Agence spatiale canadienne Canadian Space Agency

CSA ASC

CSA-STRATOS-RD-0017

Canadian Space Agency
Stratospheric Balloons Program

STRATOS Expandable Balloon Payload Requirements Document

Rev IR

February 08, 2023

Canada

This Page Intentionally Left Blank

Approvals

Prepared by:

Rosenzveig, Annie
Digitally signed by Rosenzveig, Annie
Date: 2023.02.08 10:38:18 -05'00'

Annie Rosenzveig
Electrical Engineer, Stratos Payload Manager
CSA Space Science and Technology

Date

Prepared by:

Chila, Matthew
Digitally signed by Chila, Matthew
Date: 2023.02.08 10:39:44 -05'00'

Matthew Chila
Mechanical Engineer
CSA Space Science and Technology

Date

Verified by:

Popovici, Vlad
Digitally signed by Popovici, Vlad
Date: 2023.02.08 10:50:14 -05'00'

Vlad Popovici
Electrical Engineer
CSA Space Science and Technology

Date

Verified by:

Laflamme, Martin
Digitally signed by Laflamme, Martin
Date: 2023.02.08 10:53:45 -05'00'

Martin Laflamme
Senior Electrical Engineer, Stratospheric Expandable Balloon Lead
CSA Space Science and Technology

Date

Verified by:

Martin, Francis
Digitally signed by Martin, Francis
Date: 2023.02.08 12:04:03 -05'00'

Francis Martin
Senior Mechanical Engineer
CSA Space Science and Technology

Date

Verified by:

Cindy Dornéval
Digitally signed by Dorneval, Cindy
Date: 2023.02.08 12:47:51 -05'00'

Cindy Dornéval
Safety & Mission Assurance Engineer
Programs and Integrated Planning

Date

Approved by:

Digitally signed by Vincent, Philippe
Date: 2023.02.08 15:04:49 -05'00'

Philippe Vincent
Stratos Mission Manager
CSA Space Science and Technology

Date

Revision History

Rev.	Description	Date	Initials
I.R.	Initial release. Note the requirements found herein were previously contained in the Expandable Balloon User's Manual (CSA-STRATOS-MAN-0011 rev B).	Feb. 08, 2023	AR, MC

TABLE OF CONTENTS

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

LIST OF TABLES

TABLE PAGE

1 INTRODUCTION

The Canadian Space Agency (CSA)'s stratospheric balloon program, Stratos, was created in 2011 in collaboration with the Centre National d'Études Spatiales (CNES). This program provides opportunities for Canadian academia and industry to test, validate, and demonstrate new technologies and scientific experiments at an altitude where only balloons can be operated. Stratos contributes to the training and development of a highly qualified workforce: the next generation of Canadian engineers and scientists.

Balloon campaigns alternate between locations, typically coming to Canada every other year. Up until 2018, these Canadian balloon campaigns were centered exclusively around the CNES Zero-Pressure balloon (ZPB) aerostats, even though CNES also has a light expandable balloon (ballon léger dilatable or BLD) business line.

Stratospheric Expandable Balloons (SEBs) are unmanned and usually filled with helium. The balloon carries scientific experiments and payloads (PLs) or payload gondolas (PLGs) to a "near-space" altitude of 20 to 35 km. The aerostat may also contain electronic subsystems required for tracking and operations.

1.1 PURPOSE

The purpose of this document is to provide the requirements necessary for payload developers to safely design and integrate their payload into the designated CSA gondola or to integrate their payload gondola into the CSA's aerostat for a successful SEB flight.

1.2 SCOPE

This document covers the requirements for payloads or payload gondolas that will fly on-board a SEB aerostat.
For information regarding the payload application and certification process, including the deliverables to be submitted to the CSA, refer to RD3. For information regarding campaigns, typical launch and flight phases, and guidelines and best practices, refer to RD4.

1.3 ACRONYMS

AD	Applicable Document
CAR	Canadian Aviation Regulations
CM	Centre of Mass
CNES	Centre National d'Études Spatiales
CSA	Canadian Space Agency
ESDP	Experiment Safety and Data Package
PI	Principal Investigator
PL	Payload

PLG	Payload Gondola
RD	Reference Document
RF	Radio Frequency
RFD	Request for Deviation
SBD	Short Burst Data
SEB	Stratospheric Expandable Balloon
TBC	To Be Confirmed
TBD	To Be Determined
TOC	Table Of Contents

2 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents of the exact issue date and revision level shown are applicable and form an integral part of this document to the extent specified herein. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence.

TABLE 2-1 APPLICABLE DOCUMENTS

AD No.	Document No.	Document Title	Rev. No.	Date (YYYY-MM-DD)
AD1.	CSA-STRATOS-RD-0015	Expandable Balloon System Requirements Document	B	2021-11-03
AD2.				
AD3.				

2.2 REFERENCE DOCUMENTS

The following documents provide additional information but do not form part of this document.

TABLE 2-2 REFERENCE DOCUMENTS

RD No.	Document No.	Document Title	Rev. No.	Date (YYYY-MM-DD)
RD1.	CSA-STRATOS-DD-0004	Expandable Balloon Aerostat Architecture and Design Document	Latest	
RD2.	SOR/96-433	Canadian Aviation Regulations (En) (Fr)	Latest	
RD3.	CSA-STRATOS-PR-0004	Payload and Payload Gondola Certification and Experiment Safety Data Pack Submission Procedure	Latest	
RD4.	CSA-STRATOS-MAN-0011	STRATOS Expandable Balloon Payload User's Manual	Latest	
RD5.	CSA-STRATOS-FORM-0010	Stratospheric Expandable Balloon Payload Application Technical Questionnaire	Latest	

3 STRATOSPHERIC EXPANDABLE BALLOON (SEB) OVERVIEW

High altitude balloons are commonly used for weather soundings, but in the case of the CSA's Stratospheric Expandable Balloons (SEBs), they are used to transport scientific payloads to the stratosphere. The system is multi-mission and reusable (with the exception of the balloon envelope).

