



CSA-STRATOS-MAN-0011

Canadian Space Agency Stratospheric Balloons Program

STRATOS Expandable Balloon Payload Requirements and User's Manual

Rev B

Dec 2021

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Revision History

Rev.	Description	Date	Initials
I.R.	Initial release	Jan. 20, 2020	AR
А	- Updates to the requirements and guidelines.	Dec. 07,	AR
	- Updates to the payload deliverable (documentation)	2020	
	requirements. Inclusion of a RFD/RFW Form and a Recovery		
	Procedure Template in the appendices.		
В	- Generalization of the document to be applicable to a broader	Dec. 14,	AR
	spectrum of possible payload or payload gondola applicants.	2021	
	- Re-organization of the overall document structure and the		
	document's sections, including separating the Requirements		
	and Best Practices / Design Guidelines into different sections.		
	- Modification of the payload requirements as follows:		
	modified PLD-REQ-MEC-001, PLD-REQ-MEC-005, added		
	new PLD-REQ-MEC-020B, added new PLD-REQ-MEC-		
	030B, modified PLD-REQ-MEC-040A, added new PLD-		
	REQ-MEC-040B, modified PLD-REQ-ELE-001, modified		
	PLD-REQ-ELE-10, modified PLD-REQ-ELE-020, added new		
	PLD-REQ-ELE-023, deleted PLD-PROC-REQ-001, modified		
	PLD-REQ-PROC-010, modified PLD-REQ-SAF-001, added		
	new PLD-REQ-SAF-005, deleted PLD-REQ-SAF-010,		
	modified PLD-REQ-SAF-020, deleted PLD-REQ-SAF-025,		
	added new PLD-REQ-SAF-027, modified PLD-REQ-SAF-		
	030, modified PLD-REQ-SAF-035, added new PLD-REQ-		
	SAF-037, modified PLD-REQ-SAF-040, deleted PLD-REQ-		
	SAF-050, added new PLD-REQ-SAF-055.		
	- Addition of information about the SEB aerostat and the		
	different types of aerostat configurations (integrated &		
	distributed).		
	- Removal of the information regarding the required contents		
	and submission process of the ESDP, which is instead now		
	included in CSA-STRATOS-PR-0004 rev A.		
	- Removal of the following templates: Requests for Deviation,		
	Hazard Sheets, and Recovery Procedures, which are all instead		
	now included in CSA-STRATOS-PR-0004 rev A.		

Т	ABL	E PA	GE
1	Ι	INTRODUCTION	7
	1.1	Purpose	7
	1.2	Scope	7
	1.3	ACRONYMS	7
2	Ι	DOCUMENTS	9
	2.1		0
	$\frac{2.1}{2.2}$	APPLICABLE DOCUMENTS	9
	2.2	REFERENCE DOCUMENTS	9
3	S	STRATOS PHERIC EXPANDABLE BALLOON (SEB) OVERVIEW	10
	3.1	SEB CATEGORIES	10
	3.2	CSA SEB AEROST AT	10
4	т		10
4	ł	PAYLOAD KEQUIREMENTS	13
	4.1	Environmental Requirements	13
	4	4.1.1 Mechanical Environment	13
	4	4.1.2 Thermal Environment	14
	4	4.1.3 Depressurization & Pressurization Environment	14
	4.2	ELECTRICAL REQUIREMENTS	15
	4	4.2.1 POWer	.13
		1.2.3 Wiring Hamesses	15
	4	1.2.4 Connectors	16
	4.3	Mechanical Requirements	16
	4	4.3.1 Mass Allocation	16
	4	4.3.2 Volume Allocation	16
		4.3.2.1 Integrated Configuration	17
	4	4.3.2.2 Distributed Configuration	17
	4	4.3.3 Coordinate System of the CSA Payload Bay – Integrated Configuration	1 /
	4	4.3.4 Location of the Fayload Center of Mass	10 18
		4.3.4.2 Distributed Configuration	19
	4	1.3.5 Payload Mounting Interface	19
		4.3.5.1 Integrated Configuration	19
	4	4.3.5.2 Distributed Configuration	20
	4	4.3.0 Free Parts and Debris	20
	4	4.5.7 Nut and Bolt Mountings	20
	4		20
5	S	SAFETY REQUIREMENTS	21
	51	IDENTIFICATION OF HAZARDOUS MATERIALS & FOURMENT	21
	5.2	SAFETY BARRIERS	23
	5.3	Hazardous Chemical System Hardware	23
	5.4	SAFETY CRITICAL TESTS	23
	5.5	SAFETY FACTORS	23
6	Ι	DESIGN GUIDELINES AND BEST PRACTICES	. 24
	6.1	Environmental Design Guidelines and Best Practices	24
	6.2	Electrical Design Guidelines and Best Practices	25
	6.3	Mechanical Design Guidelines and Best Practices	26
	6.4	ASSEMBLY, INTEGRATION, TESTING (AIT) AND OPERATION DESIGN GUIDELINES AND BEST PRACTICES	26

