design). Moreover, this Grounding Point shall be redundant (so 2 ground studs).	
§4.2.2.4	**Nota**: If the payload is non compliant with this exclusion area or if the Prime Contractor wants to handle the satellite by the payload, the payload handling attach fittings shall allow a vertical handling of the whole maximum equipped satellite. the whole maximum equipped satellite to be considered is the satellite maximum mass as indicated on Table 3.1-1 + 80 kg (TBC including all the non-flight harware (GSE) mounted on both the payload + platform + test PAF with associated separation device when handled).	

List of TBDs

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4. CHAPTER 4: PAYLOAD GENERAL DESIGN REQUIREMENTS

This chapter defines all the design requirements the payload shall comply in order to be compatible with the PROTEUS platform. It presents a generic specification concerning the general, mechanical, thermal, electrical design between the satellite bus and the payload.

For the phase A of a PROTEUS based mission, the User is encouraged to contact either ALCATEL SPACE or CNES in order to consider every specification notified hereafter, check whether it is applicable to the studied payload and foresee the specific analysis necessary to adapt PROTEUS to the mission requirements.

4.1 GENERAL DESIGN REQUIREMENTS

4.1.1 INTERFACE CONTROL

PL - 4.1.1 - 1

The Payload Interface Control Document (see section 10.2) shall contain at least :

- Payload Interface Data Sheet (Payload IDS framework with its filling rules are given in appendix)
- Mechanical Interface Data Sheets (IDS)
- Thermal IDS
- Power data sheets : average power consumption, transient power demand and average power dissipation
- List of connectors
- Pin allocation data sheet
- Elementary acquisitions and commands description sheet (discrete acquisition cycle)
- Description of acquisition and command via serial lines
- Description of acquisition and command via 1553 Bus
- Telecommand data sheet (number of messages per unit, delay constraint between 2 consecutive TC)
- Telemetry data sheet (number of messages per unit)
- Miscellaneous sheet (all magnetic components, non flight hardware, location of purge valves and venting holes)
- Drawings
- Grounding scheme
- Interfaces Description Drawings which completes IDS (volume, location of purge valves and venting holes, type and location of handling fixtures, definition of the conductive and radiative interface...)
- Interfaces Description Documents for functional aspects.

A copy of the Interface Data Sheet model will be provided by the Satellite Contractor in Excel software for PC, version 5.0a, on a 3.5’’ floppy disk support.

PL - 4.1.1 - 2

This model shall be filled by the Payload Contractor and supplied to the Satellite Contractor in paper and software form in the same format. This format is described in appendix.

PL - 4.1.1 - 3

The definitions (mass, power...) given in appendix in the filling rules shall be applied at payload level.

PL - 4.1.1 - 4

Masses shall be established and recorded in the IDS and the record shall account for all mass status and mass dynamics attributable to deployable, consumable, moving or jettisonable materials or assemblies.

PL - 4.1.1 - 5

The external finishes of the payload (MLI, coatings, finishes...) shall be defined along with their optical properties at BOL and EOL in the payload ICD and/or IDS.

PL - 4.1.1 - 6

All the interfaces shall be defined and documented using the international system of units (metric, SI).

4.1.2 MATERIAL PROCESSES AND PARTS

4.1.2.1 Parts and materials

PL - 4.1.2 - 1

Material used at payload mechanical interface shall be compliant with Aluminium, steel and Titanium alloys.

The use of pure Mercury, Cadmium and Zinc is prohibited.

4.1.2.2 Magnetic materials

PL - 4.1.2 - 2

Non-magnetic materials shall be used for all components of payload except where magnetic materials are essential to the function of the unit.

PL - 4.1.2 -6

All magnetic components shall be clearly identified in an Interface Control Drawing.

4.1.2.3 Outgassing

PL - 4.1.2 - 3

The Total Mass Loss (TML) of the payload shall be less than 1%.

PL - 4.1.2 - 4

The Collected Volatile Condensable Material (CVCM) of the payload shall be less than 0.1%.

4.1.2.4 Threads and locking devices

PL - 4.1.2 - 5

Every bolted assembly (STA and connectors brackets) on the payload shall include a positive locking device (such as ONDUFLEX washers, for instance).

4.1.3 IDENTIFICATION AND PRODUCT MARKING

PL - 4.1.3 - 1

The payload shall be permanently marked in French or English. The identification shall be visible when installed on the platform. The identification shall be visible with unaided eye from a 0.5 m distance.

PL - 4.1.3 - 2

The payload shall carry an identification with at least the following information :

- Payload Assembly Name
- Identification Part Number
- Serial Number

4.1.4 MOUNTABILITY, INTERCHANGEABILITY AND ADJUSTMENT

PL - 4.1.4 - 1

It shall be possible to mount and dismount several times (typically 5) the payload for integration constraints.

4.1.4.1 Hardware Accessibility

PL - 4.1.4 - 2 a

The payload shall not require assembly or disassembly to perform mounting on or dismounting from the spacecraft.

The payload design shall permit easy access to mounting bolts and to test points and components that may require adjustment.

These points shall be identified in the ICD.

PL - 4.1.4 - 3 a

Non-flight hardware shall be clearly identified (red tags or marks) and easily accessible and removable.

These non-flight hardware shall be identified in the instruments units ICDs.

4.1.4.2 Software Accessibility

PL - 4.1.4 - 4

If a payload software is to be modified during AIT operations (for uploads or software configuration changes, for instance), this shall be easily feasible through test connectors and EGSEs, without dismounting anything.

If performed, this operation shall be under the Payload Supplier responsibility.

PL - 4.1.4 - 5

The payload shall be designed such as the required adjustments (mechanical, electrical) are feasible at satellite level during AIT operations.

4.1.5 SAFETY

PL - 4.1.5 - 1

Warnings and precautions relative to personnel and payload safety and hazards shall be specified in payload handling, assembly, and test instructions.

PL - 4.1.5 - 2

Payload and GSEs shall be compliant with launch pad and mission safety requirements (mission dependent).

4.1.6 CLEANLINESS

Hardware shall be designed, manufactured, assembled and handled in a manner to insure the highest practical level of cleanliness.

PL - 4.1.6 - 1

Suitable precautions shall be taken to insure freedom from debris within the hardware, and unaccessible areas where debris and foreign materials can become lodged, trapped, or hidden shall be avoided.

PL - 4.1.6 - 2

Hardware shall be designed so that malfunctions or inadvertent operations cannot be caused by exposure to conducting or non conducting debris or foreign materials floating in a gravity free state.

PL - 4.1.6 - 3

Electrical circuit shall be designed and fabricated to prevent unwanted current paths being produced by such debris.

PL - 4.1.6 - 4

All satellite related activities (after payload delivery) will be performed in class 100 000 clean rooms. The payload shall be compatible with this class.

4.1.7 AIT SUPPORT

PL - 4.1.7 - 1

The Payload Supplier shall provide all the necessary tooling, equipment and working media for the payload assembly and test at system level.

4.1.8 PREPARATION FOR STORAGE AND DELIVERY

4.1.8.1 Retention of cleanliness

PL - 4.1.8 - 1

The payload shall be sealed for retention of cleanliness using precleaned bags as port closures and shall be retained by pressure sensitive tape applied over the bags. The payload shall be double bagged in antistatic polyethylene or polyamid film (100 micron total thickness minimum) and shall then be packed properly according to commercial practice in a manner which will provide adequate protection against hazards encountered during transportation, handling and/or storage.

4.1.8.2 Marking of the container

PL - 4.1.8 - 2

The container for the payload shall be labelled, tagged or marked to permit detailed identification of the content of the container.

4.1.8.3 Handling procedure

PL - 4.1.8 - 3

The payload handling procedure shall be delivered with the payload container and shall be accessible without opening it, in order to allow payload incoming inspection after delivery at Satellite Contractor Facilities.

4.1.8.4 Storage requirements

PL - 4.1.8 -4

Special storage conditions and constraints, if any, shall be listed by the Payload Supplier. When integrated on the satellite, the payload may be stored in clean room environment up to 8 months.

PL - 4.1.8 -5

End of storage operations shall be minimized.

4.2 MECHANICAL DESIGN REQUIREMENTS

4.2.1 PAYLOAD PHYSICAL CHARACTERISTICS

4.2.1.1 Mass

PL - 4.2.1 - 1

The payload mass shall include the total hardware that is intended to fly.

PL - 4.2.1 - 2 a

The payload mass shall be presented as follows :

- Equipped payload mass, including the STA, H02 & H03 connectors brackets and STR cables mass,
- mounting hardware such as screws, washers, bonding straps or equivalent, interface fillers when delivered.

4.2.1.2 Center of Gravity

PL - 4.2.1 - 3

The Center of Gravity (CoG) shall be identified related to the Payload Reference Frame (shown section 1.4).

4.2.1.3 Moments of inertia

PL - 4.2.1 - 4

Moments of inertia shall be identified related to the Payload reference Frame (show section 1.4).

4.2.1.4 Size

PL - 4.2.1 - 5

The volume allocated to the payload includes the total hardware that is intended to fly.

PL - 4.2.1 - 6

The nominal external dimensions of the payload shall be expressed in millimeters.

An overstepping of the maximum dimensions toward the allocated dimensions will induce a formal volume change notice.

PL - 4.2.1 - 7

The external envelope dimensions of the delivered hardware (excluding thermal blankets) shall not exceed the dimensions specified in the Interface Control Drawing by more than 1.25 mm unless specifically authorized.

4.2.2 PAYLOAD MOUNTING

4.2.2.1 Method

PL - 4.2.2 - 1

Payload mounting shall be accomplished by M8 bolts, passing through interface pods flanges, as described in section 3.1.4.

Payload mounting bolts shall be provided by the Payload Contractor.

4.2.2.2 Grounding point

PL - 4.2.2 - 2

The Payload Grounding Point shall be located as close as possible to the –Zs –Ys attachment foot and this location shall be identified in the payload ICD. This Grounding Point shall consist in a ground stud as shown in Figure 4.2-0 (TBC values are typical values which shall be defined by the Payload Supplier depending on payload design). Moreover, this Grounding Point shall be redundant (so 2 ground studs).