3.1 SEB CATEGORIES

According to Canadian Aviation Regulations (CARs) [RD2], unmanned free balloons are classified into two categories: *Small* and *Large*. They are classified according to the volume of gas contained in the balloon on the ground. If a balloon has a gas carrying capacity greater than 115 ft^3 (3.256 m^3), it will be considered as a *Large* unmanned stratospheric balloon. When falling in the *Large* balloon classification, the SEB aerostat must include a certified transponder for in-flight tracking. Note also that as soon as a transponder is included, the aerostat is automatically considered to be *Large* regardless of the gas carrying capacity.

3.2 CSA SEB AEROSTAT

A short description of the CSA's SEB aerostat is included in this section. For more detailed information, refer to the SEB Aerostat Architecture and Design Document [RD1].

Figure 1 depicts the possible CSA SEB aerostat configurations, which <u>always</u> include the following:

- **Envelope**: a latex balloon that has the ability to continually expand as outside pressure decreases to the point of balloon rupture.
- **Attachment & Connecting Cords:** nylon loops of cord to attach the envelope to the rest of the aerostat via swivels.
- **Parachute**: the parachute system which allows for the non-lethal descent of the gondola.
- **Mechanical Hardware:** swivels and threaded links used to connect the different elements of the system together. May also include eyebolts, nuts and washers.

Depending on the configuration, the flight train, which includes all elements connected to the envelope via the connecting cords, <u>may</u> also include the following:

- **Avionics Gondola**: a structure provided by the CSA that houses the electrical subsystems needed for in-flight tracking and ground recovery, including a transponder and a GPS receiver as described in further details below (refer to Section 4.3.2 for the prohibited payload / payload gondola RF emissions):
  - A certified transponder replying to both legacy Mode A/C and Mode S interrogations from both ground radar and airborne collision avoidance systems is used as the primary method of in-flight tracking. The transponder is also equipped to transmit ADS-B signal. The transponder transmits the identification and location of the aerostat throughout the flight.
  - The system also includes a separate secondary tracking system, using a GPS receiver and Iridium's Short Burst Data (SBD) service, in order to identify the landing location and recover the flight train. The device provides tracking

capabilities and ancillary telemetry from the gondola such as: latitude, longitude, altitude, speed, heading, atmospheric pressure and temperature.

- **Separator**: a self-terminating linkage between the envelope connecting cord and the parachute that will separate the system upon balloon rupture.
- **Flight Tracker:** a unit enabling flight tracking and ground recovery, used when the Avionics Gondola is not part of the flight train.
- **Payload Bay:** a supporting structure integrated to the Avionics Gondola designed to accommodate one or more payload(s).
- **Payload Gondola (PLG)**: a standalone supporting structure hosting one or more payload(s) and provided by an organization external to the CSA.

For the *Large* category, two possible payload configurations are available depending on the user's needs:

1. In the **Distributed Configuration**, the payload is located in its own standalone payload gondola (PLG) which is designed and provided by the external payload organization. Therefore, the Avionics Gondola and the Payload Gondola are distinct elements with the former located above the latter in the flight train and connected using mechanical links.
2. In the **Integrated Configuration**, the payload is integrated into the CSA-provided gondola and so the Avionics Gondola and Payload Gondola are united into a single element. In this configuration, the concept of a payload gondola does not exist, it is instead called a Payload Bay. Again, the Avionics Gondola is located above the Payload Bay.