TABLE OF CONTENTS

7 LA	AUNCH AND FLIGHT PHASES	
7.1	Pre-Launch	
7.2	Flight	
7.2	2.1 Countdown and Launch	
7.2	.2.2 Ascent, Bursting and Descent	
7.3	LANDING	
7.4	Recovery	
APPENI	NDIX A REQUIREMENTS COMPLIANCE MATRIX	
APPENI	NDIX B PAYLOAD OR PAYLOAD GONDOLA INTEGRATION	
B.1	PAYLOAD MECHANICAL INTERFACE – INTEGRATED CONFIGURATION	
B.2	PAYLOAD MECHANICAL INTERFACE – DISTRIBUTED CONFIGURATION	N

LIST OF FIGURES

FIGURE PA	ιGΕ
FIGURE 1 – SEB A EROSTA T CONFIGURATIONS	12
FIGURE 2 – SEPA RATION LOADS	13
FIGURE 3 – TEMPERATURE VS ALTITUDE CURVE, SOURCE: NASA-TM-X-74335, U.S. STANDARD ATMOSPHERE, 1976	14
FIGURE 4 – PAYLOAD BAY VOLUME (INTEGRATED CONFIGURATION)	17
FIGURE 5 – COORDINATE SYSTEM OF THE CSA PAYLOAD BAY	18
FIGURE 6 - PAYLOAD CENTER OF MASS POSITION REQUIREMENT (INTEGRATED CONFIGURATION)	19
FIGURE 7 – EXAMPLE 1D HEAT BALANCE CALCULATION	24
FIGURE 8 – PAYLOAD ARMING PLUG EXAMPLE	25
FIGURE 9 – PAYLOAD INTERFACE MOUNT MECHANICAL DIMENSIONS DRAWING, INTEGRATED CONFIGURATION	34
FIGURE 10 – PAYLOAD INTERFACE MOUNT MECHANICAL RADIAL DRAWING, INTEGRATED CONFIGURATION	35
FIGURE 11 – AVIONICS GONDOLA (TOP AND BOTTOM VIEWS)	35
FIGURE 12 – AVIONICS GONDOLA EY EBOLT INTERFACE	36
FIGURE 13 - THREADED CONNECTOR RING, MECHANICAL INTERFACE PLG TO AVIONICS GONDOLA	36

LIST OF TABLES

TABLE	P	AGE
TABLE 2-1	APPLICABLE DOCUMENTS	9
TABLE 2-2	REFERENCE DOCUMENTS	9

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 all necessary requirements and information for payload developers to safely design and integrate their payload into the designated gondola or to integrate their payload gondola into the 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. Guidelines and best practices are also presented as recommendations. For information regarding the payload application and certification process, including the deliverables to be submitted to the CSA, refer to RD3.

AD	Applicable Document
AIT	Assembly Integration and Testing
CAR	Canadian Aviation Regulations
СМ	Centre of Mass
CNES	Centre National d'Études Spatiales
CoC	Certificate of Compliance
CSA	Canadian Space Agency
ESDP	Experiment Safety and Data Package
GSE	Ground Support Equipment

1.3 ACRONYMS

PI	Principal Investigator
PL	Payload
PLG	Payload Gondola
PLM	Payload Manager
RD	Reference Document
RF	Radio Frequency
RFD	Request for Deviation
RFW	Request for Waiver
S&MA	Safety and Mission Assurance
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.				
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	IR	2021-11-01
RD2.	SOR/96-433	Canadian Aviation Regulations (En) (Fr)	Latest	Latest
RD3.	CSA-STRATOS-PR- 0004	Payload and Payload Gondola Certification and Experiment Safety Data Pack Submission Procedure	А	Draft

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 ft³ (3.256 m³), 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 4.2.2 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 ShortBurst 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 exists, 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 and mechanical requirements. Payload developers will need to demonstrate that their payload (if in the integrated configuration, per Section 3) or their payload gondola (if in the distributed configuration, per Section 3) complies to all requirements. Note that unless otherwise stated, the term "payload" used in the requirements applies to both a payload or a payload gondola provided by an organization external to the CSA.