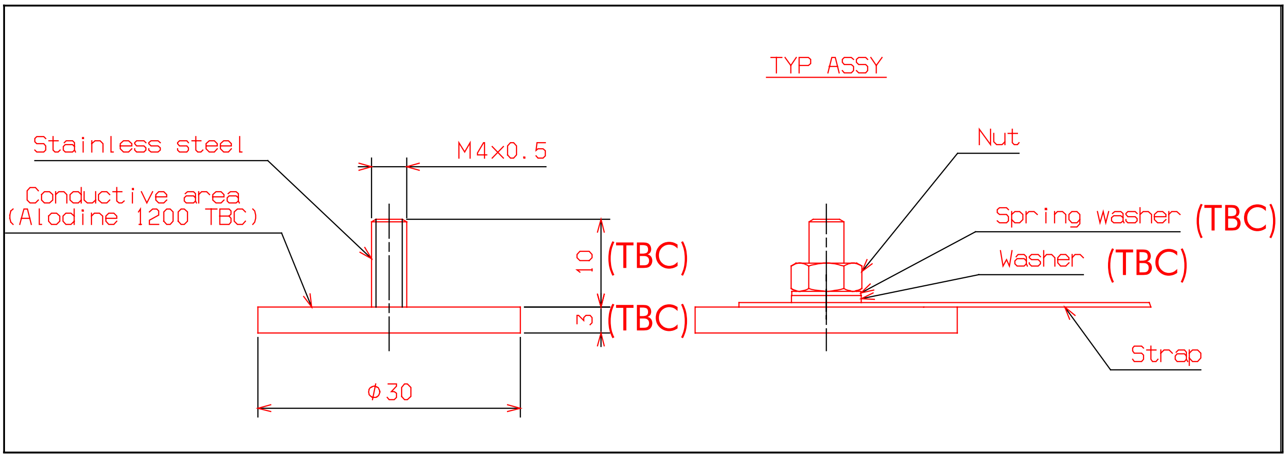

Figure 4.2-0 : Ground stud configuration

4.2.2.3 Purging and venting interfaces

PL - 4.2.2 - 3

The payload shall be vented to accommodate the specified barometric pressure rates of change for both decreasing and increasing pressure but shall avoid any pollution problem during tests or handling on ground.

4.2.2.4 Handling attach fittings/fixture

PL - 4.2.2 - 5 a

These handling attach fittings shall allow a vertical handling of the equipped Payload. Handling required environments (covering the environment encountered at ALCATEL SPACE facilities) are given in section 5.11.2.1.3 and required safety factors in section 4.2.5.2.

The payload mass to be considered shall include all the non-flight hardware mounted on the payload when handled.

In addition, in case of hazardous system handling, a fail-safe analysis (loss of one handling point) shall be performed with environments required in section 5.11.2.1.3 and safety factors given in section 4.2.5.2.

For safety reasons, this sizing shall be approved by ALCATEL SPACE.

PL - 4.2.2 - 6

deleted

The Satellite handling will be directly performed through platform dedicated handling MGSE. Schematics are provided in figure 4.2-1 and 4.2-2 to illustrate the foreseen handling procedures.

PL - 4.2.2 - 7

deleted

PL - 4.2.2 - 8

The payload shall comply with the exclusion areas indicated on the figure 4.2-1 for vertical handling MGSE (including slings). No additional exclusion area is required for the satellite horizontal handling configuration(see PL-3.1.3-3 for the payload allowed volume).

Nota: If the payload is non compliant with this exclusion area or if the Prime Contractor wants to handle the satellite by the payload, the payload handling attach fittings shall allow a vertical handling of the whole maximum equipped satellite. the whole maximum equipped satellite to be considered is the satellite maximum mass as indicated on Table 3.1-1 + 80 kg (TBC including all the non-flight harware (GSE) mounted on both the payload + platform + test PAF with associated separation device when handled).

Handling required environments (covering the environment encountered at ALCATEL SPACE facilities) are given in Section 5.11.2.1.3 and required safety factors in Section 4.2.5.2.

In addition, in case of hazardous system handling, a fail-safe analysis (loss of one handling point) shall be performed with environment required in Section 5.11.2.1.3 and safety factors given in Section 4.2.5.2.

For safety reason , this sizing shall be approved by ALCATEL SPACE.

In this case, tets at payload level shall be performed in order to demonstrate the possibility of handling the whole satellite at ALCATEL facilities. These tests shall be performed before delivery and with additional masses in order to represent the maximal satellite mass.

The maximum load encountered during nominal handling shall be tested on the flight hardware.

The maximum load encountered during degraded case (fail-safe for instance) shall be tested on a representative sample.

For safety resons, related test reports shall be provided with the payload in its acceptance.

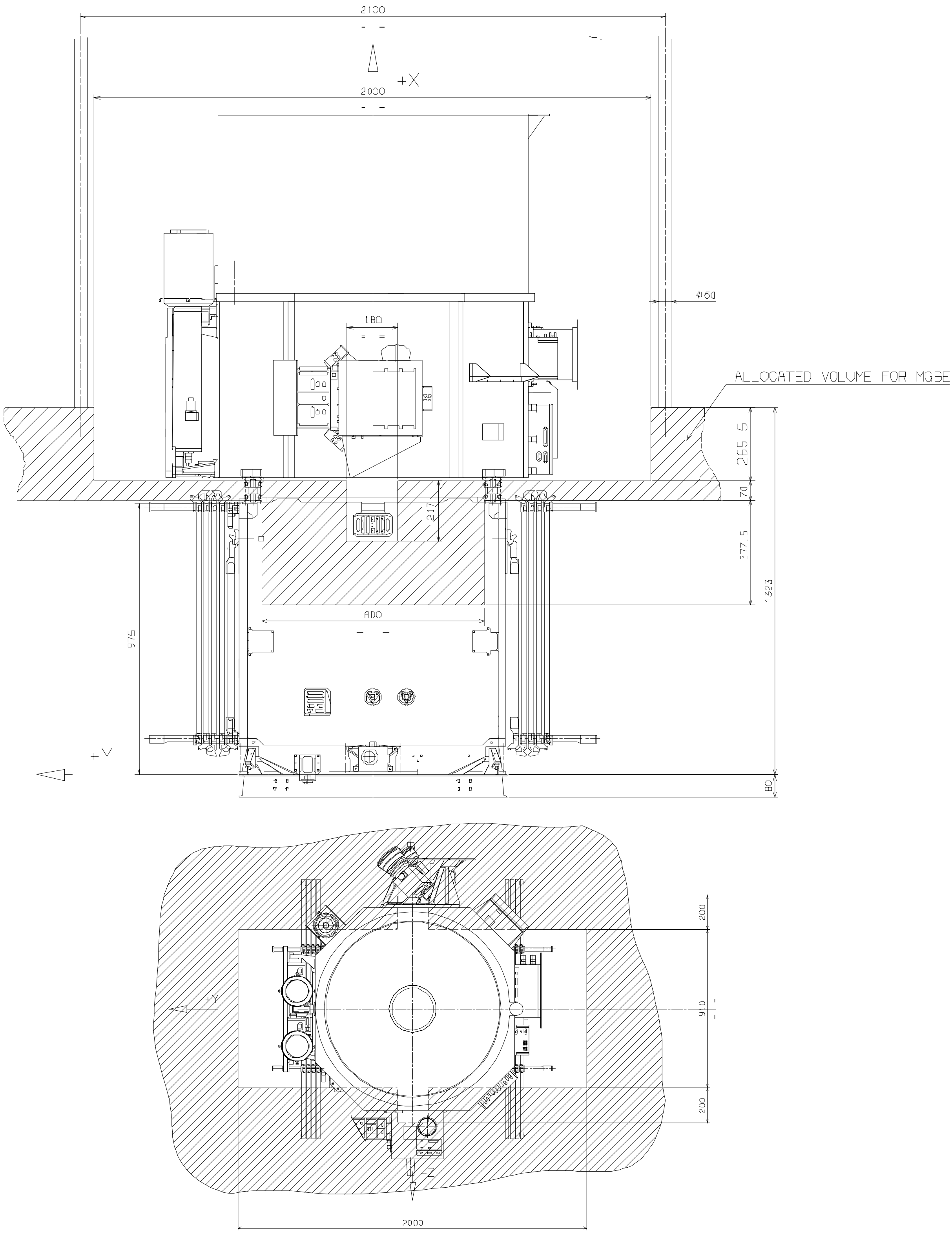

Figure 4.2-1 : Satellite vertical handling procedure and payload exclusion areas (Calipso example)

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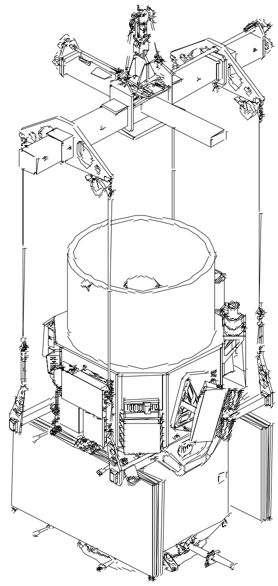

Figure 4.2-3 : Satellite vertical handling

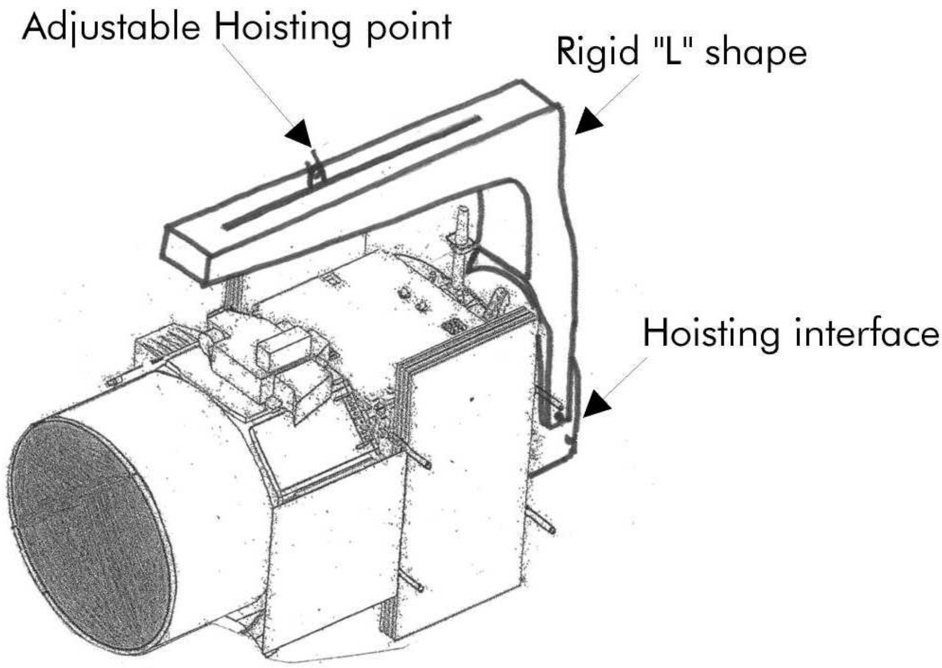

Figure 4.2-2 : Satellite horizontal handling procedure (Calipso example)

4.2.3 ALIGNMENT

The integration / alignment of the Payload on the Platform is a Satellite Contractor responsibility but it is the Payload Supplier responsibility to provide a payload design which is compatible with the required alignment accuracy. The nominal alignment measurements during satellite AIT aim at verifying the stability of the payload master reference cube between the beginning of the AIT mechanical and thermal environment tests and the end of these tests. In addition, position of this cube will be measured with respect to the STR reference cube in order to determine the relative position of the payload boresight with respect to the STR boresight. No other optical cubes are nominally controlled during satellite AIT.

