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Space systems — Launch-vehicle-to-spacecraft interfaces

Systèmes spatiaux — Interfaces entre le lanceur spatial et le véhicule spatial

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14303 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Annexes A to E of this International Standard are for information only.

Introduction

ISO 14303 together with ISO 15863 and ISO 17401 forms a set of International Standards that describes fully the process for communicating information about launch vehicle (LV) to spacecraft (SC) interfaces.

Clauses 4 to 8 of this International Standard identify the parameters of an LV–SC interface, while clauses 9 and 10 define the methodology for verification of the interface by analyses, testing or both. Clause 11 defines the operations performed on the SC to prepare it for launch and the joint operations performed until it is installed on the LV.

Some sections of this document may refer to elements of the LV or SC, or elements of both, that are not applicable to their design characteristics. These sections should therefore only be considered if applicable.

The annexes give examples of the typical presentation format of the various interface parameters, as appropriate.

Space systems — Launch-vehicle-to-spacecraft interfaces

1 Scope

This International Standard specifies the interfaces between a launch vehicle (LV) and the spacecraft (SC) being launched, to provide LV and SC organizations with the necessary format for presenting the required technical data on existing and future interfaces. Its intended purpose is to minimize costs and reduce the risks from errors resulting from miscommunication. It does not limit the ability of LV or SC organizations to specify unique requirements.

2 Terms and definitions

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

2.1
spacecraft system
SC system
spacecraft bus, payload and all items supplied by the SC contractor in support of the launch effort

2.2
launch vehicle system
LV system
launch vehicle and associated launch services supplied by the launch services contractor or subcontractors or both

2.3
separation plane
plane where launch vehicle and spacecraft separation occurs

2.4
mating plane
interface between the spacecraft, or the spacecraft-provided payload adapter, and the launch vehicle

2.5
payload adapter
PLA
structure that mates the spacecraft to the launch vehicle, including the SC–LV separation system

NOTE The PLA is a part of the LV and does not separate with the SC.

2.6
usable volume
volume available to the payload within the launch-vehicle fairing or carrying structure

3 Abbreviated terms

The following abbreviations are used in this International Standard.

ACS	Attitude control system
CG	Centre of gravity
CLA	Coupled loads analysis
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
GSE	Ground support equipment
GTO	Geosynchronous transfer orbit
ICD	Interface control document
IRD	Interface requirements document
LEO	Low Earth orbit
LV	Launch vehicle
LVS	Launch vehicle system
MEO	Medium Earth orbit
PLA	Payload adapter
PLF	Payload fairing
RF	Radio frequency
SC	Spacecraft
SPF	Spacecraft processing facility
SPM	Solid propellant motor
SSO	Sun synchronous orbit
TBD	To be determined
TM	Telecommand

4 Mechanical interfaces

4.1 General

This clause identifies the mechanical interfaces between the SC and the LV. The methodology for verifying these interfaces is discussed in clauses 9 and10.

4.2 Mechanical configurations

The SC shall be mated to the LV by a payload adapter (PLA). If the LV provides the PLA, it shall include a pyrotechnically activated separation system. If the SC provides its own separation system, then a static bolted interface to the LV in accordance with 4.4 shall be used. During final launch processing and launch ascent, the SC shall be contained in a structure provided by the LV contractor.

4.3 SC characteristics

4.3.1 SC fundamental natural frequency

The SC's fundamental natural frequency in the longitudinal and lateral axes shall not be less than a value specified by the LV with the SC cantilevered from the mating plane.

4.3.2 SC mass properties

The SC-CG location, and the inertia properties for the x, y and z axes, shall be defined, and shall include the SC propellant-tanking characteristics to be used for the LV provider's sloshing analysis.

4.4 Usable volume

The SC shall be accommodated in the LV's usable volume, as characterized in annex A, without interference. The static envelope of the SC shall not exceed the usable volume, in order to ensure that there is no physical contact between the SC and the LV in a dynamic environment. Protrusions outside this usable volume may be allowed by mutual agreement between SC and LV contractors.

4.5 PLA interface

4.5.1 General

The LV–SC interface shall be characterized by the following elements, for each PLA type as shown in annex B, Figures B.1 and B.2.

4.5.2 LV-supplied PLA

The SC–LV mating surface for LV supplied PLA shall be defined by the following.

a) LV and PLA coordinate systems and relative angular orientation.

b) Physical configuration (including keyway location):

   1) material;

   2) coating;

   3) roughness;

   4) flatness and perpendicularity;

   5) stiffness

      — section area (mm^2)

      — applicable length (millimetres)

      — inertia (mm^4).

c) Clampband:

   1) geometry;

   2) material;

   3) roughness;

   4) allowable tension (newtons).

d) Other mating systems.

4.5.3 SC-supplied PLA

The SC–LV mating surface for SC-provided PLA shall be defined by the following.

a) LV and PLA coordinate systems and relative angular orientation.

b) Physical configuration:

   1) description of bolted interfaces (number, size, location of holes, type of bolts and torque value);

   2) material;

   3) coating;

   4) roughness;

   5) flatness and perpendicularity;

   6) stiffness

      — section area (mm^2)

      — applicable length (millimetres)

      — inertia (mm^4).

4.5.4 Separation actuators

Separation actuators (springs or pushrods) shall be characterized by

— number,

— location,

— nominal stroke (millimetres),

— reduced stroke (millimetres),

— maximum force (newtons), and

— energy per unit (joules).

4.6 Umbilical connectors and microswitches

The LV side of the interface shall have electrical connectors for electrical power and signals in accordance with clause 5. The LV connectors shall be adjustable in two planes to provide for alignment of the connectors during SC–LV mating. The SC shall have compatible connector halves. All connectors shall be characterized by

— supplier,

— number,

— location and mechanical interface,

— push-on load per connector (newtons),

— push-off load per connector (newtons),

— energy released by each plug (joules), and

— keying index.

4.7 Fluid connections

Fluid connections shall be defined to indicate

— location,

— size,

— fluid (gas or liquid) and flowrate,

— material,

— operating characteristics, and

— functional usage.

4.8 Encapsulated SC access

The LV shall provide access through the fairing or the carrying structure to the SC after encapsulation if physical access is required by the SC contractor.

A drawing shall be made with developed views of fairings and dual launch structures indicating authorized areas for access doors. The maximum number of doors authorized per SC with their corresponding size shall be defined.

5 Electrical interfaces

5.1 General

This clause identifies the parameters required to define electrical interfaces (power and signal) between the SC and LV.

5.2 Umbilical connectors

Umbilical connectors shall be defined by the following characteristics for the LV and SC sides:

— type and reference designator of connectors;

— number of pins available to the user;

— number of connectors;

— segregation between SC power and pyro-firing circuits;

— location;

— shielding;

— keying index.

5.3 Umbilical links

Umbilical links between the SC mated with the LV and the SC's electrical ground support equipment (GSE) shall be described as follows:

a) number and type of links;

b) limitations

- maximum voltage (volts)
- maximum current (amperes)
- power (watts)
- maximum one-way resistance or voltage drop (ohms or volts);

c) operating constraints

- number of functions
- types of function;

d) current at umbilical plug extraction;

e) conformance certification

- end-to-end resistance (ohms)
- line to ground insulation
- line-to-line insulation;

f) insertion of components.

5.4 Electrical commands dedicated to SC

5.4.1 General

Standard and optional commands generated by the LV and dedicated to the SC shall be listed with a description of the related characteristics.

5.4.2 Pyrotechnic commands

A general description of the electrical circuit associated with pyrotechnic commands shall be made. Optionally, a schematic drawing of the corresponding electrical circuits may be included. The following characteristics shall be indicated:

- time and number of commands;
- voltage (volts);
- pulse width (hertz);
- output insulation (ohms);
- characteristics of current delivered to pyro-charges (amperes);

- interval between two commands (seconds);
- insulation between wires and structure (ohms);
- protection of SC equipment;
- utilization constraints (inhibits) on the SC side.

5.4.3 Dry loop command

A general description of electrical circuits associated with dry loop commands shall be made. Optionally, a schematic drawing of the corresponding electrical circuits may be included. The following main electrical characteristics shall be indicated:

- number of commands available on-ground or in-flight;
- voltage (volts);
- resistance (ohms);
- insulation of the onboard circuit;
- protection on the SC side;
- utilization constraints on the SC side — maximum voltage and current (volts and amperes).

5.4.4 LV-generated SC electrical commands

A general description of the electrical circuits associated with LV-generated SC electrical commands shall be made. Optionally, a schematic drawing of the corresponding electrical circuits may be included. The following main electrical characteristics shall be indicated:

- number of commands available on-ground or in-flight;
- output voltage (volts);
- protection on the SC side;
- insulation between circuit and structure;
- Electromagnetic compatibility (EMC) — compliance with international specifications;
- utilization constraints on the SC side.

5.5 Separation status transmission

The separation status shall be indicated through the LV telemetry (TM) system modes of transmission available for separation status transmission as determined by

- microswitch or microswitches,
- break wires,
- dry loop,

and others.

5.6 In-flight telemetry

A description shall be made of the type of SC data that can be transmitted to the LV ground stations via LV TM on a standard basis or as options:

— dynamic, acoustic and thermal environment at the SC interface;

— specific internal SC measurements.

5.7 Power supply

A general description of electrical circuits associated with the electrical power supply shall be made. Optionally, a schematic drawing of the corresponding electrical circuits may be included. The following main electrical characteristics shall be indicated, together with the tolerances:

— voltage (volts);

— current (amperes);

— insulation on the SC side;

— protection on the SC side;

— EMC.

5.8 Earth potential (ground) continuity

The SC requirements for electrical continuity with respect to the Earth potential (ground) shall be expressed as follows:

— location of SC reference point or points;

— maximum resistance between SC metallic elements and the closest reference point;

— maximum resistance of SC interface separation plane.

6 RF/electromagnetic interface

6.1 General

This clause identifies the interface parameters required to define the RF interface and electromagnetic interfaces between the SC and LV. SC, LV and LV range RF emissions shall be jointly evaluated to determine compatibility and possible restrictions. For the methodology for verifying these interfaces, see clauses 9 and 10.

6.2 RF telemetry and command link

The LV contractor shall provide TM and command links between the corresponding antennae of the encapsulated SC and the SC system test equipment located in the SPF.

The link shall be enabled by RF window, pick-up antenna or other equivalent methods associated with the LV PLF. The link shall be available from the time of encapsulation of the SC on the LV until launch, except when RF transmission is limited by LV activities. The SC TM and command frequency bands shall not overlap the LV frequencies.

The following items shall be described by the LV:

a) TM

- bandwidth
- frequency
- transmitter power;

b) command destruct receiver (CDR)

- bandwidth
- frequency;

c) radar transponder (RT)

- bandwidth
- frequency
- peak power.

The RF window shall be characterized by

a) material,

b) location

- angular orientation
- station, and

c) insertion loss with frequency range.

6.3 LV-generated electromagnetic environment

The SC shall be compatible with the electric and magnetic fields generated by the LV (for the LV electromagnetic environment, see 8.6.1).

6.4 SC-generated electromagnetic environment

The SC-generated electric and magnetic fields shall be compatible with the electromagnetic susceptibility of the LV (for the SC electromagnetic environment, see 8.6.2).