Requirements are denoted by PLD-REQ-XXX-YYY, where PLD denotes "Payload", XXX is the requirement type (MEC = mechanical, ELE = electrical, PROC = procedure) and YYY is the requirement number. Requirements are summarized in the Requirements Compliance Matrix in Appendix A of this document.

The following nomenclature is used in this section:

- The term "shall" is used to indicate a <u>mandatory</u> requirement.
- The term "should" indicates a goal but is not mandatory.
- The term "TBD", which means "to be determined", designates that insufficient information currently exists to allocate a value.
- The term "TBC", which means "to be confirmed", designates that information exists regarding a requirement but further confirmation or study is necessary.

4.1 ENVIRONMENTAL REQUIREMENTS

The following sub-sections describe environmental factors present during the flight campaign. Payload developers must ensure their PL or PLG design will be able to withstand the environmental conditions and risks throughout the flight.

4.1.1 Mechanical Environment

PLD-REQ-MEC-001: The payload shall be capable of sustaining the separation loads: a vertical downward 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.



4.1.2 Thermal Environment

PLD-REQ-MEC-005: The payload shall not cause catastrophic or serious risks¹ 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 3Error! Reference source not found., 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 at 30 km, though it is possible to burst below or above.

¹As per the definitions of catastrophic and serious risks in Section 5.

The payload developer is responsible for providing any thermal blankets/covers attached to the PL or PLG to achieve the required operational temperature. However, additional external thermal blankets attached to the structure can 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

4.1.3 Depressurization & Pressurization Environment

PLD-REQ-MEC-008: The payload shall not cause catastrophic or serious risks² due to pressurization or depressurization.

Rationale: Equipment design must sustain the depressurization/pressurization during the flight. In the case where a payload enclosure is sealed, eitherventing holes should be added to the enclosure with a venting area of at least 2 cm^2 (TBC) per 1000 cm³ enclosure volume or a pressure valve should be used.

²As per the definitions of catastrophic and serious risks in Section 5.

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.

4.2 ELECTRICAL REQUIREMENTS

There is no power or communication provided by the CSA to payloads or payload gondolas at this time. PLs and PLGs are responsible for providing their own power, data storage and communication systems (if required) as per their own design requirements.

4.2.1 Power

PLD-REQ-ELE-001: Power subsystems shall be equipped with the following 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.

4.2.2 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:

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

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

4.2.3 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-025: DELETED.

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

Rationale: For safety and protection of personnel.

4.2.4 Connectors

PLD-REQ-ELE-040: Connectors of electrical circuits at risk shall be designed in such a way that there is no ambiguity in their connection (i.e. mechanical guides, fool proofing devices, etc.).

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

PLD-REQ-ELE-045: Connectors of electrical circuits 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.

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 that are rated for a current greater than the current it will carry is necessary to ensure safe operation and prevent against catastrophic failures such as fires.

4.3 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.

4.3.1 Mass Allocation

PLD-REQ-MEC-010: The mass of the payload shall be a maximum of 3 kg, including the mass of the mounting interface, the payload enclosure and any payload thermal protection.

Rationale: The mass allocation of the payload is restricted to 3kg and this must including the mass of the mounting interface (refer to Appendix B for details. For the distributed configuration, the maximum mass also includes the payload gondola provided by the payload.

4.3.2 Volume Allocation

The volume allocation requirement varies, as follows, depending on if the aerostat is in the integrated or distributed configuration.

4.3.2.1 Integrated Configuration

PLD-REQ-MEC-020A: The payload shall fit within the cylindrical envelope volume with a diameter of 285 mm and height of 524 mm.

Rationale: The gondola Payload Bay volume which can contain the payload is determined by the CSA Payload Bay dimensions, as seen in Figure 4.



FIGURE 4 – PAYLOAD BAY VOLUME (INTEGRATED CONFIGURATION)

Note: All payload components must remain within the payload volume (i.e. protruding bolts and fasteners must remain in the envelope). Upon approval by the CSA, the payload enclosure may extend beyond the payload volume (for example, it may be desirable to use a hexagonal foam enclosure of the same perimeter as the gondola to enclose the payload).

The feasibility of payload-specific needs, such as being mounted exterior to the gondola, can be discussed with the CSA.

4.3.2.2 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.

4.3.3 Coordinate System of the CSA Payload Bay – 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, Z planes can also be seen.