PL - 4.2.3 - 1

Consequently, a description of payload specific alignment method or needs during satellite AIT shall be provided by the Payload Supplier for Satellite Contractor approval before Satellite phase C.

This shall include as a minimum a definition of the payload adjustment range, a detailed description of the hardware used for that purpose, the reference cube and its field of view.

It shall be noticed that, at satellite level, all alignment measurements will be performed in vertical configuration (Satellite $+X_s$ axis in vertical position). This leads to some constraints at payload level expressed in PL - 4.2.3 - 3.

PL - 4.2.3 - 2

For each feed/antenna reflector assembly, a specific device (palmer equipped struts, as far as possible) allowing verification of the relative geometry shall be provided to the Satellite Contractor by the Payload Supplier, if geometry verification after satellite testing (mechanical, thermal, EMC) is required at System level.

PL - 4.2.3 – 3

The payload master reference optical cube shall fulfil the following requirements :

- This cube shall be duplicated (one nominal and one redundant) and the 2 cubes shall not be located on the same area (full redundancy rules)
- These 2 cubes shall be directly accessible with the satellite in vertical position that is to say by 2 perpendicular horizontal lines of sight (+Ys and +Zs for instance or any combination remaining in +Ys+Zs). Moreover, the previous line of sight shall be free of any interference,
- They shall be located on a stable area (moreover, they shall be preferably located on the +/- Ys faces of the payload)
- Their minimum size shall be 20 mm x 20 mm x 20 mm,
- They shall not be dismounted during payload or satellite test campaign.

Information about alignment references, accuracy and adjustments form part of the PL ADP. Any other payload optical cube, if measured during satellite AIT, shall be compliant with PL-4.2.3-3 except for the redundancy aspect.

4.2.4 CO-ALIGNMENT

N.A

4.2.5 STRUCTURAL DESIGN

4.2.5.1 Stiffness requirements

PL - 4.2.5 - 1

The first mode frequencies of the payload required in the chapter 3 shall be achieved with the assumption of a hard-mounted interface on an infinitely rigid interface.

4.2.5.2 Safety factors and safety margins

PL - 4.2.5 - 2

For non pressurized item, the following safety factors for yield sizing (JY) and for ultimate sizing (JU), with respect to the qualification loads, shall be applied :

Type of hardware	JY (yield)	JU (ultimate)
Metal flight hardware	1.25	1.56
Metal inserts and joints (flight hardware)	NA	2.0
with characterized materials(*)	NA	1.25
Composite flight hardware	NA	1.56
with characterized materials(*)	NA	1.25
Composite inserts and joints (flight hardware)	NA	2.0
with characterized materials(*)	NA	1.25
Ground handling	1.5	2.5

(*) : the applicable safety factors may be reduced for pieces of hardware made of materials characterized through an appropriate number of tests, yielding to a better knowledge of the admissible stress ("A" or "B" type).

Table 4.2-1: JY and JU safety factors for non pressurized item

PL - 4.2.5 - 7

For pressurized item, the following safety factors for yield sizing (JY) and for ultimate sizing (JU), with respect to the Maximum Operating Design Pressure (defined as the highest pressure occurring from maximum relief pressure, maximum regulator pressure, maximum temperature or transient pressure excursions), shall be applied.

In addition, pressure vessels design and verification shall comply with the requirements specified in Safety Regulations requirements.

Type of hardware	JY (yield)	JU (ultimate)
Pressure vessels	1.25	1.56
Pressurized components	1.5	2.5

Table 4.2-2: JY and JU safety factors for pressurized item

PL - 4.2.5 - 3

The following definitions shall be applied:

Qualification loads = 1.25 x Flight limit loads except for ground handling where:
- qualification loads = 2 x Flight limit loads for nominal analysis and
- qualification loads = 1.5 x limit loads for fail safe analysis (where 1.5 corresponds to the dynamic factor due to the loss of one handling point).

Sizing loads = JY (or JU) x Qualification loads

The safety margin is defined as follows :

$$S.M. = \frac{\sigma_{admissible}}{\sigma_{calculated}} - 1$$

where :

the admissible stress is the yield (respectively ultimate) stress when estimating the safety margin wrt yield (respectively ultimate).

the admissible stress for single points failure pieces of hardware shall be "A" type values (99% probability with a 95% confidence level),

the admissible stress for redundant pieces of hardware shall be "B" type values (90% probability with a 95% confidence level),

the calculated stress is the qualification stress times the yield (respectively ultimate) safety factor.

PL - 4.2.5 - 4 a

All safety margins shall be positive:

- local buckling criterion: there shall be no buckling under qualification loads

4.2.5.3 Notching philosophy

PL - 4.2.5 - 5

Notching at payload level is allowed during sine vibration test in order not to exceed, at the platform/payload interface, the Quasi-Static equivalent loads (resultant forces and moments at the geometrical centre of the interface points) after Satellite Contractor agreement

Notching at payload units level is forbidden.

PL - 4.2.5 - 6

For notching during random vibration tests, the Payload Supplier shall contact either ALCATEL SPACE or CNES.

4.2.5.4 Structural mathematical models

The requirements for the quality of mathematical models, numbering ranges and interface point locations are given in section 4.6.1.

4.3 THERMAL DESIGN REQUIREMENTS

4.3.1 DEFINITIONS

For information, the temperatures definition used for the PROTEUS platform are given hereafter.

4.3.1.1 Operational temperatures

The minimum and maximum operational temperatures TOPMIN and TOPMAX are the extreme temperatures a payload shall withstand during its specified lifetime for its various operational modes.

4.3.1.2 Acceptance temperatures

Acceptance temperature limits shall be deduced from operational temperature limits by an extension of 5°C :

TAMIN = TOPMIN - 5 °C
TAMAX = TOPMAX + 5 °C

4.3.1.3 Qualification temperatures

Qualification temperature limits shall be deduced from operational temperature limits by an extension of 10°C :

TQMIN = TOPMIN - 10 °C
TQMAX = TOPMAX + 10 °C

4.3.1.4 Non operating temperatures

Minimal and maximal non operating temperatures TNOPMIN and TNOPMAX are the extreme temperatures a payload shall withstand when it is OFF during specific satellite modes or during ground phase up a few days (for example transport).

4.3.1.5 Start-up temperatures

Minimal and maximal start up temperatures TSUMIN and TSUMAX are the extreme temperatures a payload shall be able to be turned ON, possibly without fulfilling all its performance requirements (for example a «cold start » after modes transition, when the satellite stayed in Safe mode for a long time before coming back to normal mode).

4.3.1.6 Storage temperatures

Minimal and maximal temperatures TSTOMIN and TSTOMAX are the extreme temperatures a payload shall withstand during storage phase up to several months.

4.3.2 THERMAL INTERFACES

4.3.2.1 Thermal mathematical models and analysis

PL - 4.3.2 - 1

A thermal analysis is required at payload level covering the most thermally critical operating modes and including transient cases where relevant.

In a standard approach, no Payload reduced mathematical model is required. Nonetheless, the platform thermal control design has to take into account radiative coupling with the payload.

PL - 4.3.2 – 2

So, the Payload Supplier shall provide an external radiative geometrical model, in flight (before payload PDR) and satellite-level test configurations (six months before test) in the Payload Interface Control Document.

This model is an external representation of the Payload including for each main surface :

- Thermo-optic characteristics
- Worst temperatures assumption (cold and hot).

4.4 ELECTRICAL DESIGN REQUIREMENTS

4.4.1 SYSTEM GROUNDING

4.4.1.1 General

PL - 4.4.1 - 1

The satellite structure shall not be used as a current carrying conductor.

PL - 4.4.1 - 2

Shields shall not be used for signal returns except for RF signals.

PL - 4.4.1 - 3

An overall zero volt and grounding diagram shall be provided in the ICD/IDS for assessing the functional and electromagnetic compatibilities. This diagram shall indicate any AC or DC loop, the type of isolation used, any impedance coupling between zero volt and structure, and the type of connection between secondary 0 V and mechanical ground (if any).

PL - 4.4.1 - 4

The Payload Supplier shall provide a grounding diagram based on the following concepts.

