Procedures and Guidelines (PG)

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EXPIRATION DATE:	November 5, 2024	**TITLE:**	Chief, Balloon Program Office

COMPLIANCE IS MANDATORY

Responsible Office: Code 820/ Balloon Program Office (BPO)

Title: Gondola Structural Design Requirements

PREFACE

P.1 PURPOSE

This document establishes requirements for the design, development, qualification, and certification of structural flight hardware aboard a NASA scientific balloon. The criteria are intended to ensure the structural integrity of balloon flight hardware subjected to the loads experienced in the balloon flight environment.

P.2 APPLICABILITY

This PG applies to all flights conducted by or under the auspices of the NASA Balloon Program Office (BPO). The NASA BPO is administered under the Science Mission Directorate's Suborbital Research Program and implemented by Goddard Space Flight Center (GSFC) / Wallops Flight Facility (WFF) / Suborbital and Special Orbital Projects Directorate (SSOPD).

a. In this document, citations are assumed to be the latest version unless otherwise noted.

b. In this document, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The terms "may" or "can" denote discretionary privilege or permission; "should" denotes a good practice and is recommended but not required; "will" denotes expected outcome; and "are/is" denotes descriptive material.

P.3 AUTHORITY

NPD 8700.1, NASA Policy for Safety and Mission Success
NPR 7120.8, NASA Research and Technology Program and Project Management Requirements
Suborbital Research Program Plan
GSFC-STD-8009, Wallops Flight Facility Range Safety Manual
800-PG-1060.1.1H, Suborbital and Special Orbital Projects Directorate Organizations
820-PG-7120.0.1A, Management of the Balloon Program

P.4 APPLICABLE DOCUMENTS AND FORMS

NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight Hardware
NASA-STD-5020, Requirements for Threaded Fastening Systems in Spaceflight Hardware
541-PG-8072.1.2, Goddard Space Flight Center Fastener Integrity Requirements
540-PG-8072.1.2, Mechanical Fastener Torque Guidelines
OF-300-11-H, Flight Application Instructions
EL-100-10-H, LDB Support for Science
ANSI/AIAA S-080A-2018, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
ANSI/AIAA S-081B-2018, Space Systems—Composite Overwrapped Pressure Vessels
DOT-FAA-AR-MMPDS-13, Metallic Materials Properties Development and Standardization (MMPDS) Handbook
American Society for Metals (ASM) International Databases
Granta Design’s MaterialUniverse
NASA-STD-6008, NASA Fastener Procurement, Receiving Inspection, and Storage Practices for Spaceflight Hardware
NASA-STD-5006, General Welding Requirements for Aerospace Materials

P.5 CANCELLATION

OM-220-10-H, Structural Requirements and Recommendations for Balloon Gondola Design

P.6 SAFETY

None

P.7 TRAINING

None

P.8 RECORDS

Record Title	Record Custodian	Retention
Design and Analysis Deliverable Package	Contractor at CSBF on behalf of BPO	*NRRS

** NRRS 1441.1 – NASA Records Retention Schedule*

P.9 MEASUREMENT/VERIFICATION

None

PROCEDURES

1 Introduction

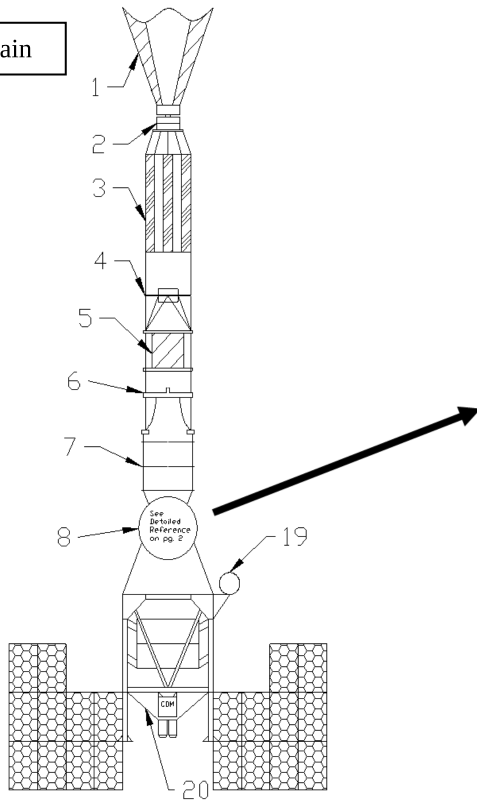
The NASA Balloon Program requires structural analysis and certification of all structural balloon flight hardware, hereafter referred to as "flight hardware," utilized in conduct of scientific balloon flight operations. The gondola certification process ensures that containment frames, suspension systems, structural fasteners, joints, and components supplied by NASA and the GP meet NASA requirements for structural integrity when the gondola is subjected to test, launch, flight, and termination loads. The gondola provider (GP) shall be responsible for ensuring the structural integrity of the gondola system (hereby broadly referred to as the "gondola"). The gondola comprises all items below the gondola suspension point (truck plate, item 10 in figure 1b); for systems utilizing a NASA rotator, all items below the lower tri-plate (item 15 in Figure 1b).