FIGURE 5 – COORDINATE SYSTEM OF THE CSA PAYLOAD BAY

4.3.4 Location of the Payload Center of Mass

The location of the center of mass requirement varies, as follows, depending on if the aerostat is in the integrated or distributed configuration.

4.3.4.1 Integrated Configuration

PLD-REQ-MEC-030A: The center of mass of the payload shall be located within a 25 mm diameter from the coordinate system origin of the CSA Payload Bay.

Rationale: The center of mass (CM) of the payload must adhere to a cylindrical positional constraint in the XY plane as shown in Figure 6. The Z coordinate of the CM can be located at any point along the z-axis of the gondola origin.



FIGURE 6 – PAYLOAD CENTER OF MASS POSITION REQUIREMENT (INTEGRATED CONFIGURATION)

4.3.4.2 Distributed Configuration

PLD-REQ-MEC-030B: The center of mass of the payload gondola shall be located within a 25 mm diameter from the payload gondola attachment point³ under 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 of the gondola origin.

³Refer to 7.4B.2 for details.

4.3.5 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 Appendix B for further information regarding the PL or PLG mounting interface.

4.3.5.1 Integrated Configuration

PLD-REQ-MEC-040A: The payload mounting interface shall be provided by the payload team to be reviewed and approved by the CSA and must be compatible with the CSA Payload Bay.

Rationale: The payload mounting interface must be provided along with the payload itself. The interface must be designed to the specifications provided by the CSA. Please refer to Appendix B.1 for the mechanical drawing of the interface mount.

The description of the payload's mounting interface must be included as part of the submission made to the CSA. The interface can 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 to

allow for ease of assembly when integrating the payload with the gondola. Further details can be found in Appendix B.1.

4.3.5.2 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 eyebolt under the CSA Avionics Gondola.

Rationale: To ensure compatibility with the interface of the Avionics Gondola. Please refer to Appendix B.2 for details.

4.3.6 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.

4.3.7 Nut and Bolt Mountings

PLD-REQ-MEC-060: Nut and bolt mountings shall either have a torque mark affixed, or shall use a device to prevent loosening (i.e. spring lock washers, torque wrench with flat washers, thread-lock, etc.).

Rationale: In order to be able to monitor the behaviour of nut and bolt mountings.

4.3.8 Handling, Transportation and Shipping

Payloads and payload gondolas are responsible for their own transportation or shipping to and from the launch site. They are also responsible for the transportation of any necessary pre-flight testing and integration tools and equipment (ground support equipment) to the launch site. It is recommended that PLs and PLGs are packaged in a way to minimize the risk of damage during transportation or shipping.

PLD-PROC-REQ-001: DELETED.

PLD-PROC-REQ-010: A payload safe recovery procedure shall be provided to the CSA for review.

Rationale: Procedures on how to ensure the safe recovery of the payload, including identification of mitigations for any potential hazard, is required to ensure personnel safety during recovery operations. Any specialized tools or equipment that is needed should be identified and should be brought to the launch location by the payload team. Refer to RD3 for more information and for a recovery procedure template.

5 SAFETY REQUIREMENTS

This section includes safety requirements. Payload developers will need to demonstrate that their payload (if in the integrated configuration, per Section 3) or payload gondola (if in the distributed configuration, per Section 3) complies to all safety requirements. Note that unless otherwise stated, the term "payload" used in the requirements applies to both a payload or a payload gondola provided by an organization external to the CSA.

Requirements are denoted by PLD-REQ-SAF-YYY, where PLD denotes "Payload" and YYY is the safety requirement number. Requirements are summarized in the Requirements Compliance Matrix in Appendix A.

The following nomenclature is used in this section:

- The term "shall" is used to indicate a mandatory requirement,
- The term "should" indicates a design guideline. It is not mandatory that payloads comply to design guidelines, these are recommendations and best practices.

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.
- Benign: risks with non-catastrophic and non-serious severity.

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

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 Sheets⁴, taking both nominal and off-nominal operation into account:

- 1. Explosives;
- 2. Flammables;
- 3. Chemicals;
- 4. 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
- 5. Biological items;
- 6. RF transmitters;
- 7. Pressure vessels;
- 8. Radioactive materials;

- 9. Mechanics or electromechanical;
- 10. Lasers;
- 11. Exposed conductive elements with voltages in excess of 30 V DC or rms;
- 12. Exposed conductive elements with high currents: let-go current* greater than 40 mA and leakage current** greater than 3.5 mA DC or rms;
- 13. Exposed surfaces with temperatures $> 45^{\circ}C$ or $< 4^{\circ}C$;
- 14. Hazardous ground support equipment.