7 Mission performance

7.1 General

This clause identifies the parameters used to define the LV performance as a function of the mission. Performance figures shall be associated with the necessary propellant reserve in the LV upper stage so that the injection of the vehicle into the required orbit or orbits is ensured before depletion of the upper-stage tanks, with a probability level to be defined by the LV contractor.

7.2 Geosynchronous transfer orbit (GTO)

7.2.1 Performance

The geosynchronous transfer orbit shall be defined in terms of the following osculating parameters at injection of the LV into orbit:

— inclination, i (degrees);

— perigee altitude, H_p (kilometres);

— apogee altitude, H_a (kilometres);

— argument of perigee, ω (degrees);

— equivalent true altitude at first apogee passage (kilometres);

— indicative value for the longitude of descending node with respect to the Greenwich meridian, Ω (degrees).

The orbit semi-major axis (a) and the eccentricity (e) may be used as an alternative to perigee and apogee altitudes.

The performance of the LV in the GTO shall be indicated, in kilograms, for the following:

— when standard PLA and carrying structures are used, indicate the mass available for SC only, with the distinction (if applicable) between single, double or multiple launch;

— when non-standard PLAs are used, indicate the mass available for SC and PLAs, with the distinction (if applicable) between single, double or multiple launch.

Optionally, detailed performance calculation may be given for sub-synchronous and super-synchronous geostationary transfer orbits.

7.2.2 LV injection accuracies

The injection accuracy of the LV into the GTO shall be described in terms of the GTO parameters in accordance with 7.2.1.

As minimal information, the standard deviations (1σ) of the orbital parameters shall be given as follows (optionally, a covariance matrix of the same parameters, or an equivalent set of LV state parameters, may be provided):

— Δi (degrees);

— ΔH_p (kilometres);

— ΔH_a (kilometres);

— $\Delta\omega$ (degrees);

— $\Delta\Omega$ (degrees).

7.2.3 Launch windows

If the LV or the launch site have launch window constraints, these shall be indicated as part of the standard launch window presentation.

For dual- or multiple-manifest SC launches, a standard daily launch window shall be defined for a period of one year (see annex C, Figure C.1). The SC windows shall include the standard window in order to be compatible with all potential co-passengers.

A reference orbit (including the descending node) and a reference time associated with the standard dual launch window shall be defined. The lift-off time or the time of first perigee passage shall be used as the reference time.

7.3 Elliptical orbits

7.3.1 Performance

The performance capability of the LV for typical elliptical orbits shall be described by means of graphs showing the variation of the payload mass as a function of the orbital parameters (H_p, H_a, i, ω)

As minimal information, the variation of the payload mass of the LV with apogee and perigee altitudes shall be given for typical values of the orbit inclination (see Figure C.2).

7.3.2 LV injection accuracies

Envelope values shall be given for the standard deviations (1σ) of the orbital parameters:

— Δi (degrees);

— ΔH_p (kilometres);

— ΔH_a (kilometres);

— $\Delta\omega$ (degrees);

— $\Delta\Omega$ (degrees).

7.3.3 Launch windows

If the LV or the launch site have launch window constraints, these shall be indicated.

7.4 Sun synchronous orbits (SSOs)

7.4.1 Performance

The performance capability of the LV for SSOs shall be described by means of graphs showing the variation of the payload mass as a function of orbit altitude, with indication of the corresponding inclination (see Figure C.3).

7.4.2 LV injection accuracies

As a minimum, envelope values for the standard deviations (1σ) of the SSO parameters shall be given as follows (optionally, a covariance matrix of the same parameters, or an equivalent set of LV state parameters, may be provided):

— Δa (kilometres);

— Δi (degrees);

— Δ(e sin ω);

— Δ(e cos ω);

— $\Delta\Omega$ (degrees).

7.4.3 Launch windows

For SSOs, launch window constraints are driven by the local time of the SC orbit and the LV performance. Any additional LV or launch site constraints shall be indicated.

7.5 Low Earth orbit (LEO) missions

7.5.1 Performance

The performance capability of the LV for low Earth circular orbits shall be described by means of graphs showing the variation of the payload mass as a function of orbit altitude (see Figure C.4).

7.5.2 LV Injection accuracy

The injection accuracy of the LV into a typical low earth circular orbit shall be described in terms of orbital parameters specific to circular orbits (see 7.3.2).

As a minimum, the standard deviations (1σ) of the typical circular orbit parameters shall be given; optionally, covariance matrix of the same parameters, or an equivalent set of LV state parameters, may be provided.

7.5.3 Launch windows

If the LV or the launch site have launch window constraints, these shall be indicated.

7.6 Escape missions

7.6.1 Performance

The performance capability of the LV for escape orbits shall be described by means of graphs showing the variation of the payload mass as a function of the square of the escape velocity, v_∞^2, for typical declinations of the escape velocity with respect to the equatorial plane (see Figure C.5).

7.6.2 LV Injection accuracy

The injection accuracy of the LV into a typical escape orbit shall be described in terms of parameters specific to escape missions.

As a minimum, the standard deviations (1σ) of the typical escape orbit parameters shall be given (optionally, a covariance matrix of the same parameters, or an equivalent set of LV state parameters, may be provided):

— Δi (degrees);

— $\Delta \omega$ (degrees);

— Δv_∞ (kilometres per second);

— $\Delta \Omega$ (degrees);

— ΔH_p (kilometres).

7.6.3 Launch windows

For escape missions, launch window constraints are driven by the orientation of the escape velocity vector in inertial space and the LV performance. Any additional LV or launch site constraints shall be indicated.

7.7 Circular Earth orbit missions

7.7.1 Performance

The performance capability of the LV to make various earth circular orbits shall be described by means of graphs showing the variation of the payload mass as a function of orbit altitude and inclination (see Figure C.6).

7.7.2 LV injection accuracy

The injection accuracy of the LV into typical circular earth circular orbit shall be described in terms of orbital parameters specific to circular orbits (see 5.3).

As a minimum, the standard deviations (1σ) of the typical circular orbit parameters shall be given; optionally, a covariance matrix of the same parameters, or an equivalent set of LV state parameters, may be provided.

7.7.3 Launch windows

If the LV or the launch site have launch window constraints, these shall be indicated.

7.8 Spacecraft orientation and separation

7.8.1 General

The description of the manoeuvring capabilities of the LV after injection into orbit shall include the following specific information:

a) type of ACS and propellants (gaseous, hydrazine, etc.);

b) typical sequence or sequences of events from LV orbit injection until the end of LV mission for various SC requirements, including

   — 3-axis stabilization,

   — spin stabilized SC, and

   — multiple separations (if applicable);

c) time constraints on the manoeuvring phase.

7.8.2 Orientation performance

An orbital reference frame shall be defined so that required SC orientations can be specified by orientation of the longitudinal axis for a spinning SC and orientation of two axes for a three-axis stabilized SC. The following shall be defined:

— the necessary data to be provided by the SC for time-dependent orientations (as a function of the launch time), if this LV capability exists;

— spin performance, consisting of maximum spin velocity and related dispersions;

— pointing accuracy for three-axis stabilized SC (attitude error for all three SC axes prior to separation) and spin stabilized SC (pointing error of kinetic momentum vector after separation);

— minimum relative velocity provided by the LV separation system.

8 Induced environment and load limitations

8.1 General

This clause identifies the parameters required for characterizing the SC environment during pre-launch operations and LV flight.

8.2 Mechanical environment

8.2.1 General

Throughout this clause, all quoted loads shall cover flight level loads and ground loads with a stated probability level.

8.2.2 Quasi-static flight limit loads

A table shall be produced showing the quasi-static limit loads at the SC centre of gravity with a stated probability level (see annex D, Figure D.1). Variations of loads with payload mass shall be indicated if applicable.

8.2.3 Low frequency longitudinal vibration

The LV contractor shall give the maximum equivalent longitudinal sinusoidal vibration level at the base of the SC, taking into account all sine and transient longitudinal vibrations over the frequency range of interest (see Figure D.2).

8.2.4 Low frequency lateral vibration

The LV contractor shall give the maximum equivalent lateral sinusoidal vibration level at the base of the SC, taking into account all sine and transient lateral vibrations over the frequency range of interest (see Figure D.2).

8.2.5 SC centre of gravity location

The centre of gravity location shall be illustrated with appropriate figures showing the limitations associated with SC centre of gravity location and mass versus PLA capability, for the various PLAs available (see Figure D.3).

8.2.6 Random vibrations

The LV contractor shall provide a figure showing the envelope spectrum of the flight level random vibrations in the longitudinal and lateral directions in terms of spectral density expressed in g^2 per hertz (see Figure D.4).

8.2.7 Acoustic noise

The LV contractor shall provide a figure showing the flight level noise spectrum under the LV fairing or carrying structure expressed in octaves or one-third octave (see Figure D.5). The associated fill factor (ratio of SC to PLF volumes) shall be indicated.

8.2.8 Shock

The shock spectrum shall be shown, based on the following criteria.

a) **LV-provided PLAs**: give the highest shock spectrum generated by the LV at the separation plane of the SC for all PLA versions (see Figure D.6).

b) **SC-provided PLAs**: give the highest shock spectrum acceptable by the LV at the interface between the LV and the SC-provided PLA (see Figure D.6).

8.2.9 Line load limitations

The LV contractor shall define the maximum allowable loads generated by the SC at the PLA interface as a percentage of the design line load of the corresponding PLA.

8.3 Thermal environment

8.3.1 General

The thermal environment of the SC shall be described for the following operation phases:

a) SC preparation phase in corresponding buildings and during inter-site transports;

b) pre-launch phase when the SC is mated to the LV;

c) flight phase.

8.3.2 Air conditioning system

The air conditioning systems used for ground operations shall be characterized by the following set of parameters:

— inlet temperature (with adjustable range);

— typical outlet temperature and humidity;

— filtration (size of particles);

— air flow rate (volume per hour);

— air velocity (when the SC is inside the fairing or carrying structure);

— acoustic noise generated by the ventilation system.

8.3.3 In-flight temperature

A graph showing typical temperature time history of the fairing internal surface during flight shall be included (see Figure D.7).

8.3.4 Aerothermal flux at fairing jettisoning

The LV contractor shall indicate the maximum aerothermal flux at fairing jettisoning.

8.3.5 Thermal flux from stage separation rockets

The maximum flux and flux duration generated at the SC base by stage separation rockets (if applicable) shall be indicated.

8.4 Static pressure

The LV contractor shall provide a graph showing the time history of the static pressure inside the fairing or the carrying structure during the flight, with indication of the maximum slope (see Figure D.8).

8.5 Contamination and cleanliness

8.5.1 Contamination on SC (if required)

The LV contractor shall define the total organic deposits generated on the SC from material outgassing and separation systems of the LV, considering the following sequence of events:

a) operations in clean rooms;

b) transportation in containers;

c) transfer to launch pad;

d) ground and flight phases in LV fairing or carrying structure;

e) LV-induced plume.

8.5.2 Air cleanliness

The LV contractor shall define the air cleanliness class guaranteed in SC operations buildings, SC transportation containers, on the launch pad and inside the LV fairing or carrying structure, during on-pad operations and in flight.

8.6 Radio and electromagnetic environment

8.6.1 LV generated

The LV contractor shall describe the following spurious radiation interference levels:

— spurious radiation emitted by the LV's narrow-band electric field (see Figure D.9);

— spurious radiation emitted by the LV's wide-band electric field (see Figure D.10);

— spurious radiation emitted by the LV's narrow-band magnetic field (see Figure D.11).