1.1 Deviations

If a deviation from the requirements documented in this PG is considered necessary, a written request shall be submitted to the Balloon Program Office Chief, or designee no later than the Science Critical Configuration Review which occurs at L-15 months. Deviations will not be used as precedents for future applications. The request will at a minimum include:

1. The article or system under consideration;
2. The requirement for which the deviation is necessary;
3. The rationale for why the requirement cannot be met;
4. An alternative approach, equivalence, or mitigation to allow deviation from the requirement;
5. A technical assessment that the deviation will not present an additional safety risk.

Figure 1a: flight train



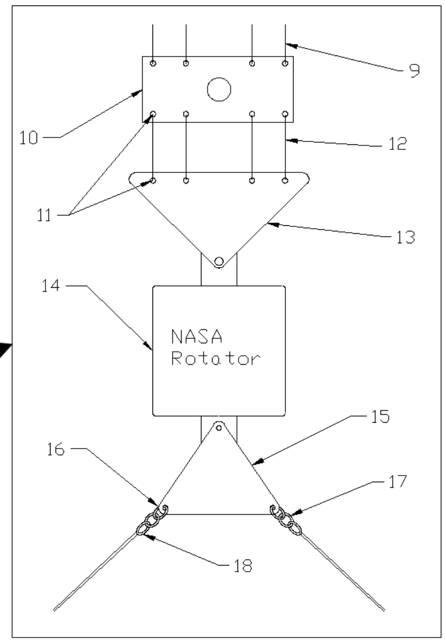


Figure 1b: flight train, detail

ITEM	DESCRIPTION	ITEM	DESCRIPTION
1	Balloon	11	Shackles
2	Terminate fitting	12	Truck plate – tri plate extension cables (optional)
3	Parachute	13	Rotator upper tri-plate (optional)
4	Lower parachute ring	14	NASA rotator (optional)
5	External battery box (optional)	15	Rotator lower tri-plate (optional)
6	Cutaway clevises	16	Shackles
7	Cable ladder	17	Shackles
8	*Refer to detail	18	Cable
9	Cable ladder	19	Over the horizon antenna
10	Truck plate	20	Ballast hopper cables

Figure 1: Typical Gondola System

Assessment of structural suitability and formal certification of the gondola for flight based upon the criteria documented herein will be performed by CSBF personnel with NASA oversight, as needed. The GP shall perform the structural analysis in conformance with the NASA requirements and guidelines addressed in this document and referenced governing documents. Failure to meet the following requirements may result in liens or forfeiture of launch or acceptance onto NASA facilities.

The GP should utilize the companion documents, *Balloon Flight Application Instructions* (OF-300-11-H) and *LDB Support for Science* (EL-100-10-H), for additional guidelines and non-structural requirements including analysis and testing of mechanical ground support equipment, design recommendations, volumetric constraints, facilities, as well as other aspects of scientific balloon operations.

The GP shall interface with NASA at the onset of the concept phase and throughout the mission life cycle to ensure compliance with requirements and guidelines, as well as other factors that influence gondola design. The GP may request additional support from CSBF or NASA on the design, development, and analysis of the gondola. Requests beyond the normal baseline of support or for additional/unique capabilities shall be coordinated and approved through the NASA Balloon Program Office.