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

⁴Refer 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;
- b.) Combustion engines.

PLD-REQ-SAF-010: DELETED.

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.

PLD-REQ-SAF-025: DELETED.

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 approved⁵ by the CSA through a hazard report containing at least two independent safety barriers.

Rationale: In order to reduce likelihood of catastrophic events.

⁵Payloads 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 shall switch to a safe mode.

Rationale: In order to reduce likelihood of catastrophic events.

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.

5.4 SAFETY CRITICAL TESTS

PLD-REQ-SAF-050: DELETED.

5.5 SAFETY FACTORS

PLD-REQ-SAF-055: The payload shall demonstrate a positive margin using a safety factor of 2 for the separation loads in PLD-REQ-MEC-001.

6 DESIGN GUIDELINES AND BEST PRACTICES

This section summarizes recommended design guidelines and best practices. The intent of this section is to include information that can help maximize payload mission success. Implementing these recommendations is not mandatory. Payload developers can choose to follow any or all of these recommendations based on their payload mission requirements and their level of risk tolerance for the mission success.

6.1 ENVIRONMENTAL DESIGN GUIDELINES AND BEST PRACTICES

Thermal

• It is recommended as a first step to perform a 1D heat balance of the system prior to starting any detailed thermal analysis. This allows for a comparison of the thermal analysis results with the analytical calculations to help validate the thermal analysis. If both analyses correlate well, the 1D heat balance can be used to rapidly test different thermal coating options prior to running any simulations. Results can be validated by testing. Refer to the Figure 7 below for an example 1D heat balance calculation that considers a layer of insulation. A similar calculation could be performed to obtain a first approximation for the temperature of the payload.



FIGURE 7 – EXAMPLE 1D HEAT BALANCE CALCULATION

Radiation

• Radiation is not considered to be significant for the flight altitude and short flight duration of Stratospheric Expandable Balloon flights.

Outgassing

• Outgassing is not considered to be significant for short duration flights. However, volatiles may affect measurements for some high precision instruments. It is recommended to apply best practices when choosing materials.

6.2 ELECTRICAL DESIGN GUIDELINES AND BEST PRACTICES

Payload Power System

- The design and capacity of the payload power system should take into consideration time for testing of the payload prior to launch, as well as a potentially prolonged countdown and extended flight time. The payload power system should be sized in order to accommodate the typical pre-launch countdown period of at least 30 minutes (TBC), as an addition to the flight duration of 2 to 3 hours.
- Energy storage units should include a passivation system such as an arming/disarming plug to easily turn the payload on and off during ground handling and recovery. An example of an arming plug can be seen in Figure 8**Error! Reference source not found.** below. As per this schematic, when the arming plug is disconnected, the payload ("load") is not connected to the battery and is therefore OFF. When the arming plug is connected, the payload ("load") is connected to the battery since the arming plug shorts pin 7 to 2 and pin 6 to 1 and the payload is ON. The connector should be located on the outside of the enclosure so that before launch the arming plug can be easily connected to turn the payload on and during recovery the arming plug is simply removed to remove power from the payload (this is an Apply Before Flight system instead of a Remove Before Flight system). Note that the arming plug connector must be rated for the maximum current of the battery.



FIGURE 8 – PAYLOAD ARMING PLUG EXAMPLE

Electromagnetic Compatibility and Electrostatic Discharge

- All equipment should minimize electromagnetic emissions, as well as be immune against electromagnetic interference (EMI) from within the gondola and from external sources. Components that are sensitive to EMI should be shielded.
- Electrostatic Discharge (ESD) is the flow of electricity between two electrically charged objects, such as static electricity caused by induction, which can damage parts of equipment. ESD protection should be considered within the payload design, and best practices should be followed, such as those found in the following link:

https://workmanship.nasa.gov/lib/insp/2%20books/links/sections/11-01%20General%20Requirements.html.

Wiring Harnesses and Connectors

- All wiring harnesses should be protected against any potential usage or environmental damage and should be supported by flexing at the breakouts to avoid overstressing of the wires.
- Harnesses should provide slack to prevent against mechanical strain (sharp turns or pulling), to allow the replacement of terminations and to permit shifting during maintenance operations.
- Splices should be avoided. If splices need to be used, they should follow standard workmanship practices such as those found in the following link: https://workmanship.nasa.gov/lib/insp/2%20books/links/sections/407%20Splices.html.
- Connectors should be protected against deterioration using connector savors.
- Connector caps should be installed on external connectors whenever they are not in use.