8.6.2 SC-generated

The LV contractor shall describe the spurious radiation interference acceptable by the LV's narrow-band electric field (see Figure D.12).

8.6.3 Launch-range-generated

The LV contractor shall describe the launch-range electromagnetic environment, including TM, TC and radar transponders.

9 Verification analysis and documentation

9.1 Verification tasks

9.1.1 Calculate SC injection parameters into a target orbit for a launch with a given type of LV and define the associated launch window.

9.1.2 Analyse SC attitude pointing, clearance and spacing after separation from the LV.

9.1.3 Generate requisite data for conducting SC verification tests and interpret the test results. This includes coupled loads, thermal, radio compatibility and contamination analyses environment studies.

9.1.4 Verify SC and LV safety during combined operations and flight.

9.1.5 Generate requisite data for evaluation of LV TM information and post-flight assessment of the actual trajectory and flight environment. The following are examples of typical flight events to be analysed:

- engine ignition;
- thrust cut off;
- stage separation;
- fairing jettison;
- LV stabilization prior to SC separation;
- separation of the SC from the LV.

9.2 Verification analysis method

Analytical verification methods that may be used include

a) mathematical modelling and simulations,

b) probability calculations and statistic assessments,

c) performance evaluation of technical systems,

d) analysis and interpretation of study results, and

e) comparison of calculation results with known families of data.

9.3 Verification analysis phases

9.3.1 Feasibility analyses

Feasibility analyses are decided by mutual agreement between SC and LV contractors with the objective of assessing the basic compatibility between LV and SC in specific technical areas.

9.3.2 Preliminary analyses

Preliminary analyses are based on reference input data and mathematical models supplied by the LV and SC contractors prior to conducting their individual verification tests.

9.3.3 Final analyses

Final analyses are performed with input data based on the final launch configuration and test-verified mathematical models supplied by the LV and SC contractors.

9.4 Input data for analyses

The SC contractor shall provide the following input data for all SC configurations associated with operations conducted by the LV contractor:

- required orbit, separation attitude and spin velocity (if applicable);
- mass and inertia characteristics;

— overall drawings and geometric model;

— mathematical dynamic model including modal characteristics;

— mathematical thermal model;

— definition of mechanical and electrical interfaces;

— radio frequency characteristics and transmission plan;

— characteristics of electromagnetic radiation during ground and LV–SC combined operations.

Digital data and mathematical models shall be provided by the SC contractor in a format and in coordinate systems agreed upon with the LV contractor. Digital data shall be described as nominal values and related tolerances.

Any additional data required to perform verification analyses shall be provided by the SC contractor under mutual agreement with the LV contractor.

9.5 Description of verification analyses

9.5.1 General

In order to ensure the compatibility of the SC with the LV environment, the LV contractor shall carry out the following analyses (9.5.2 to 9.5.9) with the input data provided by the SC contractor.

9.5.2 Trajectory and performance analysis

The LV contractor shall calculate the LV trajectory and related performance reserve such that they correspond to the SC required orbit and meet SC mission constraints. The analysis shall include

a) description of flight sequence and flight path,

b) list of main LV parameters,

c) performance reserve and associated probability,

d) visibility from LV tracking stations, and

e) verification of SC mission constraints.

9.5.3 Launch window analysis

If launch window constraints are related to the LV performance or LV systems, an explicit calculation of the time period favourable for launch shall be done by the LV contractor for every day of the launch slot available for the SC. The resulting window shall be combined with the SC provided launch window.

9.5.4 Pointing, separation and spacing analysis

The capability of the LV to orient the SC in the required attitude with, if necessary, a predetermined spin velocity, shall be analysed. The ejection process and dynamics of the SC separation from the LV shall be described in terms of SC kinematics condition immediately after separation. The absence of repeated contact between the SC and any other body after separation shall be demonstrated, with justification of the selected separation energies. Spacing of the various orbiting bodies shall be calculated over a period of time to be agreed upon with the SC contractor.

9.5.5 Coupled loads analysis

The coupled loads analysis allows the LV contractor to predict the SC loads and the relative displacements between SC and LV. The analysis results shall be used by the SC contractor to verify the compatibility between the SC design and the LV environment and to adjust the SC vibration test levels.

The longitudinal and lateral loads of the coupled SC–LV structure shall be calculated for all critical ground and flight events. External forces and forcing functions shall be described and explained. Responses at the LV–SC interface shall be provided. SC internal responses shall be calculated at SC contractor request, within the limits of the agreed analysis format.

9.5.6 Clearance analysis

The LV contractor shall analyse critical clearances between the SC and the PLF or LV structure during flight and SC separation.

9.5.7 Thermal analysis

The thermal environment analysis allows the LV contractor to predict SC temperature during ground operations and flight and to adjust the ground air conditioning system in order to meet SC thermal constraints insofar as the system permits. The SC contractor can then use the analysis results to verify the compliance of the SC subsystems with the LV environment.

The thermal influence of the LV on the SC environment shall be predicted from SC encapsulation until SC separation in flight. The aerothermal flux at fairing separation shall be calculated.

9.5.8 Radio frequency link analysis

An analysis of the radio frequency links between the SC and the various ground facilities available on the launch range shall be carried out in order to determine RF link margins.

9.5.9 Electromagnetic compatibility and interference analysis

The electromagnetic compatibility and interference analysis between the SC and the LV and launch range relevant facilities shall be done by the LV contractor. Verification tests shall be conducted if necessary.

The LV contractor shall provide the SC contractor with the characteristics of electromagnetic emissions in the vicinity of the payload during combined LV–SC ground operations and during flight, before and after SC separation.

9.5.10 Contamination analysis — Optional

A contamination analysis covering separation phases and post-separation events between the LV and SC may be performed.

9.6 Safety

Verification of safety during combined ground operations and launch shall be performed by the LV contractor using SC-provided information that includes accepted safety factors and strength margins for high-pressure vessels and other SC components.

The following two situations shall be considered for ground operations:

a) personnel present around the SC or hazardous items;

b) no personnel present around the SC or hazardous items.

9.7 Launch readiness assessment

The evaluation of the results of the verification analyses and related tests shall be done jointly by the LV contractor and the SC contractor in order to proceed with launch operations. The corresponding process is defined formally in the LV–SC interface control document (ICD) (see 9.9.3).

9.8 Post launch assessment

After launch, the LV contractor shall produce a report on flight assessment from the LV TM data analysis. The following information shall be provided:

a) execution of the time sequence of prelaunch and launch operations, LV flight including PLF separation, LV attitude pointing and SC separation;

b) evaluation of the orbital parameters;

c) induced environment during prelaunch operations and flight, with the description of out-of-family phenomena if applicable.

9.9 Documentation

9.9.1 SC to LV interface requirements

The following minimum information shall be prepared by the SC contractor as an early input to the program:

— technical characteristics of the SC;

— required SC orbit with acceptable dispersions;

— required SC separation attitude and spin with acceptable dispersions;

— SC constraints and limitations;

— required SC launch window;

— required orbital services (if applicable).

9.9.2 Verification plan for LV–SC compatibility

A verification plan shall be prepared jointly by the LV and SC authorities containing the following (see annex E, Table E.1):

— list of verification objectives;

— strategy for verification taking into account accepted waivers;

— sequence of verification activities;

— schedule of verification activities.

9.9.3 Interface control document

The ICD is prepared by the LV contractor in agreement with the SC contractor on the basis of the IRD input data. This document contains all technical elements needed to define and verify compatibility between the LV and SC.

10 Verification tests

10.1 General

The SC contractor shall verify that the SC is compliant with the interface and environmental requirements (mechanical, electrical, radio frequency, electromagnetic and functional) of the LV and launch site. These requirements shall be verified by analysis, inspection and/or using the following tests:

— vibration and load test;

— pyro shock and separation test;

— functional interface test;

— launch site interface test.

The verification plan (see Table E.1) — test methods, test condition, schedule — prepared by the SC contractor shall be agreed to by the LV contractor. The verification test results shall be reviewed and accepted by both parties.

The tests given in 10.2 are typical, but not always required.

10.2 Vibration and load tests

10.2.1 General

The SC contractor shall confirm that the SC is qualified to the LV flight environment by the following tests.

10.2.2 Static load test

This test verifies strength and stiffness requirements under the launch environment.

The level corresponds to the maximum quasi-static acceleration (which may account for a dynamic component) at SC centre of gravity in the flight.

The qualification levels are the product of the appropriate factors and the flight levels.

The static load test is only applied to the structural test model.

The limit load factors given in Table E.2 are defined by the LV.

10.2.3 Modal survey

This is the verification of fundamental natural frequency requirements and response characteristics, including damping — the verification of mathematical model on SC dynamics (for format, see Table E.3).

10.2.4 Sinusoidal vibration test

This test verifies strength and stiffness requirements under the launch environment.

The qualification levels are the product of the appropriate factors and the flight levels.

Notching is a technique for avoiding unrealistic loads generated by the difference in boundary conditions between tests and actual flight. The notching levels are determined based on the coupled loads analysis and modal survey results, and are mutually agreed by SC and LV. The qualification levels (for format, see Table E.4) are defined by the LV.

10.2.5 Acoustic test

This test verifies the capability to withstand the acoustic levels of the launch environment. The qualification levels are the sum of the flight levels plus an additional amount defined by the LV (for format, see Table E.5).

10.2.6 Random vibration test

This test verifies conformity with strength and stiffness requirements under the launch environment. The qualification levels are the product of the appropriate factors and the flight levels. The levels (for format, see Table E.6) are defined by the LV. Random vibration may be covered by the acoustic environment.

10.3 Pyro-shock and separation test

This test verifies SC function under the shock environment generated by pyrotechnics ignition and release of mechanical energy at separation or at staging of the LV. Separation testing is optional. Shock testing is required at the qualification stage and optional for flight acceptance testing.

10.4 Functional interface tests

10.4.1 General

The following tests are performed by a composite team from the LV and SC organizations. The place and time of each test shall be determined by LV/SC coordination.

10.4.2 Electrical interface test

This test consists of the verification of the electrical interface between the LV and SC.

10.4.3 Mechanical compatibility test

This test is performed only for new SC–LV interfaces and consists of the verification of the mechanical interface between the two at the separation plane.

10.4.4 Match mate verification

Matching of the mechanical interface between LV and SC at the separation plane shall be verified before launch site operations for new-design SCs, and is optional for follow-on versions.

10.4.5 Umbilical connector pullout test — Optional

This test is a verification of the pull-out function of the umbilical connector. The pullout force (see Table E.7) should be defined according to the connector shell size and connector specification.

10.5 Launch site interface test

10.5.1 General

The following SC–LV integrated tests shall be performed based on the launch site interface test plan, which is prepared by the LV and reviewed and agreed to by the SC.

10.5.2 End-to-end electrical test

This test verifies the wiring between the SC and the GSE.

10.5.3 RF link test

This test verifies the RF link between the SC and the GSE, including the tracking/acquisition system of the launch site.

11 Spacecraft launch preparation operations

11.1 General

SC field operations include the following phases:

— preparation and checkout;

— hazardous operations;

— combined operations for encapsulation and mating with LV.

The major SC ground operations are listed in 11.2, from preparation through the encapsulation phase to mating with the LV. The SC operations requirements shall be expressed by the SC contractor. Services and facilities made available on the range shall be defined by the LV contractor. The LV contractor is to give a detailed schedule of activities on preparation of the LV to launch, pointing out the joint operations with the SC.