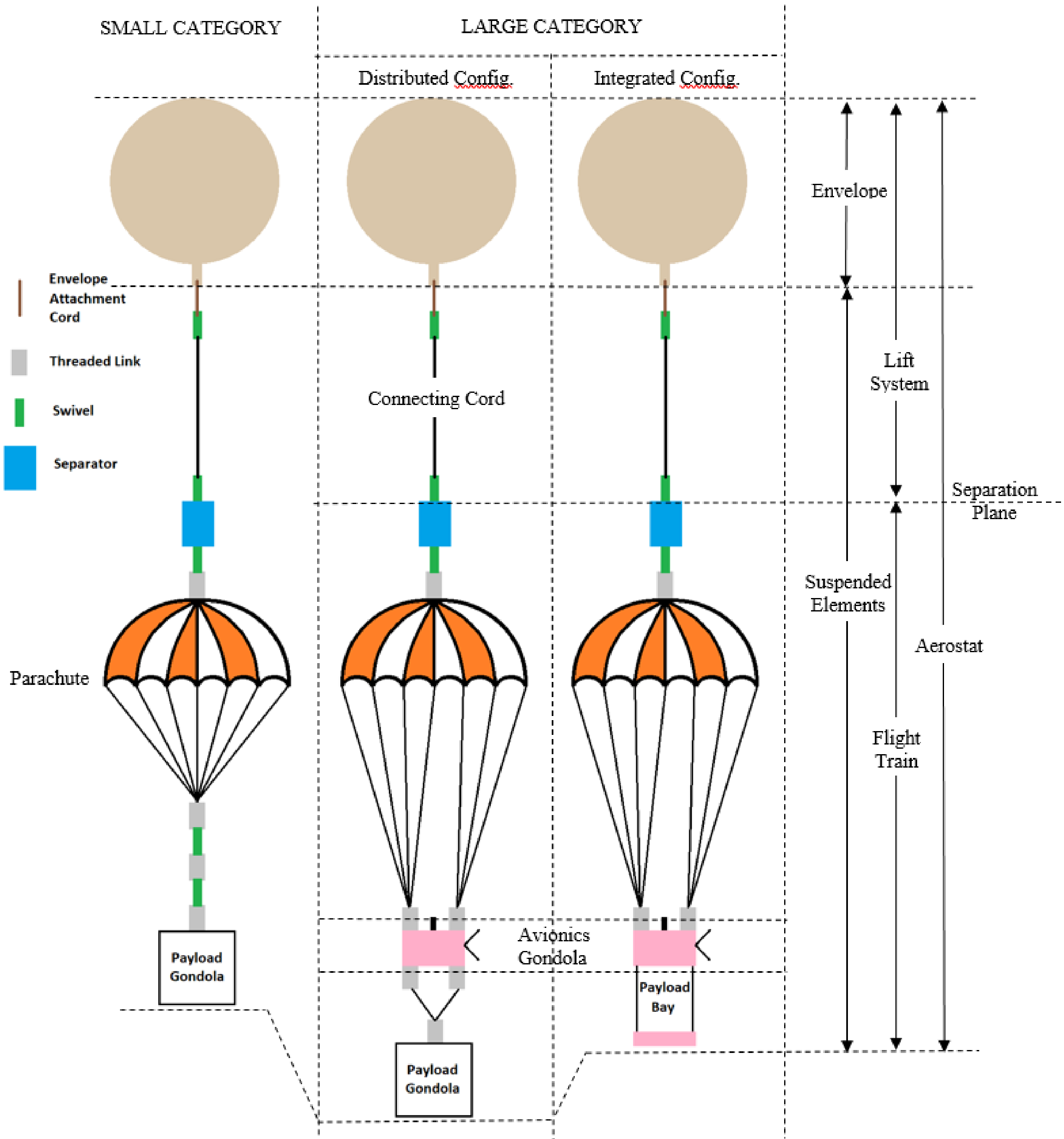

FIGURE 1 – SEB AEROSTAT CONFIGURATIONS

Note: Although it is not shown, the *Small* Category aerostat may also include a separator.

4 PAYLOAD REQUIREMENTS

This section includes environmental, electrical, mechanical and safety requirements. Payload developers will need to demonstrate that their discrete payload or payload gondola (refer to Section 3) complies with all requirements. Note that unless otherwise stated, for the rest of this document the term “payload” (PL) will be used interchangeably to refer to either discrete payloads or payload gondolas (PLG).

Requirements are denoted by “*PLD-REQ-XXX-YYY*”, where *PLD* denotes “Payload”, *XXX* is the requirement type (MEC = Mechanical, ELE = Electrical, SAF = Safety) and *YYY* is the requirement number. Requirements are summarized in the Requirements Compliance Matrix in Appendix A of this document.

4.1 DEFINITIONS

The following nomenclature is used:

- The term “**shall**” is used to indicate a <u>mandatory</u> requirement.
- The term “**should**” indicates a goal but is not mandatory.

Risk levels are defined according to the following degrees of severity:

- <u>Catastrophic</u>: loss of human life or total destruction of the flight system.
- <u>Serious</u>: serious injury to people, partial destruction of the flight system, or significant damage to property or to the environment.
- <u>Benign</u>: risks with non-catastrophic and non-serious severity.

Systems at risk are systems that could induce a catastrophic or serious risk.

4.2 ENVIRONMENTAL REQUIREMENTS

The following sub-sections describe environmental requirements. Payload developers must ensure their payload will be able to withstand the environmental conditions and risks throughout the flight environment.

4.2.1 Mechanical Environment

PLD-REQ-MEC-001: The payload shall be capable of sustaining the separation loads: a vertical (Z-axis) G-force of 10G and a lateral G-force of 7.5G in any direction in the XY plane, applied to the payload's center of mass.

Rationale: At separation, the gondola and payload assembly will undergo accelerations as a result of parachute deployment. The resultant acceleration created by the combination of the vertical and lateral accelerations, as per Figure 2, must be taken into consideration during the design of the payload. The resultant acceleration must be theoretically applied to a minimum of three critical, worst-case orientations to the payload to ensure design integrity.

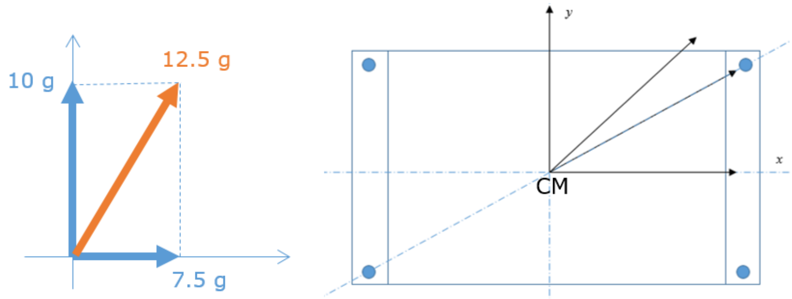

FIGURE 2 – SEPARATION LOADS

4.2.2 Thermal Environment

PLD-REQ-MEC-005: The payload shall not cause catastrophic or serious risks[1] due to the flight thermal environment.

Rationale: During flight, the gondola and payload will be subject to decreasing pressures and varying temperatures as the altitude increases. As shown in Figure 3, the temperature profile drops to approximately -56 °C at the 10-20 km altitude range. The burst altitude is dependent on various factors. Typically burst occurs around 30 km, though it is possible to burst below or above that altitude.

[1]As per the definitions of catastrophic and serious risks in Section 4.1.

The payload developer is responsible for providing any thermal protection (e.g. blankets/covers) for the PL or PLG to achieve the required operational temperature. However, additional external thermal blankets attached to the gondola structure may be added by the CSA in certain circumstances upon the payload developer's advance request.