2 Deliverables and Review Schedule

The process deliverables shown below are for a typical mission timeline. For flights planned in a more constrained lifecycle or for re-flights, the GP should contact CSBF for process deliverables and review schedules. This table is a subset of the reviews and deliverables specific to gondola certification.

Table 1: Deliverables and Review Schedule

Review / Deliverable	Schedule (L +/-)
Science Requirements Review TIM between NASA, CSBF, GP that will include communication of gondola structural requirements and recommendations. CSBF will provide requirements package to GP.	Award / Ongoing
Science Configuration Review TIM between NASA, CSBF, GP to verify high-level requirements and initial design concepts are acceptable. Initiate definition/identification of critical hardware. Determine methodology and configuration of support hardware.	L-27 months
Science Critical Configuration Review Science presentation to NASA/CSBF to provide verification that all structural requirements have been met/addressed.	L-15 months
Structural Analysis Package Complete structural documentation submission from GP to NASA/CSBF.	L-6 months
Science/Support Compatibility Test Final mechanical and configuration inspection between NASA, CSBF, and GP to verify gondola "as-built" represents certified design.	L-2 days

3 Gondola Design Requirements

3.1 General

This section sets forth the requirements of gondola structural design, which shall be met as part of the gondola certification process. All structural components of the gondola and its suspension system shall be designed to the requirements given below. The GP shall be responsible for the design, identification, analysis, and testing of GP-provided hardware. The GP will refer to the Structural Analysis Package in accordance with Section 4.3, Analysis Deliverables and outlined in Section 4.5, Analysis Guidelines, to ensure compliance.

A broad set of gondola design considerations, recommendations, configurations, volumetric constraints, and other significant aspects of design guidelines and methodology may be found in the Balloon Flight Application Instructions (OF-300-11-H) and LDB Support for Science (EL-100-10-H). Gondola Providers shall utilize this document and the aforementioned to ensure adequate gondola design. The GP shall contact CSBF during the design stage for information on equipment configurations, mass, and other considerations for the flight.

3.2 Material Selection

Materials shall be selected based upon mechanical or other physical properties from relevant test data or recognized standards. NASA does not rule out specific materials, rather the GP shall be responsible for determining appropriate materials for the loading case and flight environment.

3.2.1 Standards

The GP shall utilize recognized standards for material properties databases including but not limited to: e.g., Metallic Materials Properties Development and Standardization (MMPDS) Handbook, American Society for Metals (ASM) International Databases, and Granta Design's MaterialUniverse. The MMPDS Handbook will be used by NASA in checking allowable strength limits on the materials used for the gondola system design, where applicable. Worst case properties (i.e., in consideration of the sections below) of selected materials shall be used unless the GP provides NASA sufficient rationale and documentation for the use of nominal or typical material properties in their analysis. In lieu of a recognized standard, the GP may provide certified material/mill test report for material properties justification in accordance with Section 4.4.1.

3.2.2 Environmental Factors

All material properties, design criteria, and stresses shall be suitably adjusted to the relevant flight environment. At a minimum, the GP shall factor in 10°C margin based on thermal analysis of the worst-case temperature range the mission will experience. In lieu of thermal analysis, which may not be available until late in the design phase, the following temperature extremes (which include margin) should be factored into the design and analysis, and the worst-case material properties utilized: -70°C and +65°C.

Note: 1) Steels shall not be used below their ductile-brittle transition temperature. 2) The 5000-series aluminum alloys containing more than 3 percent magnesium shall not be used in hardware that provides critical functions where the temperature exceeds 66 °C (150 °F).

3.2.3 Testing and Inspection

Materials used for critical components, that is, components constituting a single point failure or whose failure may propagate to further component failures shall be source-traceable and have certified material/mill test reports.

Structural members composed of composite materials shall be proof-tested as well as analyzed in accordance with Table 3: Design Factors of Safety.

3.2.4 Re-Flight and Reuse Considerations

Materials or assemblies designated for re-flight shall at a minimum be inspected and assessed by the GP for re-use. The GP shall provide sufficient documentation to NASA regarding the flight heritage, storage, and subsequent inspection and testing of structural components. NASA reserves the right to require non-destructive testing of components or assemblies as necessary to ensure structural integrity of the system.