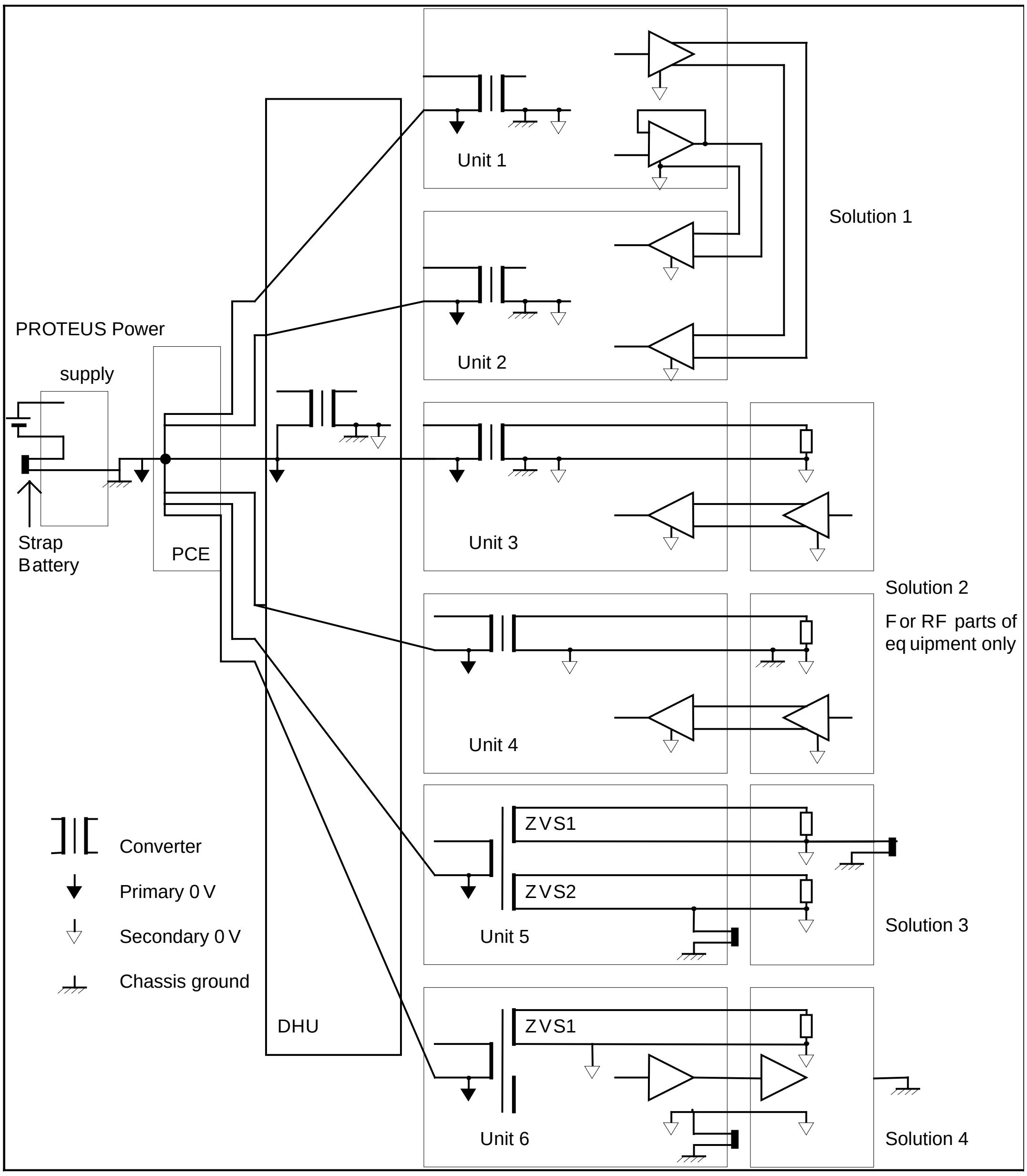

Figure 4.4-1 : Grounding concepts

PL - 4.4.1 - 5

The following rules and symbols shall be used to draw grounding diagrams

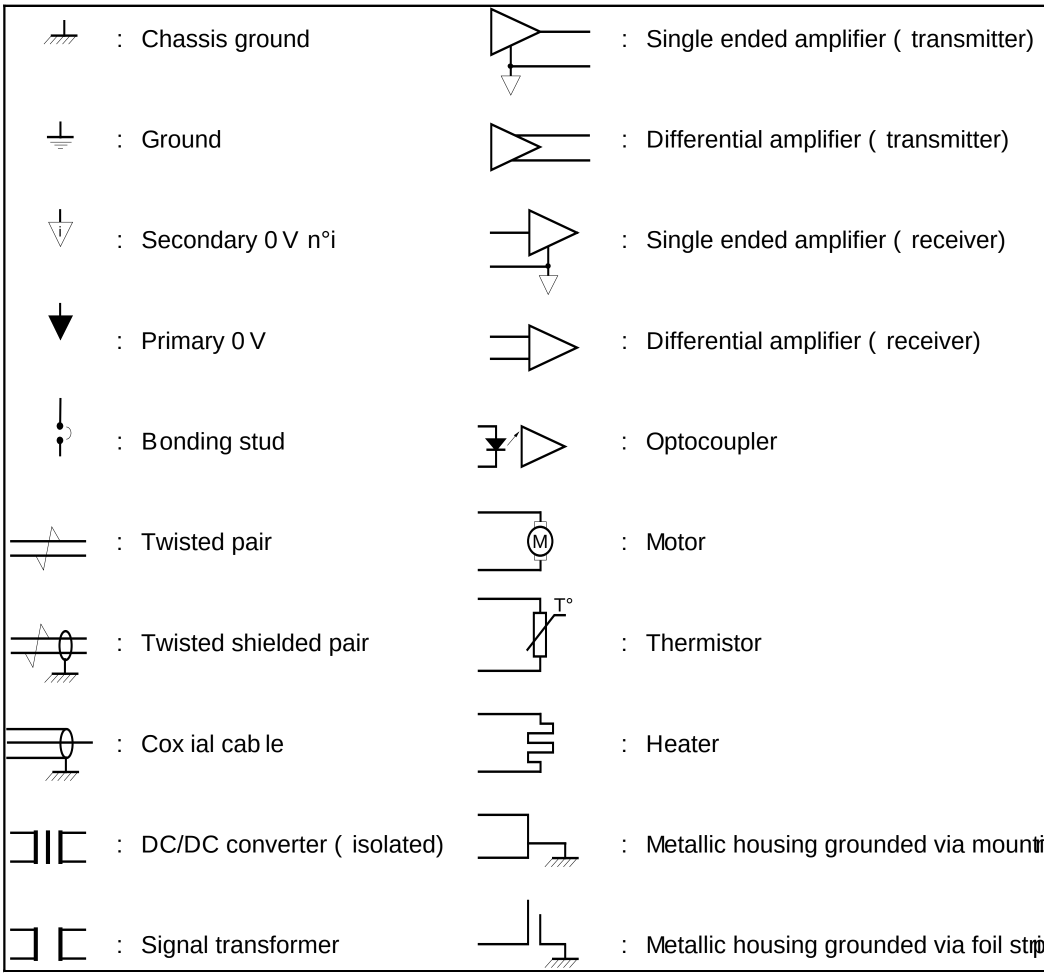

Figure 4.4-2 : Symbols for grounding diagrams

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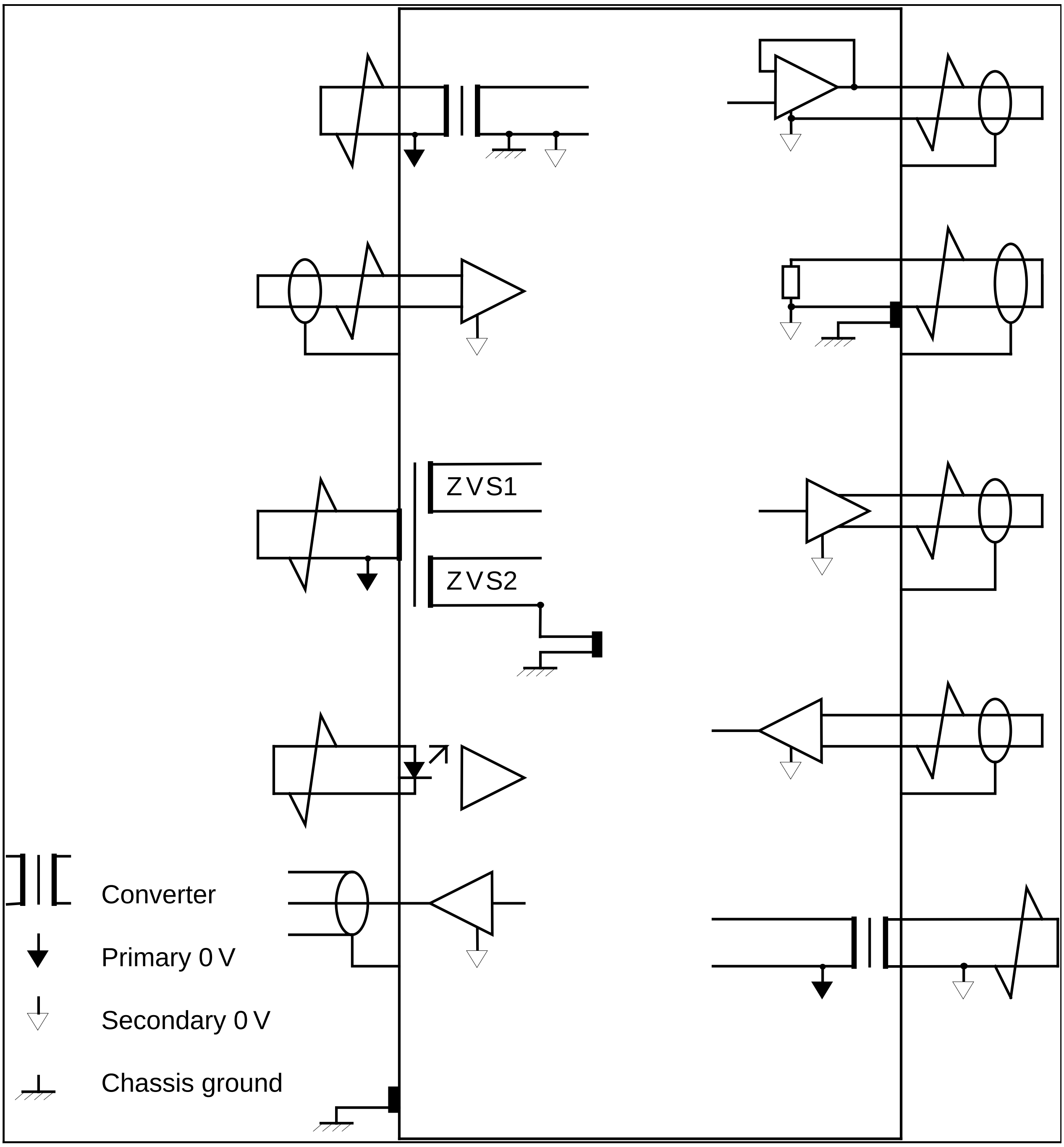

Figure 4.4-3 : Example of grounding diagram

4.4.1.2 Structural grounding

PL - 4.4.1 - 6

All structural members of the satellite and payload chassis and enclosures shall be designed to provide electrical conductivity across all mechanical joints, except where DC isolation is required for maximum electrical reliability. Conductive surface protection coatings such as Iridite, Alodine, or plating shall be used at all joints. The DC resistance across fixed joints shall not exceed 2.5 mOhm.

PL - 4.4.1 - 7

Redundant bonding straps shall be employed across joints where direct metal-to-metal contact cannot be assured. The DC resistance of these straps shall not exceed 10 mOhm.

4.4.1.3 Thermal grounding

PL - 4.4.1 - 8

The conductive surfaces of all metal or metallic coated thermal components, such as heat shields and metallized layers of thermal blankets (that shall include one conductive layer) shall be electrically grounded to the satellite structure with a DC resistance lower than 10 mOhm. The number of bonding points per sheet of MLI shall be compliant with the following rules:

- Sheets of 0.5m^2 max: two points, at corners of the longest diagonal, as a minimum,
- Sheets of 1 m^2 max: four points, at each corner, as a minimum,
- Sheets greater than 1 m^2 : one bonding point at diagonal corners and intermediate points along outer sheet edges to ensure bonding areas not to exceed 1 m^2.

PL - 4.4.1 - 9

In addition, the resistance between two bonding points in a MLI shall be lower than 80 Ω.

PL - 4.4.1 - 10

The use of non conductively coated insulators shall be minimized.

4.4.1.4 Electrical bonding

PL - 4.4.1 - 11

Electrical bonding shall be in accordance with Table 4.4-1 with the following additions :

a. The exterior case, including connectors and all metallic external covers shall be electrically bonded, directly or indirectly to chassis ground with a resistance of no greater than 2.5 milliohm per bond except for composite components.

b. For composite components, the DC resistance per bond shall be no greater than 100 Ohm.

c. The mounting surface shall be such that it may be electrically bonded to the structure upon which it is to be mounted at installation in the spacecraft.

d. All internal mechanical assemblies shall be electrically bonded directly or indirectly to the base plate.

e. Gimbaled, hinged, or jointed interfaces shall be bonded by means of redundant grounding straps.