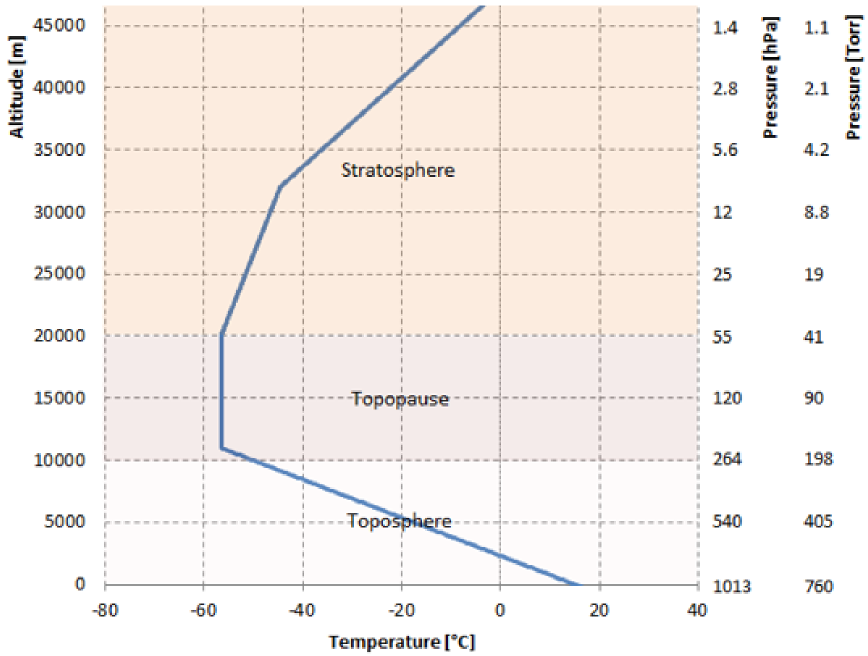

FIGURE 3 – TEMPERATURE VS ALTITUDE CURVE, SOURCE: NASA-TM-X-74335, U.S. STANDARD ATMOSPHERE, 1976

4.2.3 Depressurization & Pressurization Environment

PLD-REQ-MEC-008: The payload shall not cause catastrophic or serious risks[2] due to pressurization or depressurization.

Rationale: Equipment must sustain the depressurization/pressurization induced by the flight environment. Note that sealed systems have the potential to cause serious or catastrophic risks and need to be analyzed.

[2]As per the definitions of catastrophic and serious risks in Section 4.1.

Pressure vessels must be designed in accordance with applicable national consensus codes such as the American Society of Mechanical Engineers' (ASME's) Boiler and Pressure Vessel Code or other codes acceptable to the CSA, if applicable.

4.3 ELECTRICAL REQUIREMENTS

The following sub-sections describe the electrical requirements. Discrete payloads and payload gondola providers are responsible for providing their own power, data storage and communication systems as per their mission requirements. The CSA may be able to offer power to payloads upon request, as detailed in the User's Manual [RD4]. Note that there is no communication system provided by the CSA to payloads.

4.3.1 Power

PLD-REQ-ELE-001: Power subsystems shall be equipped with the following safety protective systems, at minimum, to prevent safety hazards:

1. **Over-current protection (such as a fuse),**
2. **Over discharge protection (battery cut-off for under-voltage).**

Rationale: Without proper protection, defective or compromised batteries can lead to catastrophic failures such as fires. Therefore, the power subsystem must include protective systems.

It is recommended to also implement protections against over-charge (if using rechargeable batteries), external short-circuits and temperature related detrimental effects.

If the payload has requested the use of the CSA's payload power subsystem [see RD4], this subsystem includes the required safety protection systems.

It is important to note that depending on the selected battery cell chemistry and format, the CSA may require that the battery undergoes and passes vacuum testing in order to be accepted.

4.3.2 Intentional RF transmitters

PLD-REQ-ELE-010: The payload's frequency plan, listing all the frequencies of the transmitters and receivers used by the payload, shall be submitted to the CSA.

Rationale: Identification of all Radio Frequency (RF) transmitters and receivers on the payload must be identified in order to check for compatibility and be incorporated in the Gondola's RF frequency plan.

PLD-REQ-ELE-015: The payload shall not emit in the following wavebands:

1030 MHz	CSA transponder Rx
1090 MHz	CSA transponder Tx
1616 to 1626.5 MHz	CSA Iridium Beacon
1575.42 MHz	CSA GPS

Rationale: The payload must not interfere with the transponder and GPS frequencies used by the CSA for the aerostat flight train.

4.3.3 Wiring Harnesses

PLD-REQ-ELE-020: All cables and harnesses shall be rated for a current greater than the rating of the protective device (i.e. fuse).

Rationale: Selection of the wiring harnesses must ensure safety under all operations.

PLD-REQ-ELE-023: All cables and harnesses shall be rated for a current greater than that of the signal it carries under all operating conditions.

Rationale: Selection of the wiring harnesses must ensure safety under all operations.

PLD-REQ-ELE-030: All cables shall be insulated and secured.

Rationale: For safety and protection of personnel.

4.3.4 Connectors

PLD-REQ-ELE-040: Connectors of electrical circuits at risk[3] shall be designed in such a way that there is no possible way to connect them in an incorrect orientation (i.e. mating connectors can only connect to each other in one possible orientation).

Rationale: To ensure that circuits at risk (such as the power supply) cannot be connected incorrectly.

[3]As per the definitions of systems at risk in Section 4.1.

PLD-REQ-ELE-045: Connectors of electrical circuits at risk[4] shall include a system for locking the connections in position.

Rationale: To ensure that connectors do not come loose and that their connections will not become disconnected.

[4]As per the definitions of systems at risk in Section 4.1.

PLD-REQ-ELE-050: All connectors of electrical circuits shall be rated for a current greater than that of the signals they carry under all operating conditions.

Rationale: Selection of connectors must ensure safe operations and prevent against catastrophic failures such as fires.

4.4 MECHANICAL REQUIREMENTS

The following sub-sections describe the mechanical requirements. Depending on the aerostat configuration (integrated or distributed), some of the requirements below vary as specified. Payload developers must ensure their PL (integrated configuration) or PLG (distributed configuration) design will meet these requirements.

4.4.1 Mass Allocation

PLD-REQ-MEC-010: The mass of the payload shall be a maximum of 10 kg, including the mass of the mounting interface, the payload enclosure, the payload power and any payload thermal protection.

Rationale: The mass allocation of the payload is restricted as this is what the gondola and aerostat have been qualified for. The total payload mass includes the payload itself and all supporting systems (mounting interface, power, thermal protection, fasteners, etc.). For the distributed configuration, the maximum mass also includes the payload gondola provided by the payload developer.