3.3 Design Limit Loads (DLL)

Gondolas shall be designed so that all load-carrying structural members, joints, connectors, decks, and suspension systems show a ***positive*** margin of safety (***MS > 0.0***) when subjected to the design limit loads listed below in Table 2 and the desired design factor(s) of safety given in Table 3. Note: some components can only be shown to have positive MS against ultimate strength (e.g. composites).

Table 2: Design Limit Loads

Structural Flight Hardware	**Design Limit Loads (DLL) G's**		
	Vertical	**45 Deg**	**Horizontal**
	8	4	4

NOTE:

Metallic materials with a fracture strain of 5% or less, at worst case temperature limit, shall be considered brittle and an additional factor of 1.5 shall be applied to the Design Limit Loads. That is, the particular element that is fabricated using a brittle material must be able to sustain a 12g vertical load, a 6g load applied at 45 degrees off vertical, and a 6g horizontal load without failure.

3.4 Factors of Safety

Design factors of safety (FS) for the gondola structural components and its suspension system are given in Table 3. The Design FS are based upon the worst-case termination event and historic flight profiles. It is paramount that the gondola design ensures that no scientific equipment, CSBF equipment, or ballast separate from the flight system during any phase of flight operation.

Table 3: Design Factors of Safety

TYPE OF HARDWARE	**DESIGN FACTOR OF SAFETY**		
	Yield	**Ultimate**	**Proof Test**
Metallic Structures			
Flight Structure - metallic only	1.25	1.4	N/A
Preloaded Joints	1.25	1.4	N/A
Fasteners	1.25	1.4	N/A
Welds	N/A	1.5	1.2
Suspension Systems			
Wire Rope Cables, Slings, Cable assemblies, Shackles, Turnbuckles, etc.	N/A	1.4	*
Soft-body Structures			
Slings, Webbing	N/A	2.0	*
Composite Flight Structure			
Uniform Material	N/A	1.5	1.2
Bonded Joints/Inserts	N/A	2.0	1.2
Stability/Buckling			
Stability/Buckling – metallic only	N/A	1.4	N/A
Stability/Buckling – composite	N/A	1.5	N/A
Pressure Vessel Systems	Ref: GSFC-STD-8009, ANSI/AIAA S-080A-2018		
*: based upon NASA review of GP hardware			

3.5 Margins of Safety

The strength of the gondola system shall be demonstrated by showing a positive margin of safety (MS) for individual components and assembly interfaces for the given loading environment when the factors of safety given in Table 3 are applied.

The margins of safety are determined by multiplying the design limit load (or stress) by the appropriate factor of safety and comparing it to either the yield or ultimate material allowable strength as shown in the following equations:

$$MS_u = \frac{P_u}{FS_u \mathrm{P}} - 1$$

and

$$MS_y = \frac{P_y}{FS_y \mathrm{P}} - 1$$

where

FS_u	is the ultimate Factor of Safety
FS_y	is the yield Factor of Safety
P	is the limit load (or stress) calculated in the analysis
P_u	is the load (or stress) at which material failure will occur
P_y	is the load (or stress) at which material yielding will occur
MS_u	is the Margin of Safety against ultimate failure
MS_y	is the Margin of Safety against material yielding

At pre-loaded interfaces, the analysis shall show positive margins for all components which comprise the interface – fittings, bolts, rivets, etc., when subjected to the loads given in Section 3.3 and the margins given in Section 3.4. Fitting analysis of critical components shall meet Section 4.4.2, Certification of Fasteners.

3.6 Mechanical Connections

3.6.1 Welded and Bonded Components

In general, the GP should avoid welded or bonded joints for critical elements of the gondola system design due to uncertainties in strength and workmanship. If a welded or bonded joint must be used, the effects of the weld or bond on the strength of the joint and parent materials shall be considered and analyzed accordingly. The GP shall perform proof testing on critical welded and all bonded joints as part of the deliverables for every flight in accordance with Table 3. The GP shall perform inspections and nondestructive testing in accordance with NASA-STD-5006 prior to each flight on all structural welded or bonded joints. The joint and its components shall have positive margins of safety against ultimate strength when subjected to the Design Limit Loads of Section 3.3 along with the applicable factors of safety from Table 3.