11.2 Preparation and checkout

A general flow diagram of preparation and checkout operations shall be presented by the SC contractor, which shall include

— unloading of SC and associated equipment from aircraft or ship,

— transport from place of arrival to the launch range,

— unpacking of SC, ground equipment, pyrotechnics, solid propellant motor (if applicable),

— handling of hazardous fluids,

— SC preparation and functional tests (mechanical and electrical),

— validation of equipment and facilities, and

— storage of hazardous items (pyrotechnics, solid motor, propellants, radioactive sources).

All of the above operations shall be described, together with associated constraints and time line.

The LV contractor shall clearly identify the various locations and buildings to be used for each of these operations and provide a list of facilities and services available, including

— range personnel,

— range power and operational network,

— transport and handling facilities,

— GSE, and

— measuring equipment calibration.

11.3 Hazardous operations

11.3.1 General

A general flow diagram of hazardous operations shall be presented by the SC contractor, which shall include

— pyrotechnic items preparation,

— preparation of solid propellant motors (SPM), if applicable,

— operations on SC, and

— final SC assembly.

For each of the operations described in 11.3.2 to 11.3.5, the LV contractor shall identify the building in which the operation is carried out and provide a list of facilities and services available.

11.3.2 Pyrotechnic item preparation

The SC contractor shall describe checks to be made on pyrotechnic systems before integration into the SC.

11.3.3 Preparation of SPM

The SC contractor shall describe the various steps associated with the SPM preparation:

— removal from storage;

— x-ray examination of results;

— assembly of motor;

— ignition system check and installation into the motor;

— handling of assembled SPM before mating with SC.

11.3.4 Operations on spacecraft

The SC contractor shall describe the various operations associated with the SC preparation before encapsulation:

— installation of SC in assembly hall;

— fluid filling, pressurization and emergency detanking;

— charging of SC batteries;

— assembly of pyrotechnics, radioactive sources and other items;

— installation of gas purges.

The LV contractor shall provide a complete description of the ground support facilities available to the SC user, together with their respective locations and interconnection links, including

— pressure and temperature monitoring,

— remote control,

— electrical power supply,

— hazardous circuits activation, and

— fluid analysis and delivery.

11.3.5 Final spacecraft assembly and checks

The final assembly operations preceding the beginning of the combined operation plan shall be described by the SC contractor and shall include

— balancing and weighing,

— arming, and

— electrical, mechanical and pyrotechnics checks and inspections.

The LV contractor shall, if required, provide a description of the ground support facilities available to the SC, with their respective locations and interconnection links, including

— SC weighing and balancing,

— SC–LV mechanical fit check, and

— RF/electrical checks.

11.4 Combined operations for SC encapsulation and mating with LV

A general flow diagram of the combined operations for encapsulation and mating with the LV shall be presented by the SC contractor, including

— SC and PLA assembly,

— handling operations of SC–PLA assembly, and

— the encapsulation phase and mating with LV.

For each of these operations, the location shall be clearly identified. Electrical connections and radio links between buildings shall be explained.

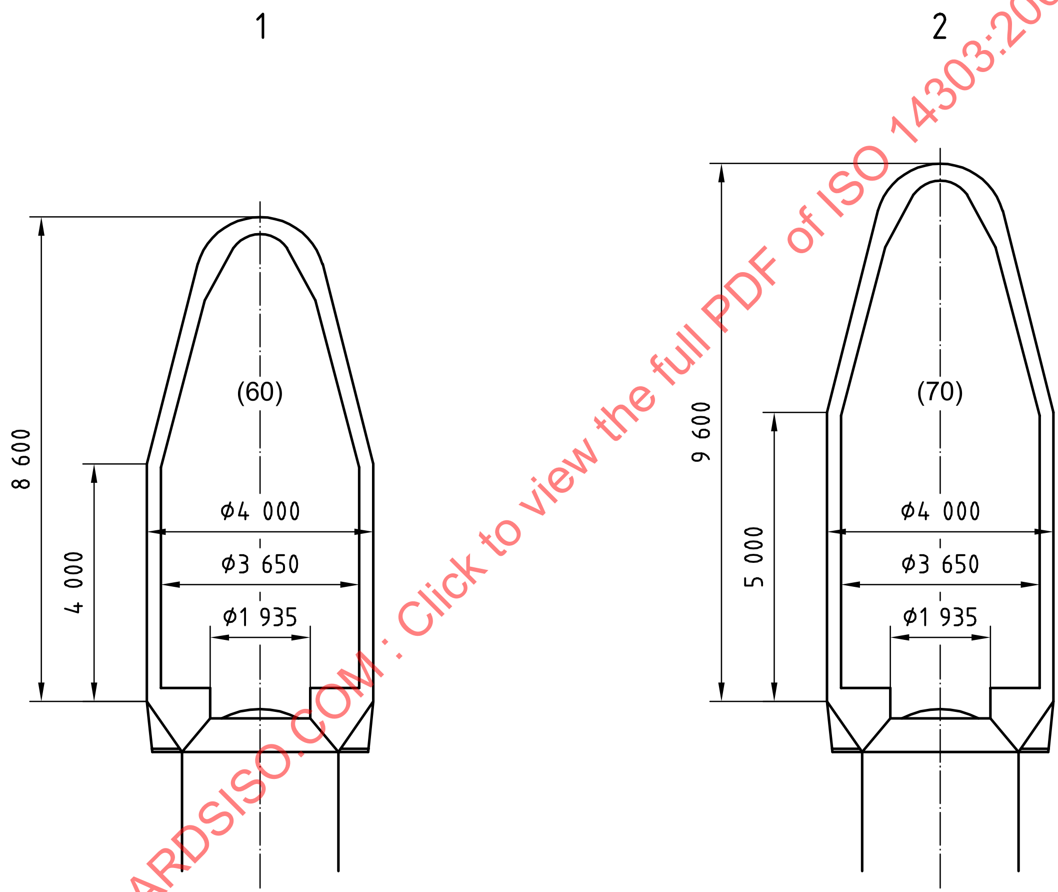
Typical encapsulation and mating sequences shall be described with appropriate figures for single, dual or multiple launches, where applicable. Multiple launch structures and associated handling hardware shall be mentioned.

Annex A
(informative)

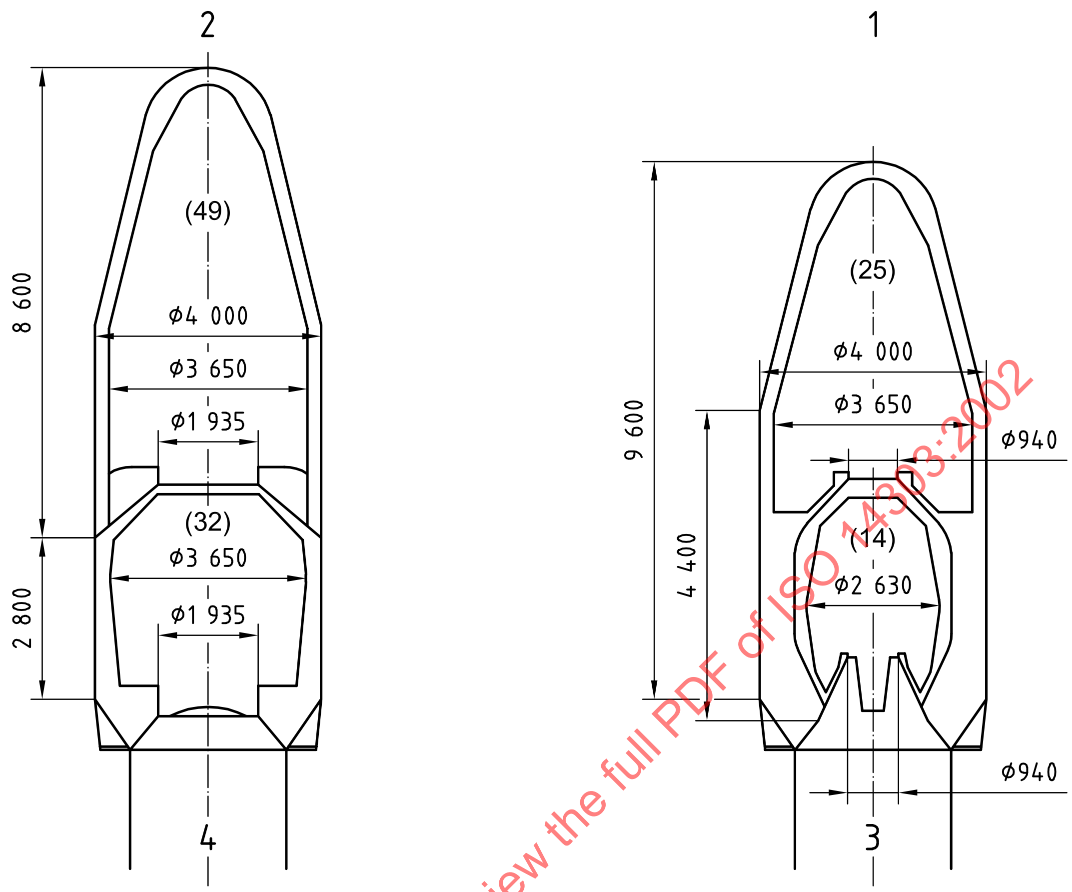
Usable envelopes

See Figures A.1 to A.4

Dimensions in millimetres
(Area values between parentheses in cubic metres)