Bonded configuration	max DC resistance (Ohm)
RF boxes to Panel Ground Reference (PGR)	0.010
Non-RF boxes to PGR	0.020
Electrical boxes on graphite panels (if any) to PGR	0.050
Across hinges (antenna deployed booms & solar array)	0.100
Units, optical heads to PGR	0.020
Harness shields to PGR	0.020
Antenna to PGR	300.0
Thermal blankets ground to Single Ground Point (SGP)	0.010
Mechanical equipment to SGP	1.0
Thermal blanket to multiple grounding tab to tab	0.010
Thermal shields (thrusters) to structure	1.0
Panel Ground Reference to SGP	0.10

Table 4.4-1:PROTEUS Bonding Requirement

4.4.2 CABLING SHIELDING AND GROUNDING

4.4.2.1 General

PL - 4.4.2 -21

The design shall preclude sneak circuits and unintentional electrical paths

PL - 4.4.2 - 1

The primary electrical power distribution system will have the power negative grounded to the spacecraft structure at a single ground point (SGP).

PL - 4.4.2 - 2

The electronic boxes supporting structure shall be designed with a panel ground reference (PGR). The PGR shall consist of ground studs, or inserts for ground straps, to be connected between the panel and the adjacent panels.

The DC resistance between PGR and panel structure shall be lower than 10 mΩ.

PL - 4.4.2 - 3

Secondary power return lines shall be connected to the equipment structure in a single point. Exceptions are RF communication equipments and electrical units with operating frequency > 10 MHz where the secondary return can be connected to the structure with a lot of points.

PL - 4.4.2 - 4

Command signal wiring:

In general, the wiring for the command signals shall be implemented using 26 gauge twisted pair wire from the branch module. Command signal with rise times $\leq$ 200 µs which are routed through harness paths common to signal wires with susceptibility thresholds less than 10 V and less than 10 ms pulse response time, shall be shielded.

PL - 4.4.2 - 5

Each power line shall be electrically isolated with a dedicated return.

4.4.2.2 Serial digital data acquisition, serial digital commands and low level commands grounding

PL - 4.4.2 - 6

Serial digital data acquisition and command signals shall be carried on shielded twisted pair wires and shall use structure as signal reference. Receiver shall be isolated from the primary ground ; emitter shall be ground referenced.

Low level commands shall also be carried on shielded twisted pairs.

4.4.2.3 Digital relay acquisitions, and relay commands grounding

PL - 4.4.2 - 7

Digital relay acquisitions and relay commands shall be completely electrically isolated with dedicated return.

4.4.2.4 Bi-level acquisitions grounding

PL - 4.4.2 - 8

Bi-level acquisitions shall use secondary power.

4.4.2.5 Thermistors acquisition and heaters commands grounding

PL - 4.4.2 - 9

Thermistors/heaters lines shall be electrically isolated. Thermistors acquisitions shall use twisted shielded pair wires. Heaters commands shall use twisted pairs.

4.4.2.6 Analog signals grounding

PL - 4.4.2 - 10

Each analog acquisition line shall use a dedicated return which will be grounded at user end.

Analog signals at interfaces shall be arranged to allow the use of twisted shielded wire.

Exception for high accuracy, analog acquisition which shall not be grounded.

4.4.2.7 EED

4.4.2.7.1 General EED Wiring.

PL - 4.4.2 - 11

All EED wiring circuits shall use double shielded twisted pair wires. The return side of the circuits shall be grounded at the power supply; exceptions shall be submitted to Satellite Contractor for approval. The shields shall be grounded at the connector backshell at all connectors.

4.4.2.7.2 EED Circuit Shields

PL - 4.4.2 - 12

Firing circuit shields shall provide a minimum of 20 dB attenuation from 30 kHz to 18 GHz. All firing circuit bundles shall use a double shielding configuration that has zero aperture from the power control unit to the electroexplosive devices (EED). The inner shield on these harnesses shall be the regular flat braided shield of the cables, which provides a minimum coverage of 90%. The outer shield shall be an overall shield to provide complete coverage from end to end. There shall be no gaps or discontinuities in the shielding, including the terminations at the back faces of the connectors. Electrical continuity and isolation of the inner and outer electroexplosive circuit shields shall be maintained.

4.4.2.7.3 EED Cabling

PL - 4.4.2 - 13

Bundles shall be manufactured such that several electroexplosive device circuits are contained in a common shielded bundle. Splices within the bundles are forbidden. When breaking of a circuit is required, a mating connector pair shall be provided. All bundles shall be routed as close to the conductive metal ground plane of the platform/payload structure as feasible, with provision for tie-downs a maximum of 15 mm apart.

4.4.2.7.4 EED Circuit Connectors

PL - 4.4.2 - 14

Connectors used in the electroexplosive bundles shall be of the circular MIL-C-26482 Series 2 type with conductive nickel slated metal shell bodies. These shall be self-locking and compatible with the mating equipment interface connectors. There shall be only one wire per pin, and in no case shall a connector pin be used as a terminal or a tie-point for multiple connections.

PL - 4.4.2 -20

All connectors used with the electroexplosive devices shall:

- be approved by the procuring activity,
- have a stainless steel shell or suitable electrically conductive finish,
- complete the shell-to-shell connection before the pins connect,
- provide for 360° shield continuity.

There shall be only one wire per pin, and in no case shall a connector pin be used as a terminal or a tie-point for multiple connections.

The source circuits shall terminate in a connector with socket contacts.

Connectors shall be selected such that they are not subject to demating when exposed to the maximum anticipated environment.

Connectors that twist and lock into position are preferred.

4.4.2.7.5 EED Circuit Redundant Wiring

PL - 4.4.2 - 15

Redundant EED circuits shall be wired and routed in separate wire bundles where required. Separation of wire bundles shall be maintained to the maximum extent possible, including the use of separate connectors if feasible.

4.4.2.7.6 EED Harness Electrical Bonding

PL - 4.4.2 - 16

The EED harness hardware shall be bonded to the spacecraft local panel ground reference through the mating equipment chassis. Each connector and shield termination shall be assembled (mated) and tested to insure a maximum resistance of 10 mΩ (between connector or shield and PGR).

4.4.2.7.7 EED Harness identification.

PL - 4.4.2 - 17

Each EED harness shall be positively identified by part number and serial number. Identifying information may be attach directly to the wiring harness by a sleeve attach to the harness. Other forms of identification such as mylar nameplates, metal nameplates, metal stampings, vibropeening, acid, electrical or mechanically etched, embossed, forged, brazed, cast or molded methods of manufacture shall not be used.

4.4.2.7.8 EED Harness Records

PL - 4.4.2 - 18

Each EED wiring harness assembly shall have inspection and test records maintained by appropriate number and with a connector mate log maintained for all connectors from initial assembly and test throughout unit and satellite integration and acceptance test lifetime.

4.4.2.8 Shielding

PL - 4.4.2 - 19

The general shielding guideline shall be such that each line function is evaluated to determine if it is possible to cable the line as an unshielded wire.

The shielding guidelines are as follows :

a. All telemetry lines shall be shielded individually or in functional groups.

b. Unit interfaces which interconnect with sensitive or susceptible circuitry or are proximate to sensitive or susceptible circuitry shall be shielded.

c. All command lines may use shielded wiring (except the digital command lines which may use unshielded wires).

d. Regulated power lines shall use shielded wire.

e. Shields shall not carry currents (except RF).

f. Shields shall be jacketed to provide isolation from ground and chassis except at designated points.

g. Shields shall provide a minimum of 90 percent coverage (e.g. tinned copper braid and woven copper).

h. All pyrotechnics lines shall be double shielded. Firing circuits shielding shall provide a minimum of 20 dB attenuation from 30 kHz to 18 GHz. All firing circuit harnesses shall use a double shielding configuration that has zero aperture from the DHU to the electroexplosive devices (EED). There shall be no gaps or discontinuities in the shielding, including the terminations at the back faces of the connectors. Electrical continuity and isolation of EED circuit shields shall be maintained. All electrical cables may be fabricated such that several EED circuits are contained in a common shield cable bundle. There shall be no splices within the cable bundles.

i. Each end every cable or waveguide going through the Payload shall have shield bonded to the payload structure over 360 deg.

4.4.3 HARNESS REQUIREMENTS

PL - 4.4.3 - 1

Circuits having incompatible electromagnetic interference characteristics shall be segregated in cabling and connectors to the maximum extent possible to minimize interference coupling.

Separation is necessary for the following circuits categories :

DC power and command circuits

Digital signals (0 - 5 V)

Analog signals (0 - 5 V)

Electro Explosive Devices

Radio Frequency lines

Wires carrying proprietary data

MIL-STD-1553B bus

4.4.3.1 Pins assignment

PL - 4.4.3 - 2

If two or more circuit categories must share a connector, pin assignments shall be made to provide a maximum of isolation in the connector and facilitate separation of the wiring external to the connector. A minimum of two pins separation shall be used.

4.4.3.2 Harness design

PL - 4.4.3 - 3

Signal control interface harnesses, in general shall be constructed using twisted shielded wires. Signal return lines shall be shielded. However, some pulse commands and relay driver lines may not be shielded in order to save weight on the satellite. In this case, EMI analysis shall be performed to ensure EMC/ESD requirement compliance.

PL - 4.4.3 - 4

Neither the structure nor any cable shield shall be used to carry power bus return. This will minimize common mode noise input to the units.

PL - 4.4.3 - 5

For sensitive and critical functions, another shield shall be added that is continuous from the backshells of each of the associated unit connectors.

PL - 4.4.3 - 6

All shields shall be terminated to chassis external to the unit enclosure. Where external cables penetrate the enclosure of the satellite main body, they shall be terminated to the structure externally.

PL - 4.4.3 - 7 a

The following general rule on wiring shall be applied unless special approval has been granted:

a. wiring shall be sized to provide a maximum voltage drop for power lines of 240 mV between source and user. For telemetry lines, this value can be as high as 1.0 V depending on the telemetry system parameter.

b. wiring size and shield shall be :

- No 20, 22 and 24 AWG twisted shielded pairs for secondary power distribution. If flexible wiring is utilized, it shall be EMI controlled, and in accordance with MIL-P-50884B.
- No 26 AWG single through nine conductors twisted shielded wire for control and monitor.

PL - 4.4.3 - 8

For explosive parts, all circuits shall use twisted double shielded pair wires. The return side of the circuits shall be grounded at the power supply. Shield shall be grounded at both ends of the harness.

PL - 4.4.3 - 9

When feasible, redundant wiring shall be routed in separate wire bundles. Separation of wire bundles shall be maintained to the maximum extent possible, including the use of separate connectors, if necessary.