3.6.2 Threaded Fastener Integrity Requirements

Load-bearing metallic fasteners selected and procured by the GP shall be sufficiently rated to have positive margins of safety against yield strength. Threaded fasteners that are critical or single-point failure items shall provide material certifications and visual inspection in accordance with Section 4.4, Material Requirements for Critical Hardware. The limit, yield, ultimate, and separation loads shall account for interaction of the combined loading (simultaneously applied tensile, shear, and bending loads) and under all design environmental conditions. The GP may reference *GSFC Fastener Integrity Requirements*, 541-PG-8072.1.2, for fastener suitability. The GP should ensure torque specifications are in conformance with manufacturer recommendations or equivalent aerospace guidelines or applications and may refer to *Mechanical Fastener Torque Guidelines,* 540-PG-8072.1.2.

3.7 Pressure Vessel Design

Pressure vessels intended as flight hardware shall meet ANSI/AIAA S-080A-2018 for metallic pressure vessels, pressurized structures, and pressure components or ANSI/AIAA S-081B-2018 for composite overwrapped Pressure Vessels and Pressurized Systems (PVS). PVS intended as flight hardware shall comply with the Wallops Flight Facility Range Safety Manual, GSFC-STD-5009 and will be approved for use by NASA. PVS structural interfaces are considered critical structural components and shall be in compliance with applicable sections for critical and single point failure items.

4 Design Specifications and Analysis Guidelines

4.1 Assumptions and Requirements

4.1.1 Assumptions

The following assumptions are made during the NASA certification process in reviewing gondola design analyses:

- The suspension point is defined as the point where the GP-furnished gondola suspension equipment interfaces with the CSBF-furnished flight system hardware.

- The payload weight includes the gondola structure, all scientific equipment, and components including consumables, and all CSBF equipment (including ballast) affixed to the structure below the gondola suspension point.

- Visual inspection of actual gondola comparison to drawings, design, and analysis by the certifying authority. In addition, the certifying authority checks all welds and verifies that the construction matches the description submitted by the user.

4.1.2 Requirements

1. The effects of stress concentration factors shall be included in the analyses of all mechanical structures and assemblies. The yield strength of the component shall be derated proportionately to the applicable stress concentration factor. The stress concentration factors shall be based upon the specific load case and standard mechanical engineering design practices. A specific example of a structural element in which stress concentrations are to be considered is the shaft and housing of a swivel or rotator assembly.

2. If a particular component does not meet specifications when derated by the full effects of the stress concentration factor, a proof test of an assembly can be used to demonstrate the flight worthiness of such a component.

3. The ductility of all materials used for critical mechanical elements shall be considered in the analysis of the gondola structure. Specifically, NASA discourages the use of materials that are determined to be brittle or that are not recommended for use in shock loading applications.

4.2 Analysis Boundary Conditions

From launch through termination the balloon system floats unconstrained. The preferred method to analyze such a system is to use inertia relief. Inertia relief is available with most commercially available finite element model codes. In the case where the GP does not have access to a code with inertia relief, the analysis boundary conditions shown below can be used. However, it is recommended that the GP contact CSBF at the early stages of the gondola design process – prior to commencing the gondola structural analysis - to agree on proper interpretation of the design limits loads and acceptable associated analysis boundary conditions.

For every load case, all load combinations shall be analyzed with the appropriate factors of safety and positive margins of safety against yield or ultimate be demonstrated for all components attached to and/or onboard the gondola system not provided by NASA.

4.2.1 Load Case #1

A load 8 times the weight of the payload applied vertically at the suspension point.

Rationale: Vertical load path for parachute opening shock immediately after termination. Optionally, pin base and apply vertical load.