Single launch



Dual launch

Key

1 Short fairing, type 01

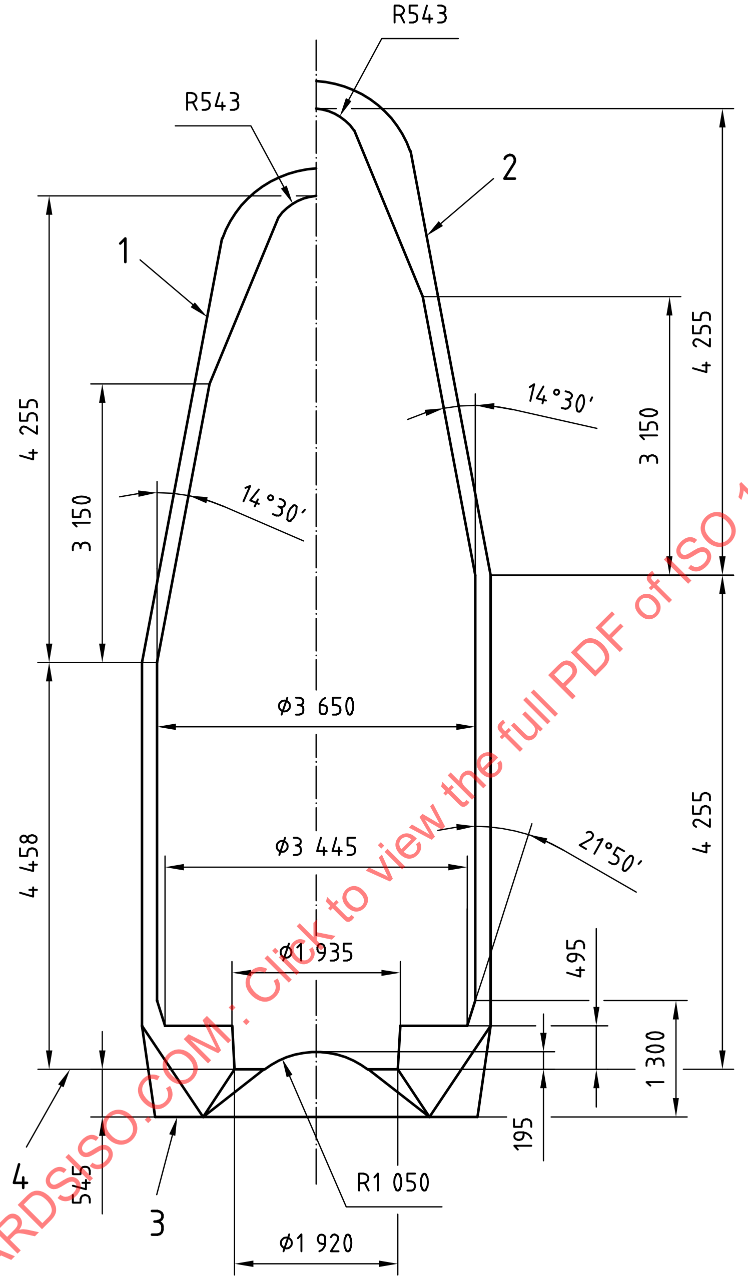
2 Long fairing, type 02

3 Type 001/dual launch structure

4 Type 10/dual launch structure

Figure A.1 — Single- and dual-launch payload compartment configuration

Dimensions in millimetres



Key

1 Fairing type 01

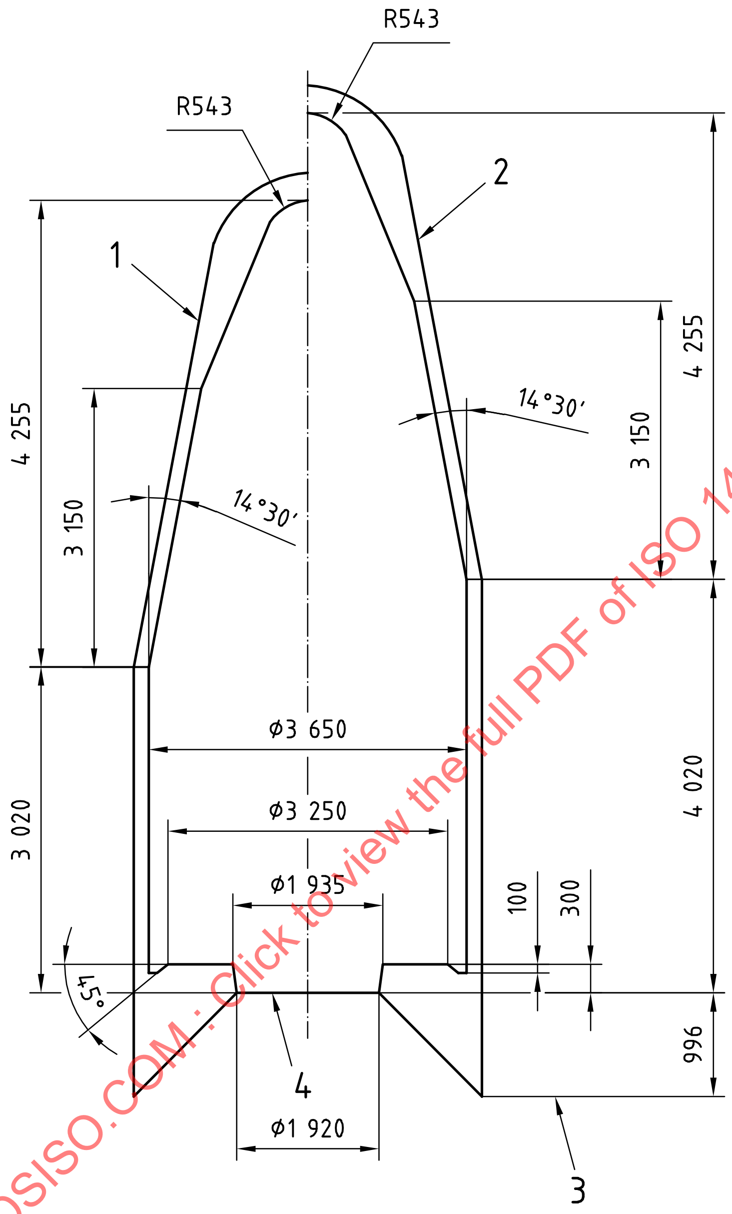
2 Fairing type 02

3 Mounting plane, vehicle equipment bay/third stage

4 Bolted interface plane

Figure A.2 — Usable volume in fairing for single-launch format presentation (interface 1920)

Dimensions in millimetres



Key

1 Fairing type 01

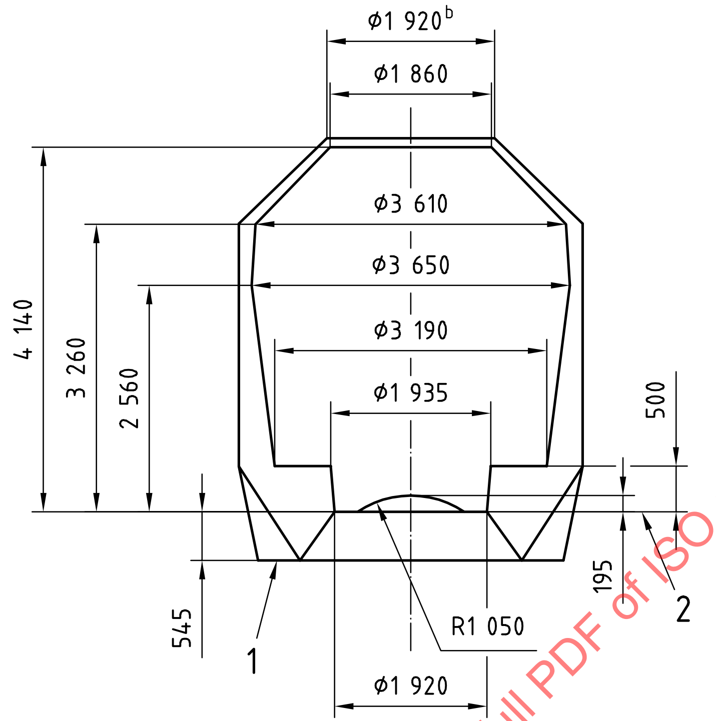
2 Fairing type 02

3 Mounting plane, fairing/dual launch structure

4 Bolted interface plane

Figure A.3 — Usable volume in fairing for dual-launch, upper-position, format presentation

Dimensions in millimetres



1 Mounting plane, vehicle equipment bay/third stage

2 Bolted interface plane

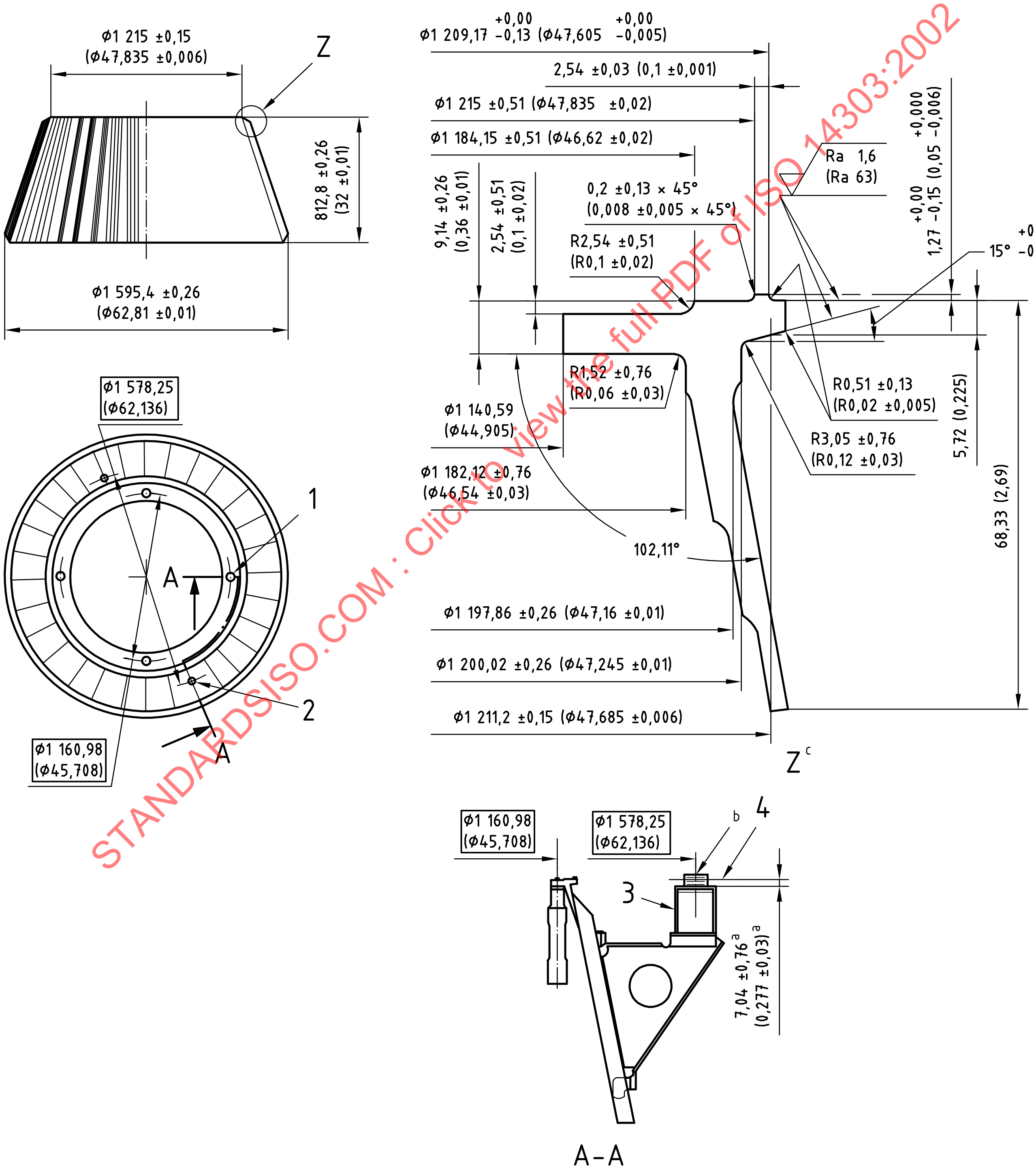
Figure A.4 — Usable volume in fairing for dual launch inner position format presentation

Annex B
(informative)

Physical interface presentations

See Figures B.1 and B.2.

Dimensions in millimetres (inches)



Key

1 Separation springs, 4 PI (equal spaces), 90° apart

2 Electrical disconnects, 2 PI, 180° apart (no angular location requirements)

3 Umbilical disconnect bracket (bracket and connector can be removed during spacecraft mate)

4 Separation plane

NOTE The figure is not to scale.