6.3 MECHANICAL DESIGN GUIDELINES AND BEST PRACTICES

- It is strongly suggested to protect the payload equipment against ingress of dust and water in case there is rain at the landing side before the recovery team arrives or the gondola lands in water.
- If any cameras or optical instruments are used, make sure to verify that the field of view (FOV) will not be obstructed once the payload has been integrated in the gondola (ex. by the gondola's carbon fiber rods).

6.4 ASSEMBLY, INTEGRATION, TESTING (AIT) AND OPERATION DESIGN GUIDELINES AND BEST PRACTICES

It is very important during the payload design phase to keep in mind the assembly, integration, testing (AIT) and operation activities that need to take place before the flight in order to make these activities easier.

- It is recommended to include LEDs that are external to the payload enclosure and that remain visible after the payload has been integrated in the gondola. These should be designed in order to rapidly determine if the payload is functioning nominally once it is turned on without having to open the payload enclosure. Different LEDs could be used to communicate different statuses (ex. green = payload on and nominal, red = computer anomaly, blue = communication system anomaly, etc.).
- It is recommended to design for "accessibility". This means thinking about providing easy access to any parts of the payload that may need to be accessed for testing / debugging after the payload has been assembled and integrated in the gondola. Some examples include:
 - If re-chargeable batteries are used, it is recommended to include a charging connector which is accessible externally after the payload has been integrated in

the gondola. This is to allow charging of the payload batteries if needed between payload integration and the launch.

- If non-rechargeable batteries are used, it is recommended to have an easily accessible method of installing and removing battery cells after the payload has been integrated in the gondola. This is to allow battery cells to be replaced if needed between payload integration and the launch.
- It is recommended to include a de-bug connector which is accessible externally after the payload has been integrated in the gondola. This is to allow the payload to easily be connected to a laptop for monitoring / de-bugging as required before the flight.
- Payloads should provide their own set of tools and spare parts as required for any testing and integration before the flight. Generic test equipment availability should be coordinated with the CSA in advance. Specialized testing equipment is the responsibility of the payload.

7 LAUNCH AND FLIGHT PHASES

This section describes the phases of a SEB flight. Flight missions are fairly simple and of short duration, lasting in the order of 2 to 4 hours, and consisting of an ascent, balloon burst/flight train separation and a descent under parachute. It is important to note that SEB flights are uncontrolled, i.e. ground operators have no control over the trajectory, flight duration or burst altitude.

7.1 PRE-LAUNCH

The launch window will be determined by the CSA in advance. Starting one week before the opening of the launch window, the CSA will check weather conditions daily and perform daily flight trajectory simulations in order to predict the best day(s) for a flight opportunity. The morning of the launch day, the CSA will confirm an initial Go or No Go for a flight that day based on the weather conditions and the flight trajectory simulation.

During the campaign and prior to the launch, the payload's Principal Investigator (PI) is responsible for performing any necessary inspections and tests of their PL or PLG. The CSA S&MA engineer (or the delegate) will perform a visual inspection to validate that the payload is compliant to its Experiment Safety and Data Package (ESDP), refer to RD3 for details regarding the creation, submission and approval of an ESDP. In some cases, the inspection may also require an experimental demonstration.

The payload will then be integrated within the Payload Bay (integrated configuration) or the payload gondola will be integrated within the flight train (distributed configuration) and inspected. The CSA S&MA engineer (or the delegate) will perform a visual inspection of the entire flight train to validate that the PL or PLG integration is compliant to the CSA's flight train Safety Data Package (SDP). If compliant, the S&MA engineer (or the delegate) will issue a Certificate of Compliance (CoC) authorizing the payload as safe for the flight.

7.2 FLIGHT

7.2.1 Countdown and Launch

Prior to beginning the countdown, the CSA will perform a final review of the weather forecasts and the simulated flight trajectory to make sure it is still acceptable to launch. The CSA will then proceed with the assembly of the flight train and will begin balloon inflation. After the balloon inflation is completed, the aerostat is fully integrated and the CSA has obtained a Go for launch, the payload gondola is held by a CSA operator and is released to begin the flight.

7.2.2 Ascent, Bursting and Descent

The aerostat will ascend at a typical average speed of 6 m/s. Depending on the burst altitude and on variations in ascent speed, ascent takes approximately 1 to 2 hours. The aerostat will experience oscillating movement during the ascent.