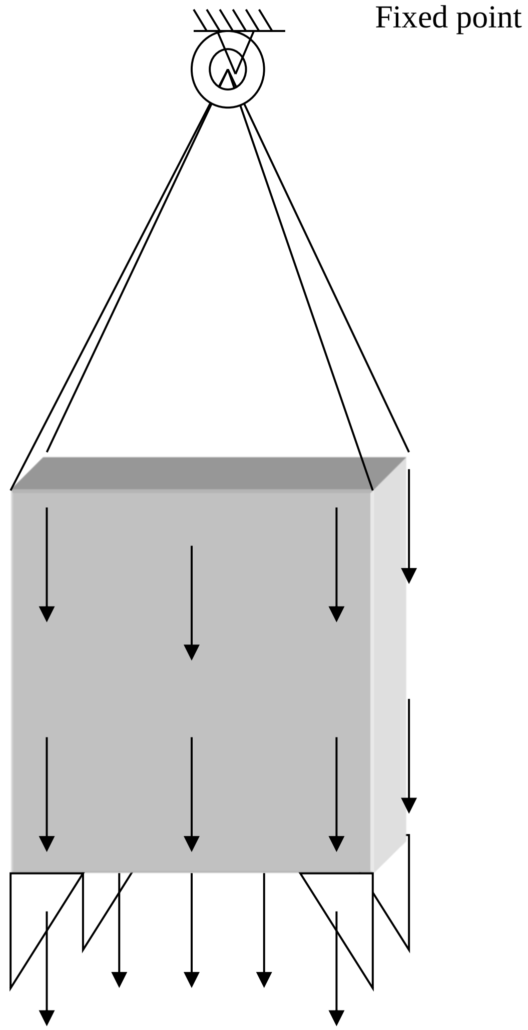


Figure 2: Load Case #1 – Gondola Vertical Loading

4.2.2 Load Case #2

For multiple-cable suspension systems, each cable must have an ultimate strength greater than 4 times the weight of the payload divided by the sine of the angle that the cable makes with horizontal (α >30 degrees) in a normal flight configuration.

Rationale: The load path through the gondola are directed through the cables so the loads are analyzed acting through the structure.

Note: In reality, the load would be reacted through the gondola inertia and not the feet. For this reason, failure modes due to tension in the feet are not considered.