PL - 4.4.3 - 10

Spare wires shall not be provided in wiring harness terminating in removable crimp-contact connectors.

PL - 4.4.3 - 11

EMI controls on printed flexible wiring includes shielding and guard conductors. A circuit pattern may have shields on one or both sides. Additional shielding may be used on circuit edges if necessary. Top and bottom shielding may be added as solid conductive material connected and tied electrically. Insulation layers (covercoats) are normally used as outside layer. Guard conductors are effective in reducing adjacent trace coupling (crosstalk).

PL - 4.4.3 - 12

Every cable submitted to the external environment (i.e external to the Payload Instrument Module) shall be overshielded.

4.4.4 ISOLATION

PL - 4.4.4 - 1

Onboard power, supplied by inverters, converters and transformer isolated power supplies, shall be defined as secondary power and shall be referenced to the mechanical ground at one location, at the secondary power source, via the shortest possible low impedance path. For those types of equipments, secondary power return is connected to the mechanical ground. In this case, the DC resistance between secondary power return line and mechanical ground shall be less than 2.5 mΩ.

Remote sensors, pressure sensors, magnetometers, or assemblies without internal power supply may be exempt from the above requirement and secondary power return is isolated from the mechanical ground.

PL - 4.4.4 - 2

Primary power :

All the users shall maintain an electrical isolation of at least 1 MΩ shunted by not more than 50 nF between:

- primary power positive and chassis,
- primary power return and chassis,
- primary power return and secondary power return.

PL - 4.4.4 - 3

Secondary power:

except secondary single point referenced, all the sources and loads shall maintain an electrical isolation of at least 1 MΩ shunted by not more than 50 nF between:

- secondary power positive and chassis,
- secondary power return and chassis,
- primary power return and secondary power return.

At no time the satellite will impose more than 1.5 V DC and 1 V peak to peak, from 15 kHz to 180 KHz, falling to 0.2 V at 15 MHz, between the primary return and secondary return.

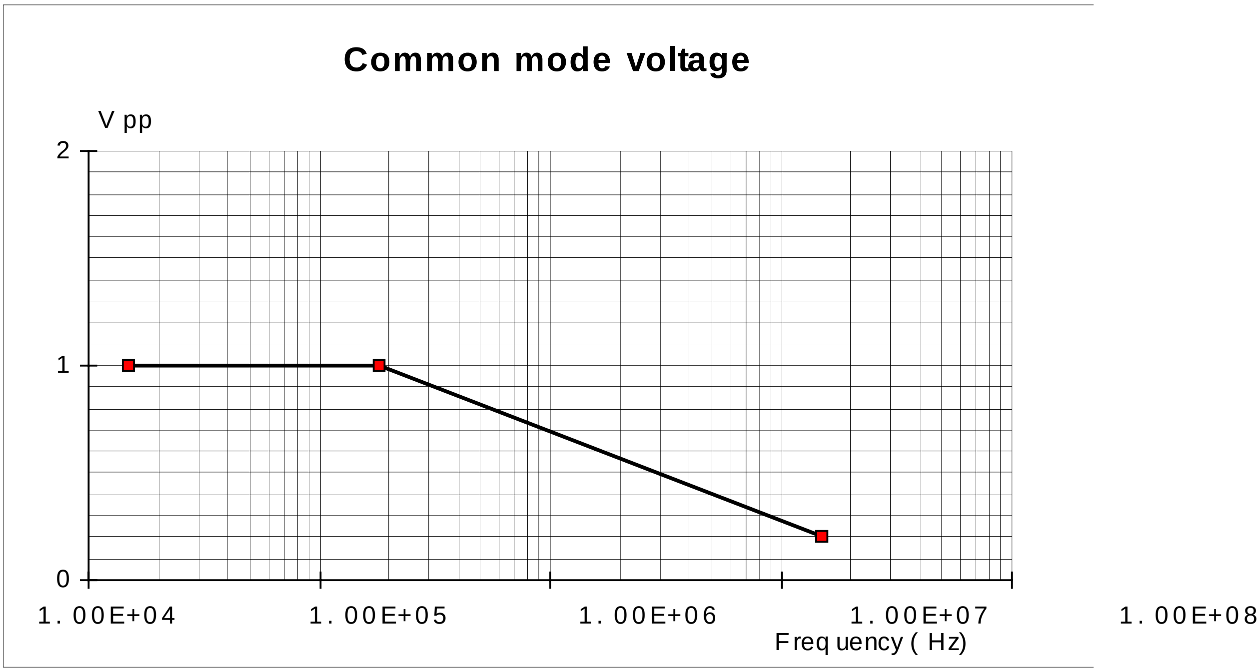

Figure 4.4-4 : Common mode voltage

PL - 4.4.4 - 4

Differential interface circuits between instrument units shall be designed to maintain a common mode isolation as described on the Figure 4.4-5.

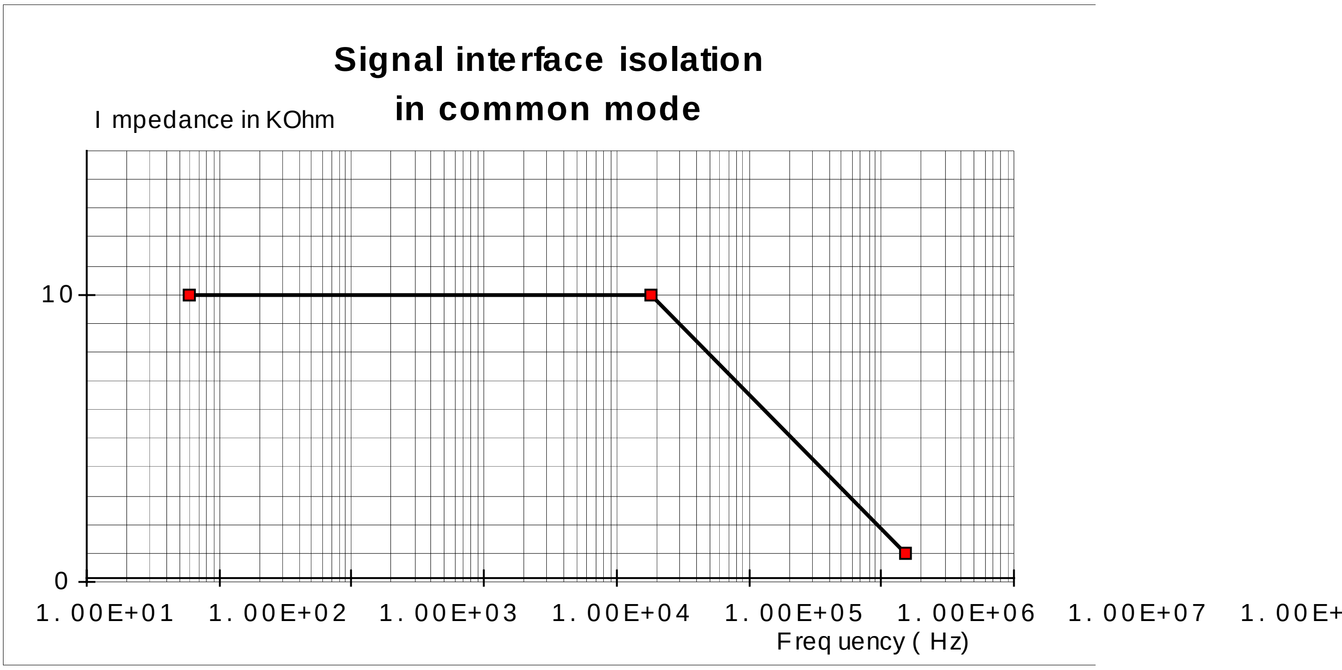

Figure 4.4-5: Signal interference isolation, in common mode

4.4.5 CONNECTORS TYPE AND KEYING

PL - 4.4.5 - 1

Use of micro-D connectors is not allowed.

PL - 4.4.5 - 2

The MIL-STD-1553B bus connectors shall be dedicated (no sharing of connectors with any other signal) and segregated (one connector for nominal bus and one for redundant bus) on each unit using this bus.

PL - 4.4.5 - 3

Deleted

PL - 4.4.5 - 4

The payload shall employ connector keying, where required, to prevent accidental mismating of connectors. The harness mating connectors shall be configured to properly maintain this keying requirement The harness shall be designed to interface with the mating connectors of the spacecraft electrical units with provision for unit and harness serviceability after assembly. Access shall be provided which supports safe and proper mating and demating of all connectors after spacecraft integration.

PL - 4.4.5 - 5

Electrical connectors shall be electrically bonded to the metallic case in which they are installed to provide electrical resistance of less than 2.5 mOhm. Except for cases otherwise approved by the satellite contractor, the connector housing shall be bonded to the chassis via a strap with a resistance of less than 10 mOhm.

4.5 COMMAND AND CONTROL DESIGN REQUIREMENTS

4.5.1 GENERAL CONVENTIONS

PL - 4.5.1 - 1

The following conventions shall be used at payload level.

4.5.1.1 Word and byte convention

A word is composed of 16 bits.

A byte is composed of 8 bits.

The numbering of the bits inside a byte shall be as follows :

Integer decimal value	bit B0 (MSB)	B1	B2	B3	B4	B5	B6	B7 (LSB)
1	0	0	0	0	0	0	0	1
128	1	0	0	0	0	0	0	0
255	1	1	1	1	1	1	1	1

Table 4.5-1: Bit numbering inside a byte

Note : there is an equivalent convention for a word, yielding to B0 as MSB and B15 as LSB.

4.5.1.2 Level 1 and 0 Conventions

Convention for direct commands :

TC 1 level shall reflect the ON or ENABLE command to the concerned circuit:

active level of a relay,

closed contact of a switch.

TC 0 level shall reflect the OFF or DISABLE command to the concerned circuit:

quiescent level of a relay,

open contact of a switch.

Convention for serial commands:

when applicable, logic one voltage (TC 1) level shall reflect the ON or ENABLE command to the concerned circuit, MSB shall be transmitted first.

Convention for direct acquisitions:

TM 1 level shall reflect the ON or ENABLE status of the concerned circuit:

closed contact of a relay,

logic one of a status.

TM 0 level shall reflect the OFF or DISABLE status of the concerned circuit:

open contact of a relay,

logic zero of a status.

Convention for serial acquisitions:

when applicable, logic one voltage (TM 1) level shall reflect the ON or ENABLE status of the concerned circuit, MSB shall be transmitted first.

4.5.2 PROCESSOR TURN-ON TIME

PL - 4.5.2 - 1

Full reset, start up, and initialization maximum duration shall be provided in their IDS for payload with flight electronic processor inside.

There shall be no polling of these units until they are declared operational by the Ground Segment.

4.6 MATHEMATICAL MODELS INTERFACES REQUIREMENTS

PL - 4.6 - 1

The delivered mathematical models shall comply with the following requirements (section 4.6.1 to 4.6.3).