Note that if any of the CSA supporting systems are used for the payload (i.e. CSA's payload interface plate or CSA's payload power subsystem [see RD4]), the mass of these supporting systems must be considered as part of the payload's mass budget.

4.4.2 Volume Allocation

The volume allocation requirement depends on whether the aerostat is in the integrated or distributed configuration:

4.4.2.1 Integrated Configuration

PLD-REQ-MEC-020A: The payload shall fit within a cylindrical volume envelope with a diameter of 300 mm and a height of 600 mm.

Rationale: The shape and size of the CSA Payload Bay and its components dictates the payload volume envelope, as shown in blue in Figure 4.

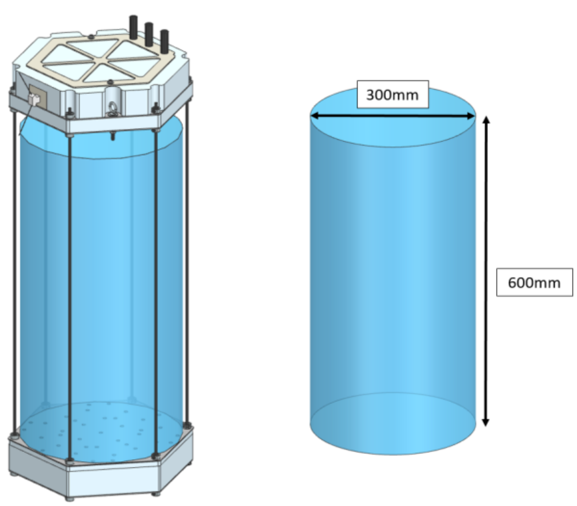

FIGURE 4 – PAYLOAD BAY VOLUME (INTEGRATED CONFIGURATION)

Note: The above figure shows the maximum volume available for a payload. In the case that the payload does not require the full volume, the height of the gondola may be reduced. Additionally, all payload components must remain within the payload volume (i.e., no small parts, such as bolts, may protrude beyond the envelope). Upon approval by the CSA, the payload enclosure may extend beyond the payload volume envelope (for example, it may be desirable to use a hexagonal foam enclosure of the same perimeter as the gondola to enclose the payload).

4.4.2.2 Distributed Configuration

PLD-REQ-MEC-020B: The payload gondola dimensions shall be provided to the CSA for review and approval.

Rationale: To ensure feasibility and ease of payload gondola integration with the flight train and of aerostat launch.

4.4.3 Gondola Coordinate System

The gondola coordinate system depends on whether the aerostat is in the integrated or distributed configuration:

4.4.3.1 Integrated Configuration

The coordinate system origin of the CSA Payload Bay is located at the base plane of the Payload Bay as depicted in Figure 5. The directional configuration of the X, Y, and Z axes can also be seen. Note that if the payload requires a nadir view, this can be accommodated by an interface plate with a nadir view port [see RD4].

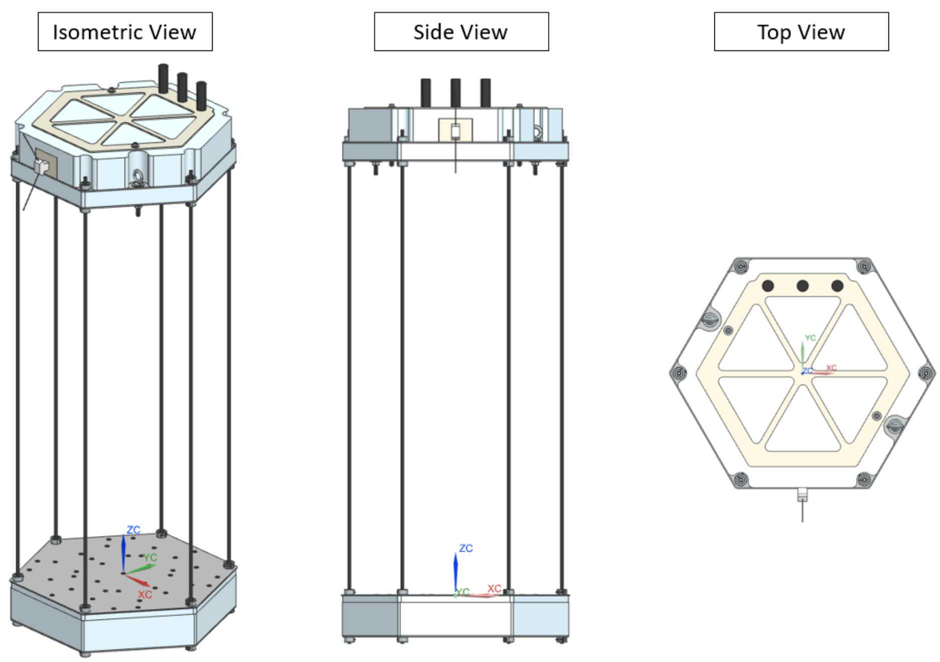

FIGURE 5 – COORDINATE SYSTEM OF THE GONDOLA (INTEGRATED CONFIGURATION)

4.4.3.2 Distributed Configuration

The gondola coordinate system origin is located underneath the CSA avionics gondola, with its Z axis passing through the geometric center of the avionics gondola (note, the image on the right shows the avionics gondola inverted):

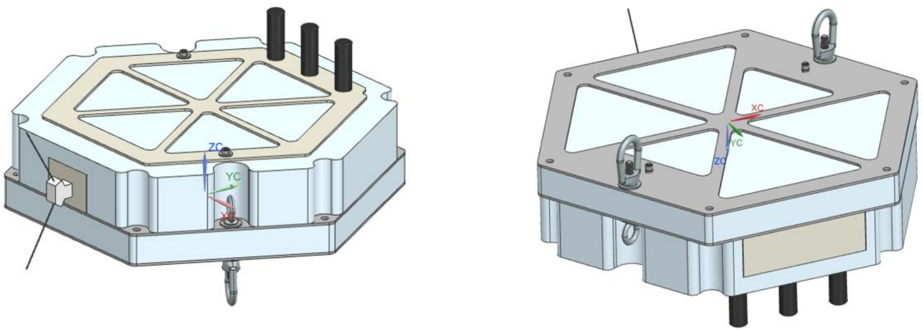

FIGURE 6 – COORDINATE SYSTEM OF THE GONDOLA (DISTRIBUTED CONFIGURATION)

4.4.4 Location of the Payload Center of Mass

The payload center of mass location requirement depends on whether the aerostat is in the integrated or distributed configuration:

4.4.4.1 Integrated Configuration

PLD-REQ-MEC-030A: The center of mass of the payload shall be located within a 25 mm diameter cylinder of the Z axis of the CSA Payload Bay.