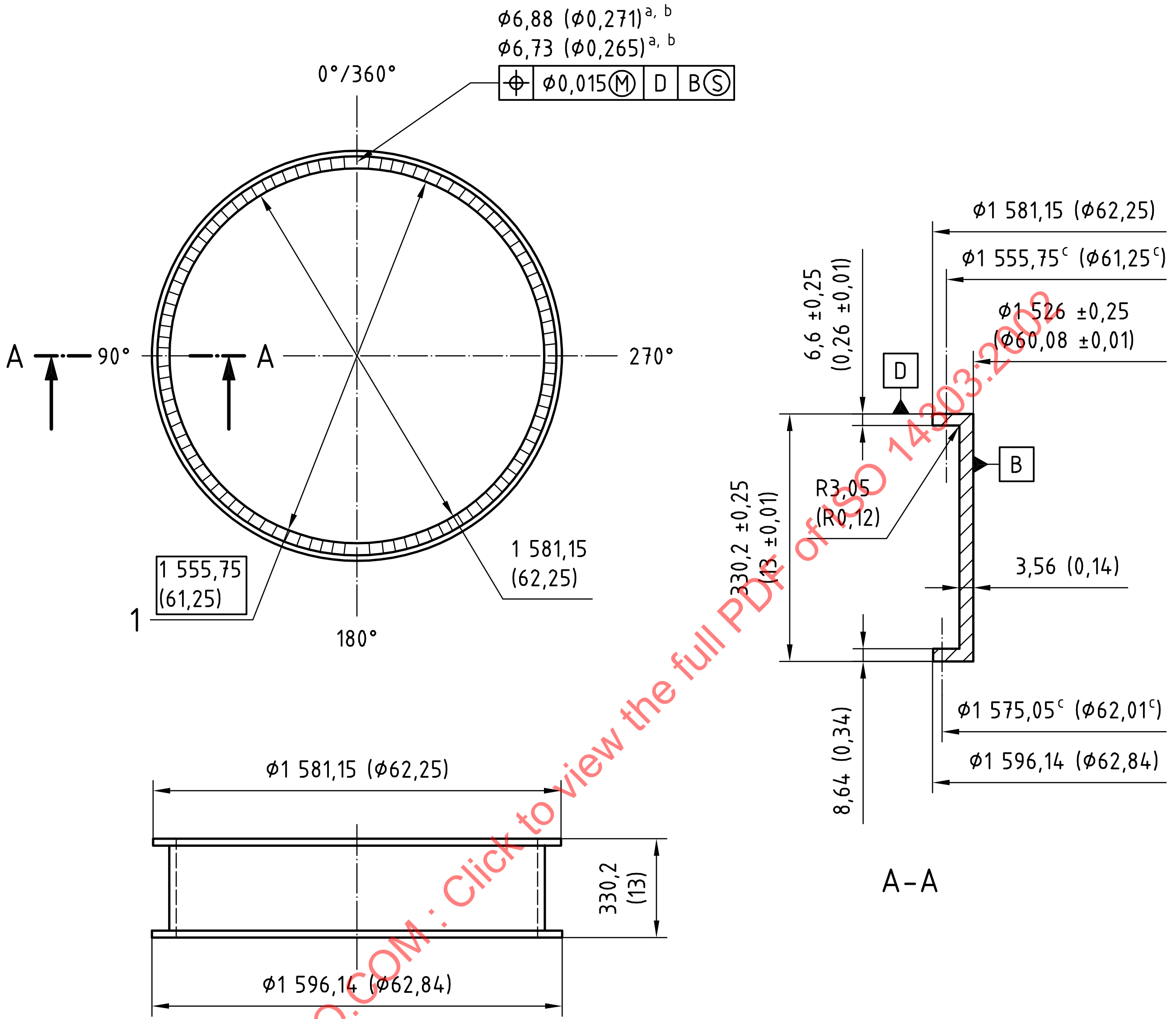
[a] To top of connector plate.

[b] Connector can be adjusted to within ∅ 3,0 mm (0,12 inches) to accommodate spacecraft connector misalignment.

[c] Chemical conversion coating per MIL-C-5541 — all surfaces.

Figure B.1 — SC-LV PLA (LV-supplied PLA)

Dimensions in millimetres (inches)



Key

1 Bolt circle

NOTE The Figure is not to scale.

a Through — hole pattern controlled by matching tooling.

b 96 holes EOL SP

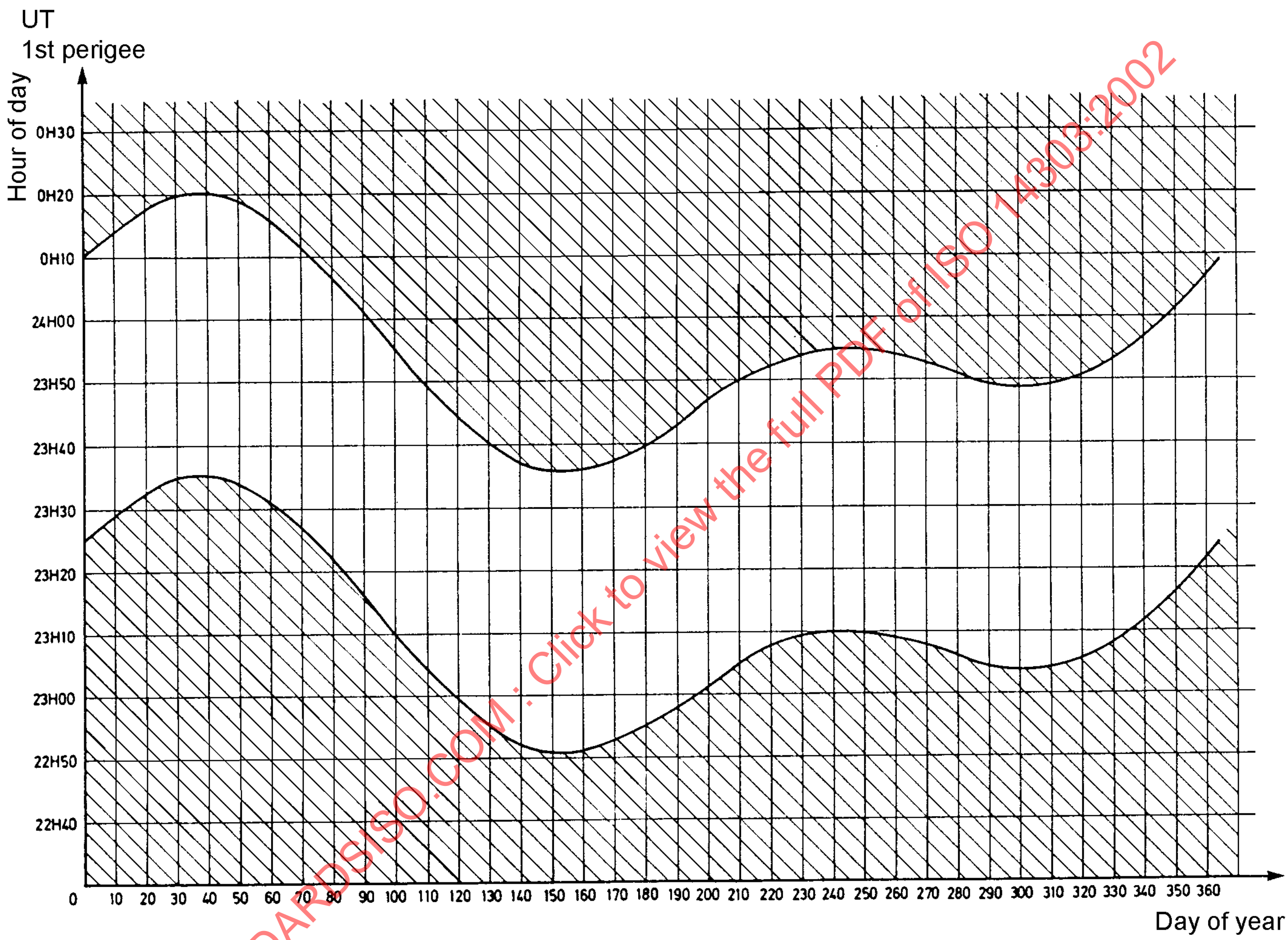
c Bolt circle

Figure B.2 — SC-LV PLA (SC-supplied PLA)

Annex C
(informative)

Performance presentations

See Figures C.1 to C.6.



Minimum launch window at first perigee passage

Reference orbit

H_p 200 km

H_a 35 786 km (apogee 6)

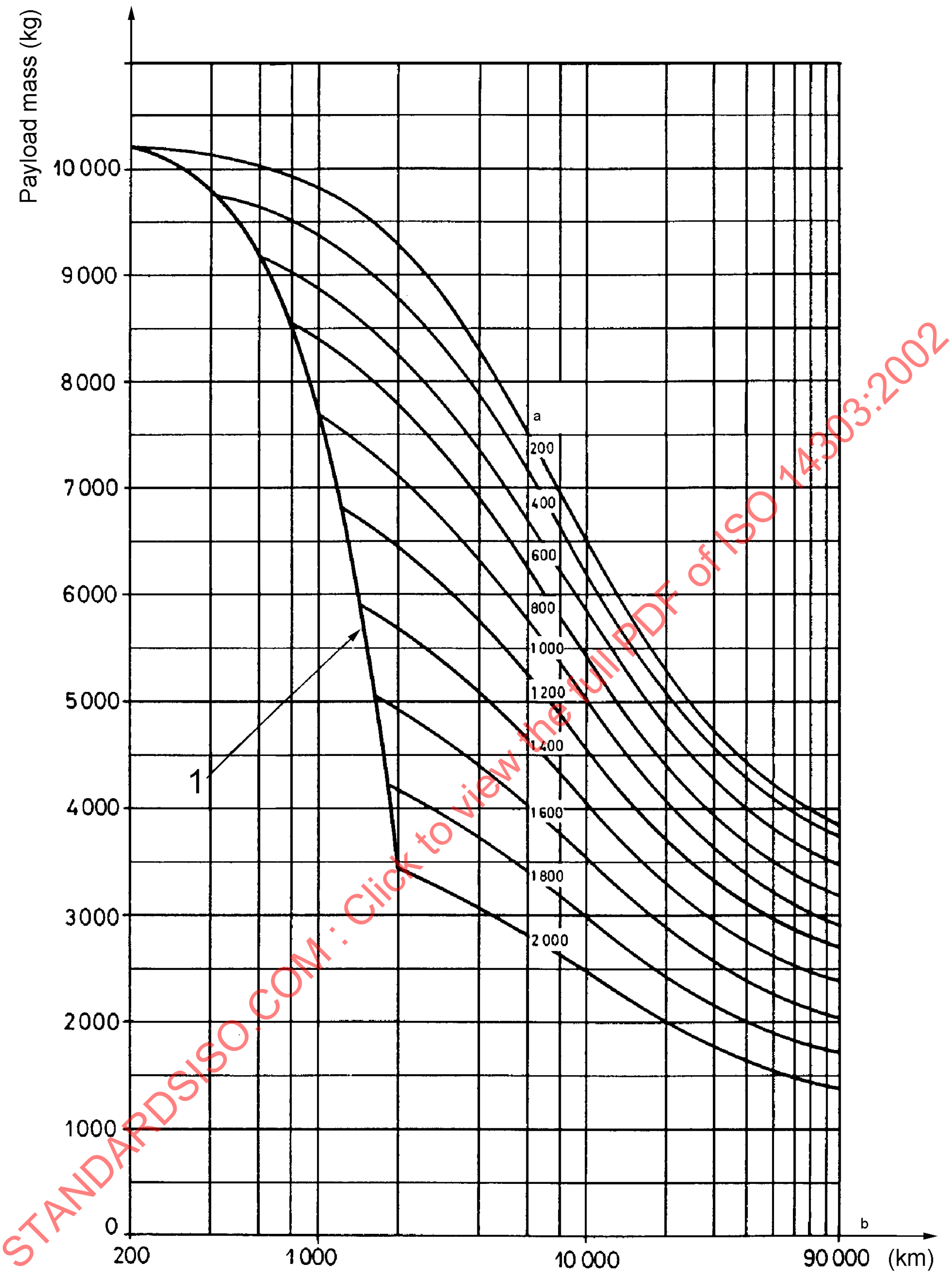
i 7°

ω 178°

Ω 11°W

NOTE Day 1 is 1st of January.