4.6.1 MECHANICAL MATHEMATICAL MODEL INTERFACES REQUIREMENTS

4.6.1.1 General

This section presents the general requirements for the delivered mathematical models which will be mounted on PROTEUS platform Finite Element Model (FEM).

The system structural analysis will be performed with the finite element code MSC/NASTRAN.

Therefore, all delivered mathematical models are required in NASTRAN format. These models will be used to perform system analyses.

The Payload Supplier must provide two kinds of model: a physical model and a reduced model (condensed or modal model).

preliminary physical and reduced models	due date: at the beginning of the satellite phase B
detailed physical and reduced models	due date: at the beginning of the satellite phase C/D
one correlated reduced model	due date: after payload qualification test

The models shall be in accordance with the following items defined in the next paragraphs:

- utilisation of versions compatible with version 70 of the NASTRAN Code,
- the basic axis system and the payload system,
- the rules of modelisation,
- the interface nodes: co-ordinates, boundaries conditions, number of degrees of freedom (d.o.f.) and identification number of the GRID cards,
- the loaded nodes: number of d.o.f. and identification number of the GRID cards,
- the conditioning of the matrices,
- the form of the delivery.

For information, the products of inertia are defined with the following sign convention :

$I_{xy} = -\int x\,y\,dm$; $I_{yz} = -\int y\,z\,dm$; $I_{xz} = -\int x\,z\,dm$

4.6.1.2 General Requirements

4.6.1.2.1 Axis systems and payload system

The basic axis system of the payload model shall be the satellite reference frame (show section 1.4).

The unit system is the International System (meter, kilogram, second, radian).

Local axis systems are prohibited for the definition of the co-ordinates and the degrees of freedom (displacements) of all the conserved nodes (loaded and interface ones).

All local axis systems must be defined wrt the basic one, and their number limited to around 5.

4.6.1.2.2 Rigid bodies

Any rigid body or rigid element connecting **interface nodes between them** is prohibited.

If an interface node is connected by a rigid element to non interface nodes, the d.o.f of the interface node must be the independent (or non constrained) d.o.f.

4.6.1.2.3 Data and capabilities requested

The physical finite elements model shall contain all the data necessary to perform eventually :

a static analysis

a modal analysis (eigen modes calculation)

a sine response analysis

a thermoelastic analysis (only Coefficient of Thermal Expansion (CTE) and reference temperature).

Concerning the thermoelastic analysis, the finite element model shall be such that it does not introduce stresses higher than 1 MPa in the payload primary structure under the following loading case :

payload with isostatic boundary conditions

coefficient of thermoelastic expansion set to 20 10^{-6} $°C^{-1}$ (only for this test) on all parts of the model

homogeneous increase of temperature of +100°C applied to the whole model.

One of the major condition necessary to fulfil this requirement is that there will be no rigid body with length > 0 connecting 2 nodes of the payload primary structure.

4.6.1.2.4 Masses representation

The masses representation (choice between concentrated masses and distributed masses) is to be defined by the supplier in order to fit as well as possible with the actual payload masses distribution. However, the meaning of the masses representation cards will be explained by comments cards.

In case of distributed mass, the following data are requested :

structural mass value (kg/m, kg/m^2 or kg/m^3 depending on the element)

non structural mass values (kg/m, kg/m^2 or kg/m^3 depending on the element)

total mass value (kg/m, kg/m^2 or kg/m^3 depending on the element).

The model rigid mass along the 3 axes must have the same value.(use of CMASS2 elements could generate problems).

4.6.1.2.5 Results of the non condensed model (physical model)

The following data are requested:

description of the model with plots of the mesh showing **clearly** the numbering of the most important nodes (conserved, loaded, interface, ...) and elements

results of the eigen mode analysis performed under free-free boundary conditions (frequencies of the 6 rigid modes + frequencies of the 3 first elastic modes)

results of the eigen mode analysis performed with the specified boundaries conditions (frequencies, effective masses and inertia, participation factors, plots of mode shapes) for the significant modes

masses, inertia, centre of gravity of the model compared with the data of the real mass breakdown

results of the test defined § 4.6.1.2.10 and § 4.6.1.2.3, allowing to state on the acceptability of the F.E.M. with regard to thermoelastic analysis requirements.

4.6.1.2.6 Results of the condensed model

The results considered in this paragraph correspond to the condensed model with the specified boundaries conditions. For the free-free condensed model, only the values of the 9 first frequencies are required.

The following data are requested:

same results and plots that for the uncondensed model, excepted thermoelastic test

In addition, a table of comparison to demonstrate the agreement between the condensed and the uncondensed models, containing for both models: the frequencies, the effective masses and inertia, the participation factors up to 150 Hz at least or until the residual masses and inertia are less than 20% (or higher if test sequence at sub-system level foresees larger frequency band).

In the frequencies range defined above, the requested representativity for the condensed model modal characteristics with regard to the physical model ones shall be:

±5% on frequencies

±15% on effective masses and inertia.

4.6.1.2.7 Data about the condensation

"Conserved nodes (or d.o.f.)" means the loaded nodes (or d.o.f.) plus the interface ones.

The following data and deliveries are requested whatever form of the delivered model:

the partitioning vector to expanse the condensed matrices (size nc x nc) to the physical matrices (size nt x nt) under the form of a column vector (DMI NASTRAN vector) where:

nc is the number of conserved d.o.f.

nt is the number of conserved nodes multiplied by 6.

the conserved GRID cards package: each conserved node shall be present on a GRID card. All the d.o.f. of the conserved nodes which do not appear in the matrices are to be permanently constrained to zero directly on the GRID card.

if the interface nodes are loaded by any mass or inertia, that shall be clearly indicated,

the ASET 1 cards package

No resequencing process must be used for the creation of the condensed matrices. It is required to use the following NASTRAN parameter:

PARAM,NEWSEQ,-1

4.6.1.2.8 Plotel cards package

Plotel elements connecting the conserved nodes are required to plot the undeformed and deformed structures with sufficient representativity.

The identification number of the Plotel cards will be taken between the same limits that for the conserved nodes for the payload.

To make more representative the plots of the substructure, some nodes could be especially conserved, but **with the 6 d.o.f. blocked** as they would be used only for the figures. They must fulfil all the requirements of the conserved nodes.

4.6.1.2.9 Check of the delivered condensed model

The payload supplier shall verify that the stiffness matrix is well conditioned by the herebelow tests and shall show the results of these tests.

A modal analysis has to be performed using large mass and NASTRAN SUPORT card in order to extract rigid modes, elastic modes and effective masses. The strain energy of the rigid modes and the conditioning parameter ε have to be low:

STRAIN ENERGY $< 10^{-3}$ J (Joule)

ε $< 10^{-8}$

The previous modal analysis with large mass can be replaced by a constraint check performed when the condensed model is in free-free configuration. The test to be performed is to calculate the strain energy as defined below for each rigid mode Φ_R:

$$S.E. = ½ .[\Phi_R]^T.[K].[\Phi_R]$$

where:

- $[\Phi_R]$ is a vector for one of the six rigid modes
- $[\Phi_R]^T$ the transposed vector of $[\Phi_R]$,
- $[K]$ is the model stiffness matrix

A unit rigid body displacement is applied on the whole structure on the 6 DOF (3 translations and 3 rotations).

The strain energy computed for each of these rigid body motions shall be:

$$< 10^{-3} \text{ J}$$

This last test shall be performed without SUPORT card.

This Strain Energy Check is used to identify constrained or grounding problems in a FEM model and ensure that the model is free-free.

This test can be performed using NASTRAN DMAP rigid body checks, or by a specific NASTRAN DMAP.

A free-free modal analysis has to be performed without large mass, without SUPORT card and without rigid interface in order to extract the six rigid modes. The frequency of these modes divided by the first elastic mode shall be :

$$< 10^{-4}$$

Moreover, the 3 first elastic free-free frequencies will be provided.

All these tests must be performed on the condensed matrices or on the physical model re-read on the delivered tape.

All the models not in accordance with these tests will be rejected.

4.6.1.2.10 Check of the delivered full model

Idem § 4.6.1.2.9

4.6.1.2.11 Magnetic tape characteristics

The package defined here above will be provided on one of the following magnetic data storage:

Streamer cartridge 150 Mbytes , SGI , UNIX , tar format

DAT 4mm (60, 90 or 120 m length) SGI , UNIX , tar format

Floppy disk 3 «1/2 DOS formatted ASCII code

The command used for the creation of the tape archive is to be delivered with the tape delivery.

If data are compressed, the uncompress software must be provided on the magnetic tape .

4.6.1.2.12 Associated documentation

The technical note delivered with the tape shall include all the items mentioned in chapter 2:

the results of the non condensed model (§ 4.6.1.2.5),

the results of the condensed model (§ 4.6.1.2.6),

the results of the tests about the matrices conditioning (§ 4.6.1.2.9),

plots of each substructure showing clearly the numbering of the nodes and of the elements of the physical model,

plots performed with the PLOTEL cards showing the conserved nodes,

a scheme showing the various local axis systems w.r.t. the basic one,

a description of each substructure and of the way to modelise,

an explanation of the modelisation hypotheses and of the equivalent representations,

the detailed mass breakdown of the model compared with the real one and indications of:

- the representation of the masses: concentrated or distributed,
- the considered offsets and rigid bodies between the masses and the structure,
- a table summarising the main structural characteristics of each substructure

a summary of the tape contents.

4.6.1.3 Requirements for the dynamic models

4.6.1.3.1 Physical models

4.6.1.3.1.1 General

The authorised NASTRAN elements are provide in the table hereunder.

Item	connectivity card	property card	material card
1D elements		PROD, PBAR, PBEAM	MAT1
2D elements	CTRIA3, CQUAD4	PSHELL	MAT1, MAT2, MAT8
3D elements	CPENTA, CTETRA, CHEXA	PSOLID	MAT1 MAT9
Masses	CONM1, CONM2, CMASS2	-	-
Local stiffness and connection	CELAS1, CELAS2	PELAS	-
Rigid element & constraint	RBAR, RBE2, MPC, RBE3	-	-
Miscellaneous	PLOTEL	-	-
NASTRAN parameter	PARAM AUTOSPC YES	-	-

Table 4.6-1: Authorised NASTRAN cards

The following NASTRAN cards are to be prohibited:

NASTRAN prohibited cards	
NASTRAN parameters *	PARAM BAILOUT PARAM K6ROT PARAM MAXRATIO PARAM EPZERO
NASTRAN parameters **	PARAM WTMASS
NASTRAN cards	CQUAD8, CQUADR, CTRIAR CTRIA6, EGRID

Table 4.6-2: Prohibited NASTRAN cards

- * parameters affecting model conditioning
- **parameters affecting the other models during FEM assembly

In case of necessity to use other cards than the authorised elements, the supplier will have to ask for the agreement of ALCATEL SPACE.