Rationale: The center of mass (CM) of the payload must lie within the cylindrical envelope centered on the Z-axis, as shown in orange in Figure 7. The Z coordinate of the CM can be located at any point along the z-axis within the payload volume envelope.

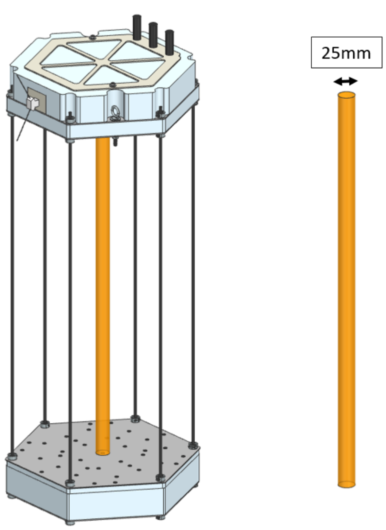

FIGURE 7 – PAYLOAD CENTER OF MASS POSITION REQUIREMENT (INTEGRATED CONFIGURATION)

4.4.4.2 Distributed Configuration

PLD-REQ-MEC-030B: The center of mass of the payload gondola shall be located within a 25 mm diameter cylinder of the Z axis of the CSA Avionics Gondola.

Rationale: The center of mass of the payload gondola must adhere to the same cylindrical positional constraint in the XY plane as for the integrated payload configuration. The Z coordinate of the CM can be located at any point along the Z-axis.

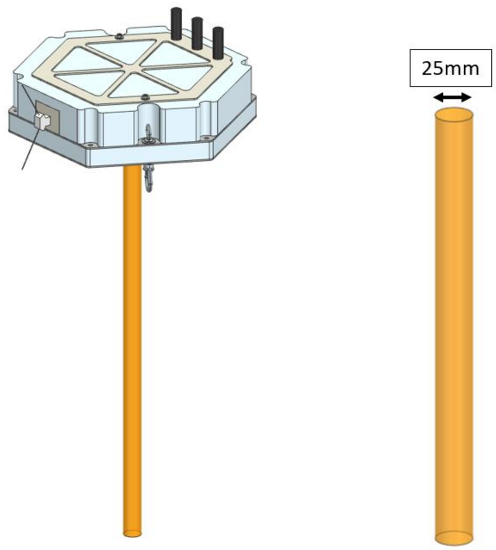

FIGURE 8 – PAYLOAD CENTER OF MASS POSITION REQUIREMENT (DISTRIBUTED CONFIGURATION)

4.4.5 Payload Mounting Interface

The payload or payload gondola mounting interface requirement varies as follows, depending on if the aerostat is in the integrated or distributed configuration. Refer to the SEB Payload Mechanical Interface Control Document [RD4] for further information regarding the PL or PLG mounting interface.

4.4.5.1 Integrated Configuration

PLD-REQ-MEC-040A: The payload mounting interface shall be compatible with the CSA Payload Bay, as per the specifications in RD4.

Rationale: The payload mounting interface must be designed to the specifications provided by the CSA in order to properly integrate within the Payload Bay.

Note that the CSA offers a mounting interface plate, with or without a nadir view, which can be requested to be used by the payload [see RD4]. It is also possible for the payload to design and provide their own custom mounting interface plate, which could be made of an appropriate material that will adhere to the design constraints posed by the environment factors. The interface must have 6 clearance holes [per RD4] to allow for ease of assembly when integrating the payload with the gondola. .

The description of the payload's mounting interface (including the type, size and number of bolts used for attachment) must be included as part of the submission made to the CSA.

4.4.5.2 Distributed Configuration

PLD-REQ-MEC-040B: The payload gondola mounting interface shall be provided by the payload team to be reviewed and approved by the CSA and must provide suitable attachment hardware which is compatible with the CSA Avionics Gondola attachment points, as per the specifications in RD4.

Rationale: To ensure compatibility with the interface of the Avionics Gondola. Refer to the SEB Payload Mechanical Interface Control Document [RD4] for details.

4.4.6 Free Parts and Debris

PLD-REQ-MEC-050: The payload equipment shall not emit nor liberate any free parts or debris under any conditions.

Rationale: All parts within the payload must remain attached to the payload during launch, flight and landing. External mechanical elements (masts, antenna, etc.) must be folded or retracted prior to landing, or must remain attached when broken.

4.4.7 Nut and Bolt Mountings

PLD-REQ-MEC-060: Nut and bolt mountings shall use a locking device to prevent loosening.

Rationale: In order to be ensure the payload is adequately secured. Examples of devices which can be used to prevent loosening includes: spring lock washers, torque wrench with flat washers, thread-lock, etc.

4.5 SAFETY REQUIREMENTS

The following sub-sections describe the safety requirements.