Figure C.1 — Standard launch window



Inclination 5,2° (injection near perigee)

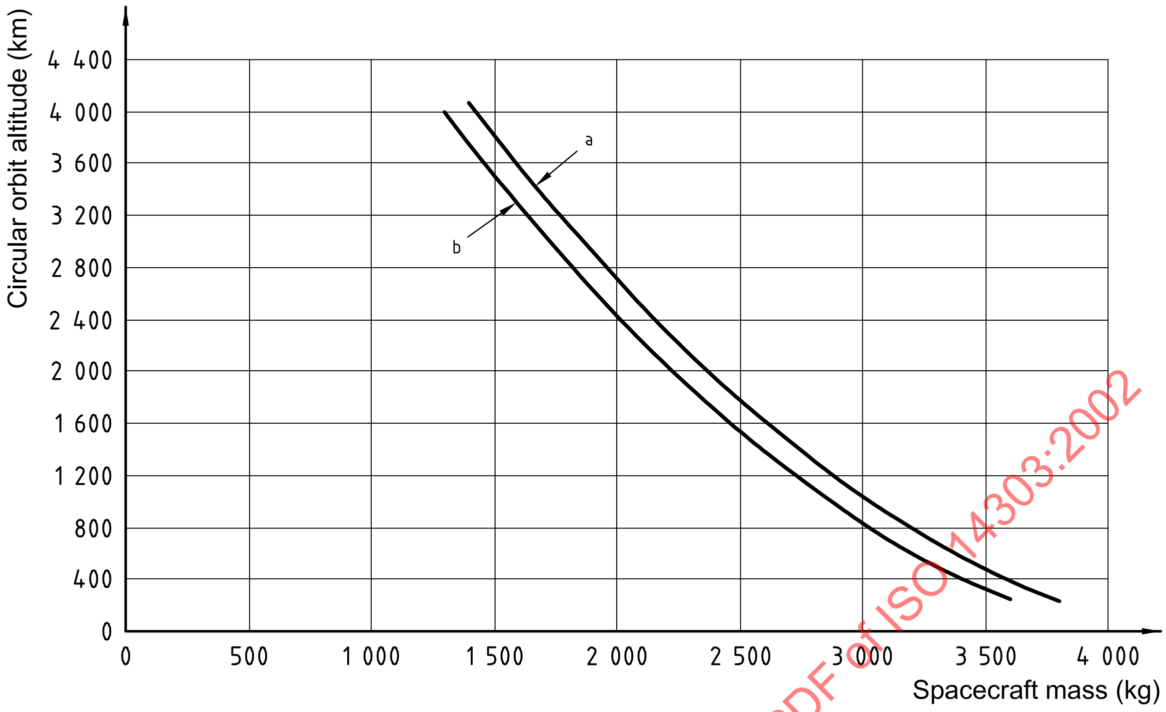
Key

1 Circular orbits

a Perigee altitude

b Apogee altitude, z_a

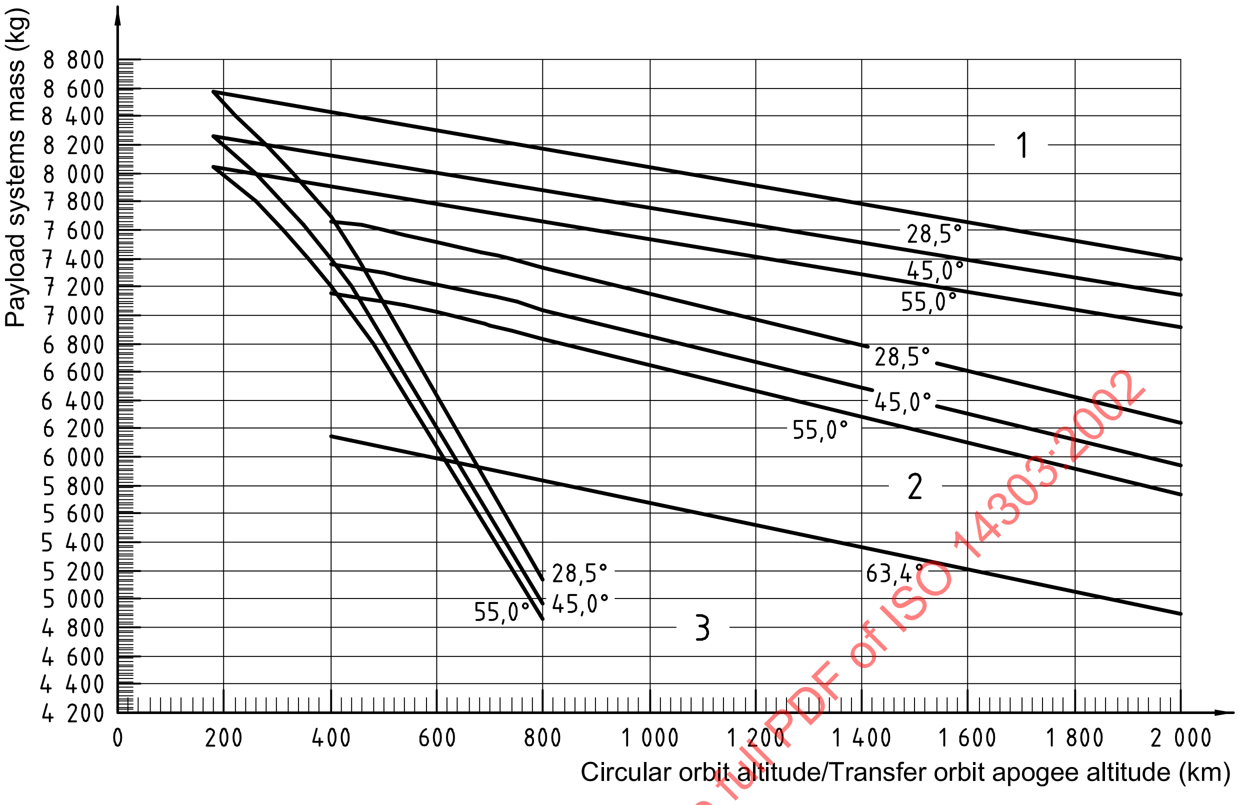
Figure C.2 — Payload mass capability for elliptical orbits as function of apogee, perigee altitude and inclination



196° minimum flight azimuth
Variable inclination
102,1 kg payload attach fitting

a 2,9 m fairing
b 3 m fairing

Figure C.3 — Sun synchronous orbit



Inclination 5,2° (injection near perigee)

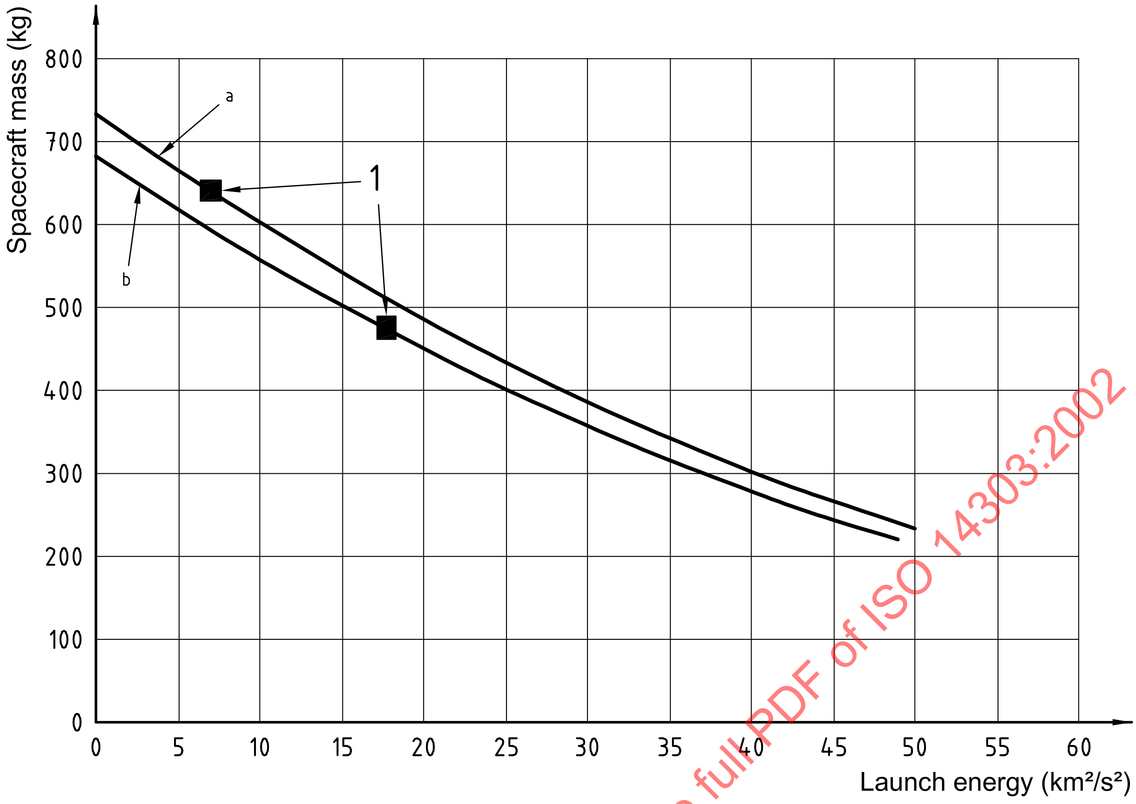
Key

1 Elliptical transfer (one burn)

2 Circular orbit (two burn)

3 Circular orbit (one burn)

Figure C.4 — Low Earth orbit



95° flight azimuth
28,7° inclination
185 km perigee altitude
45,4 kg payload attach fitting