Remarks concerning FEM rules:

It is requested to use elements RBE2 with zero length and MPC with zero length (to simplify the use for thermoelastic analyses)

The use of MPC card is forbidden to link interface nodes between substructures. The interface shall be performed with CELAS or zero length RBE2.

The interface nodes do not have to be dependent nodes of rigid bodies

The interface nodes do not have to be linked together by a rigid body

Only RBE3 with simply supported independent nodes will be allowed (independent nodes: DOF 123 (456 forbidden) , reference node: No restriction on dependent DOF)

4.6.1.3.1.2 Size limitation

The physical models are limited to 3000 nodes and 3000 elements.

4.6.1.3.1.3 List of the data to be supplied

The model will be supply on magnetic tape with the characteristics given on § 4.6.1.2.11.

The following items will be provided on the tape:

the ASET1 cards,

the CORD2 cards,

the complete Bulk Data Deck gathered in one file.

Preferably the BDD will be built in order that all the cards defining the same substructure will be gathered together in the file. Enough comments will be added to make easy the understanding of the file.

4.6.1.3.2 Condensed physical models

4.6.1.3.2.1 General

The nodal points and degrees of freedom will be defined as follows:

the degrees of freedom will be related to nodal points (6 dof maximum per nodal point ordered as follows: T_x, T_y, T_z, R_x, R_y, R_z - T for translation and R for rotation),

nodal points will be supplied in ascending numerical order,

nodal points co-ordinates will be supplied according to the satellite reference axes system (see §4.6.1.2.1). **Local co-ordinates system are not acceptable**.

nodal points must be kept at the location of the accelerometers foreseen for the sine test vibrations

nodal points must be chosen in order to plot the deformed shapes of the structure with a sufficient representativity

These rules will determine the numbering of the rows and columns of the mass, stiffness and damping (if supplied) matrices.

4.6.1.3.2.2 Size limitation

The maximum size of the stiffness, mass and damping (if supplied) matrices including the interface dof is 500 x 500.

4.6.1.3.2.3 List of the data to be supplied

The model will be supply on magnetic tape with the characteristics given on § 4.6.1.2.11.

The following items will be provided on the tape:

the ASET1 cards package,

the DMI partitioning vector,

the conserved GRID cards,

the PLOTEL cards,

the stiffness, mass and damping (if supplied) matrices in NASTRAN format OUTPUT4 option BCD non sparse, with D23.16 format for version 68 and following.

4.6.1.3.3 Modal models

4.6.1.3.3.1 General

The dynamic behaviour of the structure is described by the reduced stiffness and mass matrices, relative to the elastic cantilevered modes and rigid body modes of the structure.

The motion of the structure is represented as a superposition of the rigid body and elastic cantilevered motions.

The rigid body motion is represented by the six rigid body modes shapes referenced to unity at the structure interface. The elastic motion is represented by the elastic cantilevered structure interface modes shapes.

Thus:

$$(X) = \begin{pmatrix} \Phi_{e(p \times n)} & \Phi_{R(p \times 6m)} \\ 0_{(6m \times n)} & I_{(6m \times 6m)} \end{pmatrix} \begin{pmatrix} q \\ X_{i\,i} \end{pmatrix} \quad \begin{matrix} \text{cantilevered modal co-ordinates} \\ \text{payload interface motion} \end{matrix} \qquad (1)$$

where:

- n is the number of elastic modes
- p is the number of dof of the source model matrices
- Φ_R are the rigid body modes shapes
- Φ_e are the elastic cantilevered modes shapes (normalized such that $\Phi_e^t M \Phi_e = I^*$)
- X is the motion of the structure degrees of freedom

Using the above formulation, the modal equations of motion are:

$$(M_{GEN})\ddot{Q} + (C_{GEN})\dot{Q} + (K_{GEN})Q = F_{GEN}$$

where:

$$Q = \begin{pmatrix} q \\ X_i \end{pmatrix}$$

* At for transposed A and I for identity matrix.

or in partitionned formulation:

$$\begin{pmatrix} \mu & M_{el} \\ M_{el}^t & M_I \end{pmatrix} \ddot{Q} + \begin{pmatrix} 2\mu\xi\omega & 0 \\ 0 & K_I \end{pmatrix} \dot{Q} + \begin{pmatrix} \mu\omega^2 & 0 \\ 0 & K_I \end{pmatrix} Q = \begin{pmatrix} 0 \\ F_I \end{pmatrix}$$

where:

K_I **is the condensed stiffness matrix at interface**

M_I is the condensed mass matrix at interface

B_I	is the condensed damping matrix at interface
M_{eI}	is the elastic coupling mass matrix
$(\mu) = \Phi_e^t M \Phi_e$	is the generalized mass matrix (normalized to unity)
$(2\mu\xi\omega) = (2\xi\omega)$	is the generalized damping matrix
$(\mu\omega^2) = (\omega^2)$	is the generalized stiffness matrix
(F_I)	are the structure interface loads.

The size of M_{GEN}, C_{GEN} and K_{GEN} matrices is N rows by N columns where N is the number of elastic modes increased of the six interface rigid body degrees of freedom. These matrices must be diagonal and elastic modes with no modal mass are forbbiden.

4.6.1.3.3.2 Restitution matrices

For modal data delivery, displacement restitution matrix is necessary to provide structure internal responses. This matrix provide analytical relationship between the internal responses and the modal generalized parameters. This matrix must be a subset of the transformation matrix (see equation (1)) used to reduce the mass and stiffness matrices.

The equation is:

$$(X) = DTMQ$$

The restitution matrix must containt at least:

Nodes at the location of the accelerometers foreseen for the sine test vibrations

Nodes allowing to plot the deformed shapes of the structure with a sufficient representativity

Any other nodes considered as important by the supplier.

4.6.1.3.3.3 Matrices size and output requirement limitations

The maximum size of the stiffness, mass and damping (if supplied) matrices including the interface dof is 500 x 500.

The number of restitution parameters must be less or equal to the number of dof allowed for physical condensed model.

The delivered modal model will contain internal nodes representative to the main parts of the subsystem in order to allow the exploitation of dynamic responses inside of modal model (Notching possibilities).

For modal model, only the modes having their effective mass (or inertia) greater than 0.5 % of the total subsystem mass will have to be retained in model delivery.

4.6.1.3.3.4 List of the data to be supplied

The model will be supply on magnetic tape with the characteristics given on § 4.6.1.2.11.

The following items will be provided on the tape:

the list of dummy nodal points (see remark below), the list of dummy degrees of freedom (see remark below),

the ASET1 cards package,

the DMI partitioning vector,

the restitution GRID cards,

the PLOTEL cards,

the stiffness, mass and damping (if supplied) matrices in NASTRAN format OUTPUT4 option BCD non sparse with D23.16 format for version 68 and following,

the displacement restitution matrix format OUTPUT4.

Remark:

To allow provision of modal model in the same way as condensed physical model, definition of dummy nodal points and dummy degrees of freedom is necessary. These points and degrees will be defined as follows:

n nodal points (with 1 dof) associated to the n elastic modes (numbered in the range defined in § 5.1). For each nodal point, the co-ordinates are (1., 0., 0.).

m nodal points (with 6 dof) associated to each structure interface point. Their number have to be greater than n and must be chosen in the range given in § 4.6.1.5.1. Their co-ordinates are defined in § 4.6.1.5.2.

The such defined number of degrees of freedom will be the same as the reduced mass and stiffness matrices size (N).

4.6.1.4 Requirements for correlated models

4.6.1.4.1 Purpose

The purpose of the correlated models is to perform the System dynamic analyses to prepare the satellite system sine tests and to confirm the its behaviour in flight by means of a transient response and/or a Coupled Analysis with the launch vehicle.

The models must be representative of the last definition of the hardware and of the tests results. For the correlation with the tests the goals are:

$< \pm 5$ % on the frequencies

for the significant modes and mainly for the first ones.

For this delivery:

the physical F.E.M. are requested,

a comparison between the test results and the test predictions of the correlated model has to be provided.

4.6.1.4.2 Comparison between predictions and tests

The supplier of the payload shall provide the comparison of the frequencies and amplifications measured during the low level runs and the ones predicted by the correlated model for :

each main mode,

the point with the highest response in the correlated F.E.M.,

instrumented point with the highest response during the test of each substructure,

4.6.1.5 Specific requirement for the payload

This chapter presents the requirements concerning the numbering range and the co-ordinates of the interfaces with the platform.

4.6.1.5.1 Numbering range of the payload

	Allowed Numbering Range			
	Grids, elements rigid bodies, MPC	Properties	Materials	Co-ordinate system
Payload	50001-90000	50001-90000	50001-90000	50001-90000

Table 4.6-3: Numbering Range of the payload

The physical F.E.M. and the condensed F.E.M. of the payload shall comply with the above general numbering requirement.

4.6.1.5.2 Interface with the platform model

This paragraph refers to the interface between the payload and the platform F.E.M.

All co-ordinates are expressed in the satellite co-ordinate system defined §4.6.1.2.1.

		Co-ordinates (m)		
I/F Node name	Grid Number	X	Y	Z
P1	50001	1.070	0.430	-0.430
P2	50002	1.070	0.430	0.430
P3	50003	1.070	-0.430	0.430
P4	50004	1.070	-0.430	-0.430

Table 4.6-4: Co-ordinates of the payload-platform I/F nodes

4.6.2 THERMAL MODELS

The need of thermal mathematical model is mission dependent.

In a standard approach, only respective ICD is required (payload thermal ICD containing the geometrical model for satellite analyses and platform thermal geometrical model for payload analyses).

If necessary, the exchange of electronic model will be discussed case by case.

4.6.3 CAD MODELS

All Computer Aided Design data exchanges between the Satellite Contractor and the Payload Supplier shall be based on CATIA V4.20 software .

4.7 SAFETY REQUIREMENTS

PL - 4.5.7 -1

deleted

PL - 4.7 -1

The Payload Supplier shall provide a safety analysis: • describing the hazardous items • identifying all hazardous events and associated causes • identifying all hazard controls and safety verification methods. • This analysis shall cover all phases from Payload Supplier delivery up to the launch site activities included. • This analysis shall include the GSE and operations. Nota : hazardous items can be pressurised items, pyrotechnic devices, ionizing and non ionizing radiation including lasers, batteries, lifting points, ignition sources…

PL - 4.5.7 -2

deleted

PL - 4.7 -2

The Payload shall be compliant with the Launch pad safety regulations in accordance with the contractual launch sites (depending on mission: launcher and launch site choice).

PL - 4.7 -3

Warnings and precautions relative to personnel and unit safety and hazards shall be specified in the payload handling, assembly, and test instructions.

END OF CHAPTER