4.5.1 Identification of Hazardous Materials & equipment

PLD-REQ-SAF-001: Payloads shall identify and report all hazardous materials and equipment listed below in Hazard Sheets[5], taking both nominal and off-nominal operation into account:

1. **Explosives;**
2. **Flammables (any material than can burn easily, e.g. foam, fabric, paper, etc.);**
3. **Chemicals;**
4. **Cryogenic liquids;**
5. **Biological items (Note: the use of biological elements induces higher risks, which require consultations with several departments within and outside of the CSA. Therefore payloads with biological elements may not be approved by the CSA);**
6. **Lasers;**
7. **Batteries, as follows:**
    a. **<u>Alkaline-MnO2</u>: battery cells larger than size D, battery assembly with voltage exceeding 12 V and/or with total capacity exceeding 60 Whr;**
    b. **<u>Button cells</u>: battery cell capacity exceeding 300 mAh, more than three cells in the same circuit, any cell types that are Li SOCl2, Li-SO2, LiBCX, Li-SO2Cl2;**
    c. **<u>Unmodified rechargeable commercial batteries (Ag-Zn, NiMH, NiCd)</u>: battery assembly with voltage exceeding 20 V and/or with total capacity exceeding 60 Whr;**
    d. **<u>Unmodified rechargeable commercial batteries (Li-Ion)</u>: battery assembly with voltage exceeding 10 V and/or with total capacity exceeding 60 Whr;**
8. **Charge accumulation devices (other than batteries) that could be charged unintentionally and remain charged;**
9. **Exposed conductive elements with voltages in excess of 30 V DC or rms;**
10. **Exposed conductive elements with high currents: let-go current* greater than 40 mA and leakage current** greater than 3.5 mA DC or rms;**
11. **Any capability of creating an electromagnetic field, emitting electromagnetic waves, or creating electromagnetic interference;**
12. **Magnetic fields (induced, external, permanent magnets);**
13. **RF transmitters;**
14. **Pressure vessels;**
15. **Mechanisms (e.g. deployment) and/or exposed rotating/reciprocating equipment;**
16. **Any elements that protrude from the gondola (such as masts, antennas, mirrors, panels, etc.);**
17. **Properties of materials likely to cause injury (such as sharp edges, sharp angles, slippery or rough surfaces, etc.);**
18. **Brittle materials (such as glass);**
19. **Exposed surfaces with temperatures > 45°C or < 4°C;**
20. **Hazardous ground support equipment.**

Rationale: Hazardous materials and equipment may introduce safety-related risks which need to be carefully evaluated (including any necessary mitigations) to ensure protection of people, the environment, and public/private property.

[5]Refer to RD3 for the Hazard Sheet template and further details.

***** The let-go current threshold is the current above which a person will be unable to release his/her grip on the electrically energized surface because of involuntary muscle contractions. The threshold current for let-go is affected by the physical characteristics of the body, and the frequency and wave shape of the current. The 99.5 percentile rank recommended limits for direct current are 60 mA for a man and 40 mA for a woman.

** Leakage current is the current which flows through the equipment conductive paths to a solidly grounded source.

PLD-REQ-SAF-005: The following technologies shall be prohibited from use in payloads:

a.) Radioactive sources or materials;
b.) Combustion engines.

Rationale: *These technologies present elevated risks to personnel and/or to the flight train.*

PLD-REQ-SAF-020: Any payload hazardous equipment (per PLD-REQ-SAF-001) shall bear a visible safety marking (e.g. danger, warning, caution sign, label, tag) located on the outside of the payload enclosure in the following order of precedence:

1. **Preferred: supplier or manufacturer-issued safety marking.**
2. **Alternate: customized safety marking proposed by the payload team for CSA consideration, in cases where it can be demonstrated that the preferred option is not available.**

Rationale: The ability to rapidly identify the presence of risks and hazards will reduce risks to personnel safety, especially during pre-flight verifications and post-flight recovery activities.

4.5.2 Safety Barriers

PLD-REQ-SAF-027: Payload design and manufacturing shall prevent fault propagation to the rest of the flight train, meaning that no single failure of the payload or its components will be capable of disrupting the proper functioning of the aerostat.

Rationale: The proper functioning of the aerostat must not be affected by a payload failure.

PLD-REQ-SAF-030: No single failure (hardware failure, software error, human error, etc.) shall involve a risk of catastrophic severity, unless approved[6] by the CSA through a hazard sheet containing at least two independent safety barriers.

Rationale: In order to reduce likelihood of catastrophic events.

[6]Payloads should initiate discussions with the CSA concerning possible safety barriers as early as possible during design phases.

PLD-REQ-SAF-035: In the event of a power failure, there shall be no change in the state of any safety barrier.

Rationale: In order to reduce probability of catastrophic events.

PLD-REQ-SAF-037: In the event of a power failure, all systems at risk[7] shall switch to a safe mode.

Rationale: In order to reduce likelihood of catastrophic events.

[7]As per the definitions of systems at risks in Section 4.1.

4.5.3 Hazardous Chemical System Hardware

PLD-REQ-SAF-040: Items featuring hazardous chemicals (i.e. caustic, toxic, or reactive chemicals) shall have safety features to prevent inadvertent release of these chemicals.

Rationale: To protect personnel from the hazardous chemicals.

Hazardous chemical items which release caustic, toxic, or reactive chemicals should be designed in such a way that the flow path contains two independent safeties to prevent an inadvertent release.

Components of hazardous chemical systems should feature redundant mechanical or welded seals at all fittings to prevent the inadvertent flow or release of caustic, toxic, and/or reactive chemicals.

Materials selected for use in hazardous chemical systems must be compatible with the hazardous chemical used.

4.5.4 Safety Factors

PLD-REQ-SAF-055: The payload shall demonstrate a positive margin using the appropriate safety factor for the separation loads in PLD-REQ-MEC-001. For analysis this is a safety factor of 2, and for physical testing this is a safety factor of 1.5.

Rationale: To ensure the payload does not break down and release parts or damage the flight train during flight, it must survive the most severe loads with a margin of safety. Owing to the reduced uncertainty in physical testing, a smaller factor of safety is allowed.

APPENDIX A REQUIREMENTS COMPLIANCE MATRIX

The Requirements Compliance Matrix in Table A-1 compiles all requirements in this document.