The balloon will burst around 30 km altitude. However, there is no control over the flight termination and the balloon may burst at an altitude lower or higher than 30 km.

After the balloon bursts, the flight train descends under a parachute. Due to the thin atmosphere in the stratosphere, the descent speed is high at the beginning. The descent speed will stabilize at around 7-8 m/s closer to the ground. The descent takes approximately 30 minutes to an hour.

For the entire duration of the flight, the position of the aerostat (altitude, longitude and latitude) will be tracked using the equipment contained within the avionics gondola (refer to Section 3.2 for more information).

7.3 LANDING

The maximum permissible terminal (landing) velocity is 6.32 m/s. Expected accelerations at landing are TBD.

The gondola may become suspended in trees during landing, or it may land on the ground. The gondola's orientation may also be on its side or upside down at landing. Risks include landing in bodies of water, and rain conditions after landing and prior to recovery. Open fields are preferable landing locations, however, landing in densely wooded or swampy areas may occur.

7.4 RECOVERY

The payload gondola and flight train will be recovered from the landing site by the CSA. A truck will then carry the gondola and payload back to the launch base. The transport can cause vibrations which should be taken into account in the PL or PLG design. The goal is typically for a same day or next day recovery. However, in the case of bad weather conditions, low visibility at the recovery site, or other non-typical circumstances, recovery may be delayed. Any time-critical item must be reported to the CSA in advance.

Only the CSA personnel will participate in the recovery operations. Members of the payload team may come to a rendez-vous point near the landing site for PLs or PLGs that require time-sensitive operations post landing, but they will not be permitted at the landing site due to a lack of appropriate training and PPE.

The payload developer will provide a recovery procedure as part of their ESDP submission prior to the flight campaign. This will include details of how the recovery crew should handle and maintain the safety of payload equipment. A template recovery procedure is provided in RD3.

APPENDIX A REQUIREMENTS COMPLIANCE MATRIX

The Requirements Compliance Matrix in Table A-1 lists all requirements in this document. Note that unless otherwise stated, the term "payload" used in the requirements applies to both a payload or a payload gondola provided by an organization external to the CSA.

Payloads and payload gondolas 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:

- <u>Compliance column</u>: 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).
- <u>Method column</u>: 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.
- <u>Justification column</u>: 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).
- <u>Reference column</u>: 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	Method	Justification	Reference
		(C, NC, NA)	(A, D, I, S, T)		
PLD-REQ-MEC-	The payload shall be capable of sustaining the				
001	separation loads: a vertical downward 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-	The payload shall not cause catastrophic or serious				
005	risks due to the flight thermal environment.				
PLD-REQ-MEC-	The payload shall not cause catastrophic or serious				
008	risks due to pressurization or depressurization.				
PLD-REQ-MEC-	The mass of the payload shall be a maximum of 3 kg,				
010	including the mass of the mounting interface, the				
	payload enclosure and any payload thermal				
	protection.				