Key

1 Star 48B offload

a 2,9 m fairing

b 3 m fairing

Figure C.5 — Escape mission

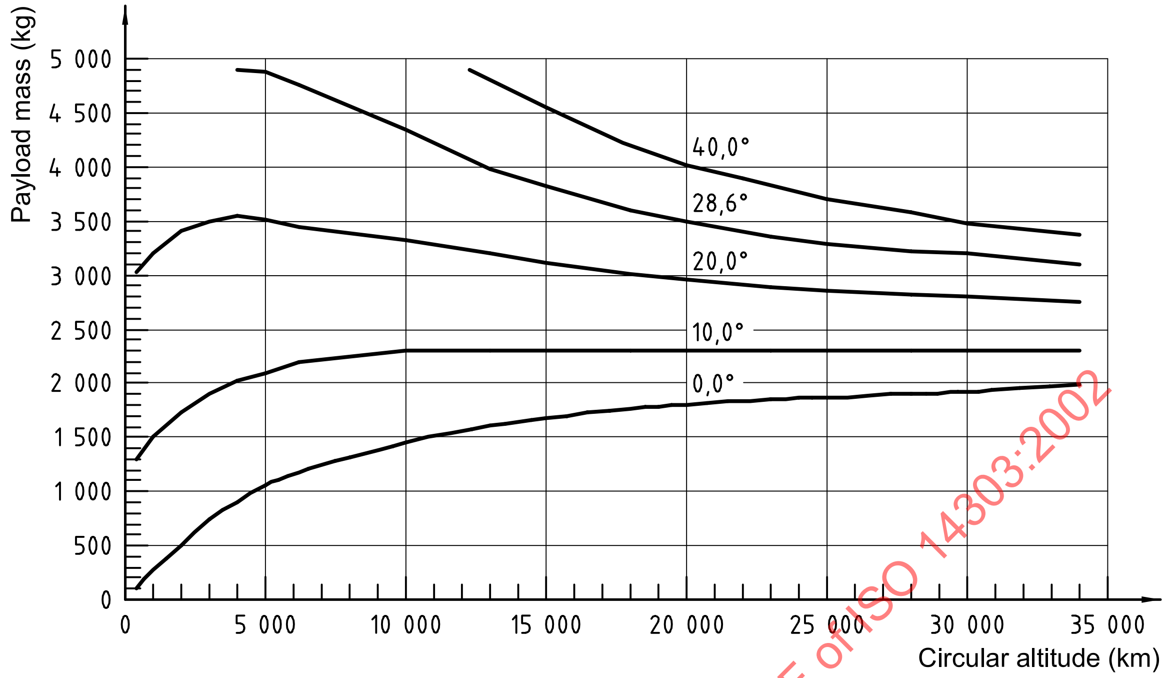
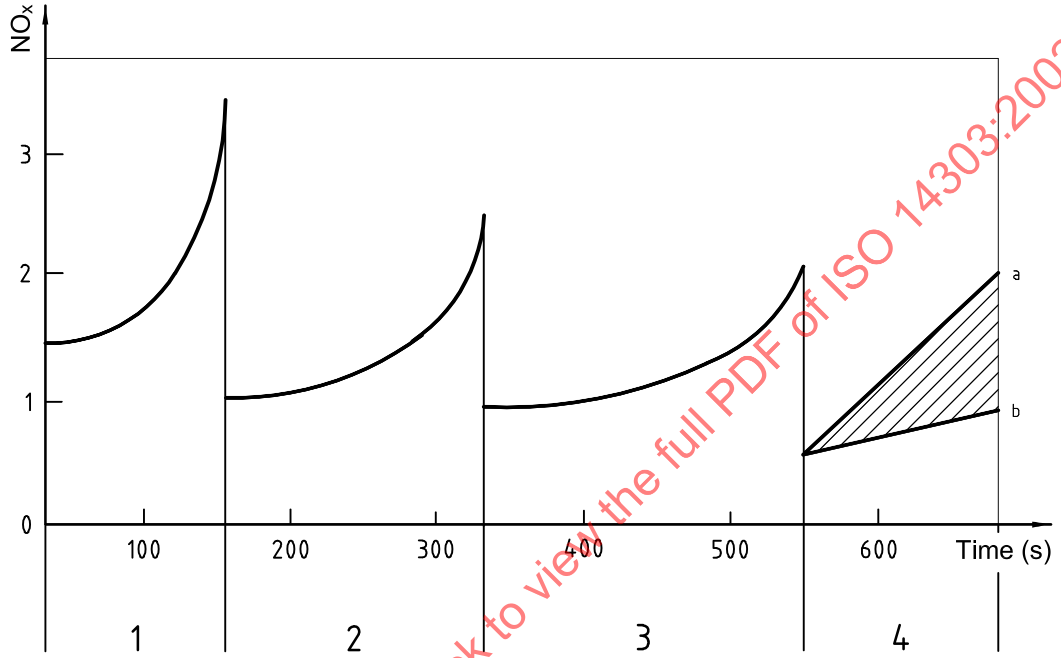


Figure C.6 — Circular Earth orbit

Annex D
(informative)

Environment presentations

See Figures D.1 to D.2.



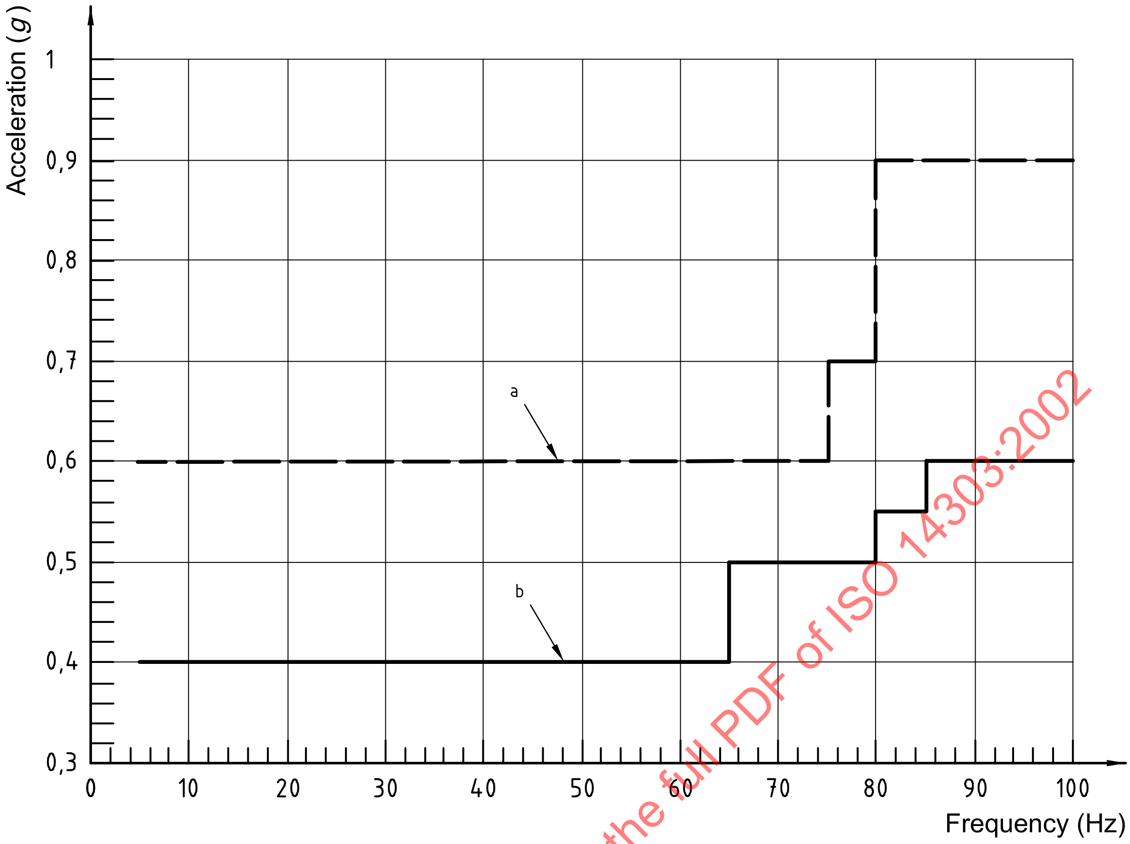
Load case	Load factors	
	Longitudinal	Lateral
Liftoff	+ 1,3	0,8
1st stage (max. Q)	+ 3,65	0,5
1st stage/2nd stage separation	+ 1,0	0,5
3rd stage	+ 2,5	0,2
4th stage	+ 2,0	0,15

Key

1 First stage
2 Second stage
3 Third stage
4 Fourth stage

[a] Mass of spacecraft is 2,1 t.
[b] Mass of spacecraft is 7,8 t.

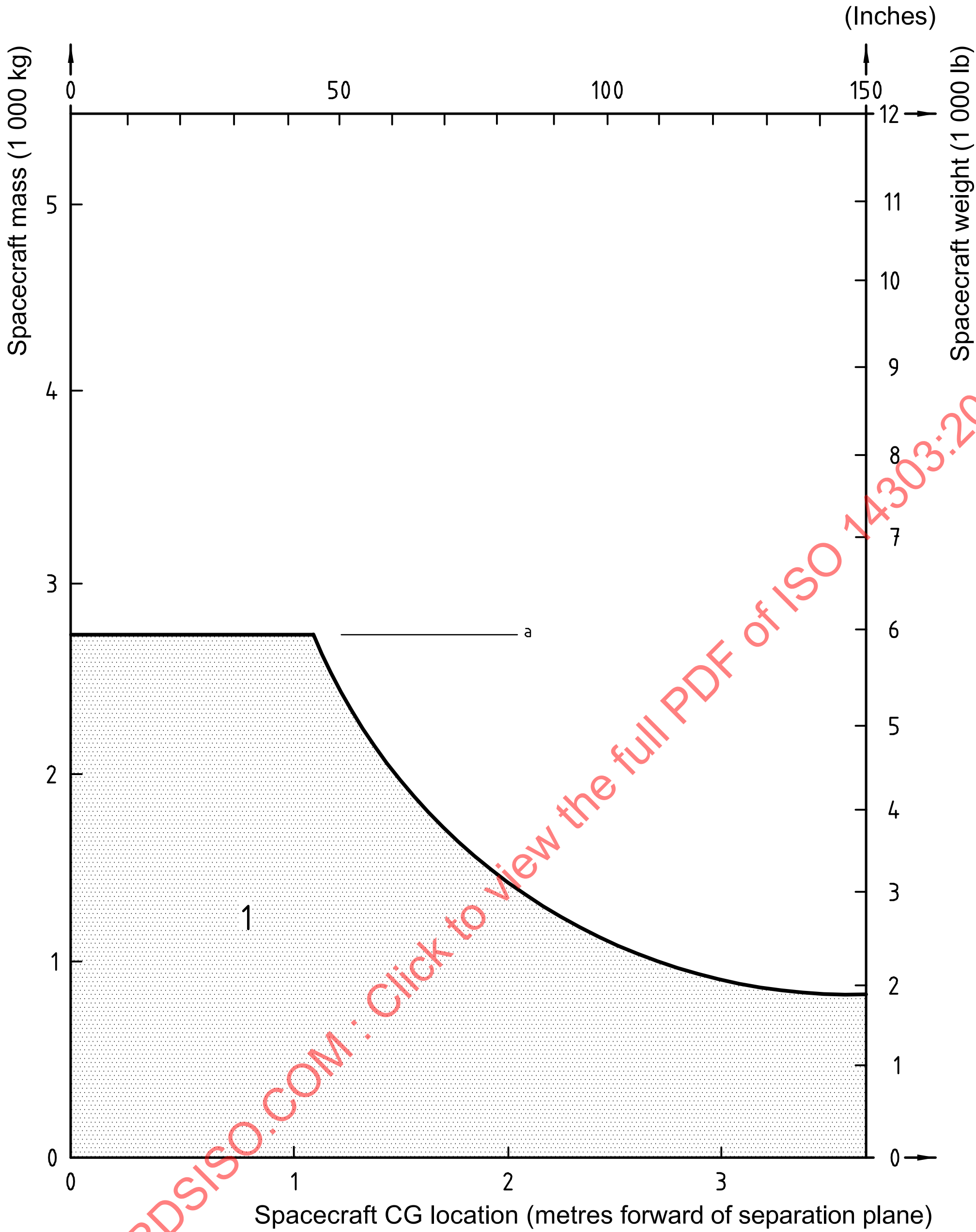
Figure D.1 — Quasi-static flight limit loads



a Axial vibration requirement

b Lateral vibration requirement

Figure D.2 — Longitudinal and lateral low frequency accelerations



Key

1 Allowable range

a Clamp limit 2 740 kg (6 025 lb)

Figure D.3 — Allowable mass vs CG envelope