Payload providers are required to include a copy of this matrix in their Experiment Safety & Data Package (ESDP), refer to RD3 for more details. For each requirement in the matrix, the following information must be filled out:

- Compliance column: Indicate that the PL or PLG is either compliant, or not compliant to the requirement, or that the requirement is not applicable. For any non-compliance, a Request for Deviation (RFD) form must be filled out and submitted to the CSA for consideration and approval (refer to RD3 for more details and for the RFD form template).
- Method column: Indicate the method used to verify compliance against the requirement, between the following options: A = Analysis, D = Review of Design, I = Inspection, S = Simulation and T = Test.
- Justification column: Brief summary for how the PL or PLG complies to the requirement, or why the requirement is not applicable (the details will be contained in the reference given).
- Reference column: Refer to the specific ESDP section that contains the analysis, test report, etc. which demonstrates compliance to the requirement, or refer to the approved RFD for non-compliant requirements.

TABLE A-1 REQUIREMENTS COMPLIANCE MATRIX

Req. ID	**Requirement**	**Compliance** *(C, NC, NA)*	**Method** *(A, D, I, S, T)*	**Justification**	**Reference**
PLD-REQ-MEC-001	The payload shall be capable of sustaining the separation loads: a vertical (Z-axis) G-force of 10G and a lateral G-force of 7.5G in any direction in the XY plane, applied to the payload's center of mass.				
PLD-REQ-MEC-005	The payload shall not cause catastrophic or serious risks* due to the flight thermal environment.				
PLD-REQ-MEC-008	The payload shall not cause catastrophic or serious risks* due to pressurization or depressurization.				
PLD-REQ-MEC-010	The mass of the payload shall be a maximum of 10 kg, including the mass of the mounting interface, the payload enclosure, the payload power and any payload thermal protection.				

PLD-REQ-MEC-020A	The payload shall fit within a cylindrical volume envelope with a diameter of 300 mm and height of 600 mm.				
PLD-REQ-MEC-020B	The payload gondola dimensions shall be provided to the CSA for review and approval.				
PLD-REQ-MEC-030A	The center of mass of the payload shall be located within a 25 mm diameter cylinder of the Z axis of the CSA Payload Bay.				
PLD-REQ-MEC-030B	The center of mass of the payload gondola shall be located within a 25 mm diameter cylinder of the Z axis of the CSA Avionics Gondola.				
PLD-REQ-MEC-040A	The payload mounting interface shall be compatible with the CSA Payload Bay, as per the specifications in RD4.				
PLD-REQ-MEC-040B	The payload gondola mounting interface shall be provided by the payload team to be reviewed and approved by the CSA and must provide suitable attachment hardware which is compatible with the CSA Avionics Gondola attachment points, as per the specifications in RD4.				
PLD-REQ-MEC-050	The payload equipment shall not emit nor liberate any free parts or debris under any conditions.				
PLD-REQ-MEC-060	Nut and bolt mountings shall use a locking device to prevent loosening.				
PLD-REQ-ELE-001	Power subsystems shall be equipped with the following safety protective systems, at minimum, to prevent safety hazards: (1) over-current protection (such as a fuse), (2) over-discharge protection (battery cut-off for under-voltage).				
PLD-REQ-ELE-010	The payload's frequency plan, listing all the frequencies of the transmitters and receivers used by the payload, shall be submitted to the CSA.				
PLD-REQ-ELE-015	The payload shall not emit in the following wavebands: 1030 MHz (CSA transponder Rx), 1090 MHz (CSA transponder Tx), 1616 to 1626.5 MHz (CSA Iridium Beacon), 1575.42 MHz (CSA GPS).				

PLD-REQ-ELE-020	All cables and harnesses shall be rated for a current greater than the rating of the protective device (i.e. fuse).				
PLD-REQ-ELE-023	All cables and harnesses shall be rated for a current greater than that of the signal it carries under all operating conditions.				
PLD-REQ-ELE-030	All cables shall be insulated and secured.				
PLD-REQ-ELE-040	Connectors of electrical circuits at risk* shall be designed in such a way that there is no possible way to connect them in an incorrect orientation (i.e. mating connectors can only connect to each other in one possible orientation).				
PLD-REQ-ELE-045	Connectors of electrical circuits at risk* shall include a system for locking the connections in position.				
PLD-REQ-ELE-050	All connectors of electrical circuits shall be rated for a current greater than that of the signals they carry under all operating conditions.				
PLD-REQ-SAF-001	Payloads shall identify and report all hazardous materials and equipment in Hazard Sheets, taking both nominal and off-nominal operation into account.				
PLD-REQ-SAF-005	The following technologies shall be prohibited from use in payloads: (a) radioactive sources or materials; (b) combustion engines.				
PLD-REQ-SAF-020	Any payload hazardous equipment (per PLD-REQ-SAF-001) shall bear a visible marking (e.g. danger, warning, caution sign, label, tag) located on the outside of the payload enclosure in the following order of preference: (1) Preferred: supplier or manufacturer-issued safety marking, (2) Alternate: customized safety marking proposed by the payload team for CSA consideration, in cases where it can be demonstrated that the preferred option is not available.				
PLD-REQ-SAF-027	Payload design and manufacturing shall prevent fault propagation to the rest of the flight train, meaning that no single failure of the payload or its components				

	will be capable of disrupting the proper functioning of the aerostat.				
PLD-REQ-SAF-030	No single failure (hardware failure, software error, human error, etc.) shall involve a risk of catastrophic severity, unless approved by the CSA through a hazard sheet containing at least two independent safety barriers.				
PLD-REQ-SAF-035	In the event of a power failure, there shall be no change in the state of any safety barrier.				
PLD-REQ-SAF-037	In the event of a power failure, all systems at risk* shall switch to a safe mode.				
PLD-REQ-SAF-040	Items featuring hazardous chemicals (i.e. caustic, toxic, or reactive chemicals) shall have safety features to prevent inadvertent release of these chemicals.				
PLD-REQ-SAF-055	The payload shall demonstrate a positive margin using the appropriate safety factor for the separation loads in PLD-REQ-MEC-001. For analysis this is a safety factor of 2, and for physical testing this is a safety factor of 1.5				

*As per the definitions in Section 4.1.