PLD-REQ-MEC-	The payload shall fit within the cylindrical envelope		
020A	mm.		
PLD-REQ-MEC-	The payload gondola dimensions shall be provided to		
020B	the CSA for review and approval.		
PLD-REQ-MEC-	The center of mass of the payload shall be located		
030A	within a 25 mm diameter from the coordinate system		
	origin of the CSA Payload Bay.		
PLD-REQ-MEC-	The center of mass of the payload gondola shall be		
030B	located within a 25 mm diameter from the payload		
	gondola attachment point under the CSA Avionics		
	Gondola.		
PLD-REQ-MEC-	The payload mounting interface shall be provided by		
040A	the payload team to be reviewed and approved by the		
	CSA and must be compatible with the CSA Payload		
	Bay.		
PLD-REQ-MEC-	The payload gondola mounting interface shall be		
040B	provided by the payload team to be reviewed and		
	approved by the CSA and must provide suitable		
	attachment hardware which is compatible with the		
	eyebolt under the CSA Avionics Gondola.		
PLD-REQ-MEC-	The payload equipment shall not emit nor liberate any		
050	free parts or debrisunder any conditions.		
PLD-REQ-MEC-	Nut and bolt mountings shall either have a torque		
060	mark affixed, or shall use a device to prevent		
	its flat, a share thread leaf at a l		
	With flat washers, thread-lock, etc.).		
PLD-REQ-ELE-	Power subsystems shall be equipped with the		
001	control to protective systems, at minimum, to prevent		
	fuse) (2) over discharge protection (battery cut off for		
	under voltage)		
	The navload's frequency plan listing all the		
010	frequencies of the transmitters and receivers used by		
010	the navioad shall be submitted to the CSA		
	The navload shall not emit in the following		
015	wavehands: 1030 MHz (CSA transponder Ry) 1090		
PLD-REQ-ELE- 010 PLD-REQ-ELE- 015	fuse), (2) over-discharge protection (battery cut-off for under-voltage). The payload's frequency plan, listing all the frequencies of the transmitters and receivers used by the payload, shall be submitted to the CSA. 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-	All cables and harnesses shall be rated for a current		
020	greater than the rating of the protective device (i.e.		
	fuse).		
PLD-REQ-ELE-	All cables and harnesses shall be rated for a current		
023	greater than that of the signal it carries under all		
	operating conditions.		
PLD-REQ-ELE-	DELETED.	N/A	
025			
PLD-REQ-ELE-	All cables shall be insulated and secured.		
030			
PLD-REQ-ELE-	The connectors of electrical circuits at risks hall be		
040	designed in such a way that there is no ambiguity in		
	their connection (i.e. mechanical guides, fool proofing		
	devices, etc.).		
PLD-REQ-ELE-	Connectors of electrical circuits shall include a system		
045	for locking the connections in position.		
PLD-REQ-ELE-	All connectors of electrical circuits shall be rated for a		
050	current greater than that of the signals they carry		
	Under all operating conditions.	 A1/A	
PLD-REQ-PROC-	DELETED.	N/A	
	A payload safe recovery procedure shall be provided		
010	to the CSA for review		
	Royloads shall identify and report all hazardous		
001	materials and equipment in Hazard Shoots taking		
001	hoth nominal and off-nominal operation into account		
	The following technologies shall be prohibited from	N/A	
005	use in navloads: (a) radioactive sources (b)	N/A	
000	combustion engines.		
PLD-REO-SAE-	DELETED		
010			
PLD-REQ-SAF-	Any payload hazardous equipment (per PLD-REQ-SAF-		
020	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- 025	DELETED.	N/A			
PLD-REQ-SAF- 027	Payload design and manufacturing shall prevent fault propagation to the rest of the flight training, 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 report 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 i nadvertent release of these chemicals.				
PLD-REQ-SAF- 050	DELETED.			N/A	
PLD-REQ-SAF- 055	The payload shall demonstrate a positive margin using a safety factor of 2 for the separation loads in PLD- REQ-MEC-001.				

APPENDIX B PAYLOAD OR PAYLOAD GONDOLA INTEGRATION

B.1 PAYLOAD MECHANICAL INTERFACE – INTEGRATED CONFIGURATION

In the integrated configuration, the payload must design and provide their own payload mounting interface. This must be compatible with the CSA Payload Bay. The mechanical drawing of the payload interface mount can be seen in Figure 9 and Figure 10.



FIGURE 9 – PAYLOAD INTERFACE MOUNT MECHANICAL DIMENSIONS DRAWING, INTEGRATED CONFIGURATION



FIGURE 10 – PAYLOAD INTERFACE MOUNT MECHANICAL RADIAL DRAWING, INTEGRATED CONFIGURATION

B.2 PAYLOAD MECHANICAL INTERFACE – DISTRIBUTED CONFIGURATION

In the distributed configuration, an eye nut interface is added under the Avionics Gondola to allow the connection of a separate payload gondola (Figure 11Error! Reference source not found.). The eye nut is the payload gondola attachment point.



FIGURE 11 – AVIONICS GONDOLA (TOP AND BOTTOM VIEWS)

The eye nut is made of 304 stainless steel (Figure 12Error! Reference source not found.) acquired from McMaster-Carr (Part Number 33045T77). This COTS component is rated for a capacity of 204 kg.



FIGURE 12 – AVIONICS GONDOLA EYEBOLT INTERFACE

It is recommended to link the Payload Gondola to the Avionics gondola using 316 stainless steel oval shaped threaded connector links (Figure 13**Error! Reference source not found.**) (acquired from McMaster-Carr with part number 8947T12). This COTS component Size 5/32" is rated for a capacity of 272 kg. The payload is responsible for providing this link.



FIGURE 13 – THREADED CONNECTOR RING, MECHANICAL INTERFACE PLG TO AVIONICS GONDOLA

An equivalent or alternative connection to the Avionics gondola can be used, but this must be reviewed and approved by the CSA and the connection must be sufficient to sustain the specified loads, as per PLD-REQ-MEC-001.