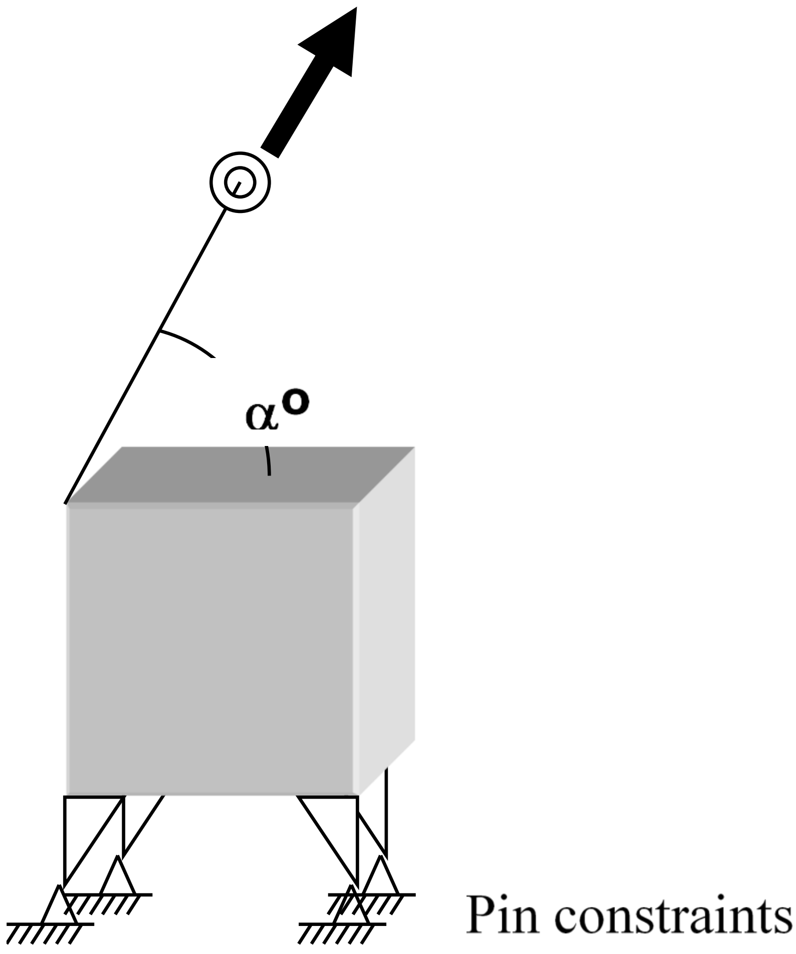


Figure 3: Load Case #2 – Gondola Single Cable Loading

4.2.3 Load Case #3

A load 4 times the weight of the payload applied at the suspension point and 45 degrees to the vertical. This load factor must be accounted for in the direction perpendicular to the gondola's short side, long side, and in the direction of the major rigid support members at the top of the gondola structure. If flexible cable suspension systems are used, they shall withstand uneven loading caused by cable buckling.

Rationale: Assumes that the gondola rotates 45 degrees descends off-axis during termination and only one or two cables are loaded at parachute opening. It is to assure that the structure and attachments can handle this initial load.

Note: In reality, the load would be reacted through the gondola inertia and not the feet. For this reason, failure modes due to tension in the feet are not considered.

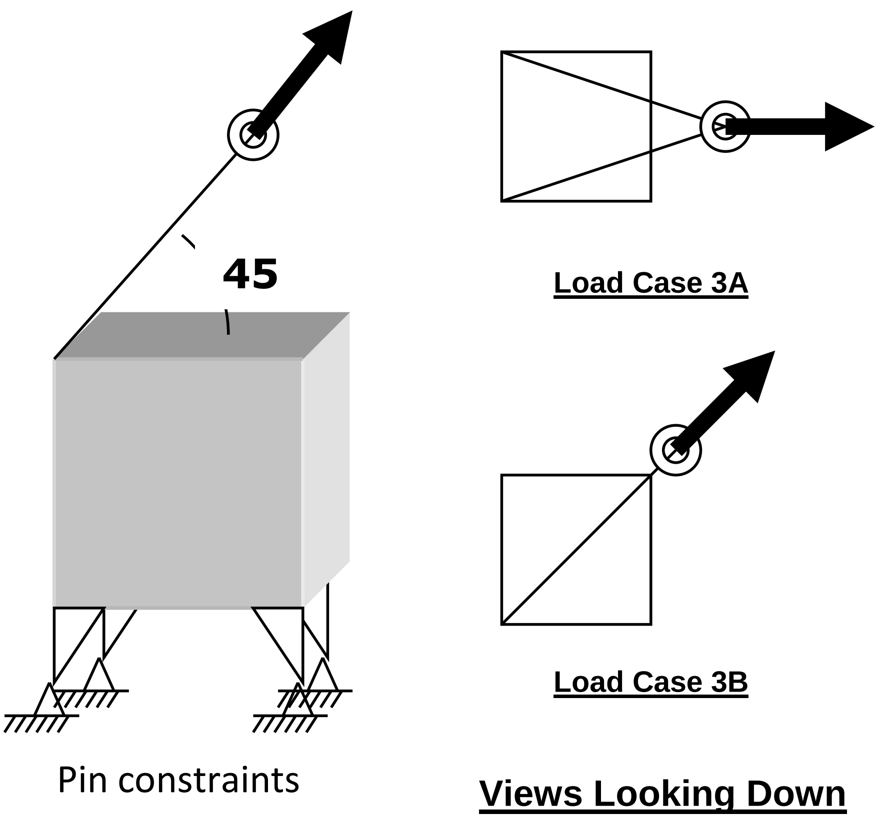


Figure 4: Load Case #3 – Off-Vertical Gondola Loading

4.2.4 Load Case #4

A lateral load of 4 times the weight of the payload applied to all components and equipment attached to and/or onboard the gondola structure or any portion of the flight system below the balloon at both principal lateral axes.

Rationale: Assumes that the gondola rotates 90 degrees descends off-axis during termination and inertial side loads are applied to components attached to the structure.

Note: Some components are analyzed individually and some are analyzed as part of the structural model. In non-symmetric situations, 4g is applied in both horizontal axis.

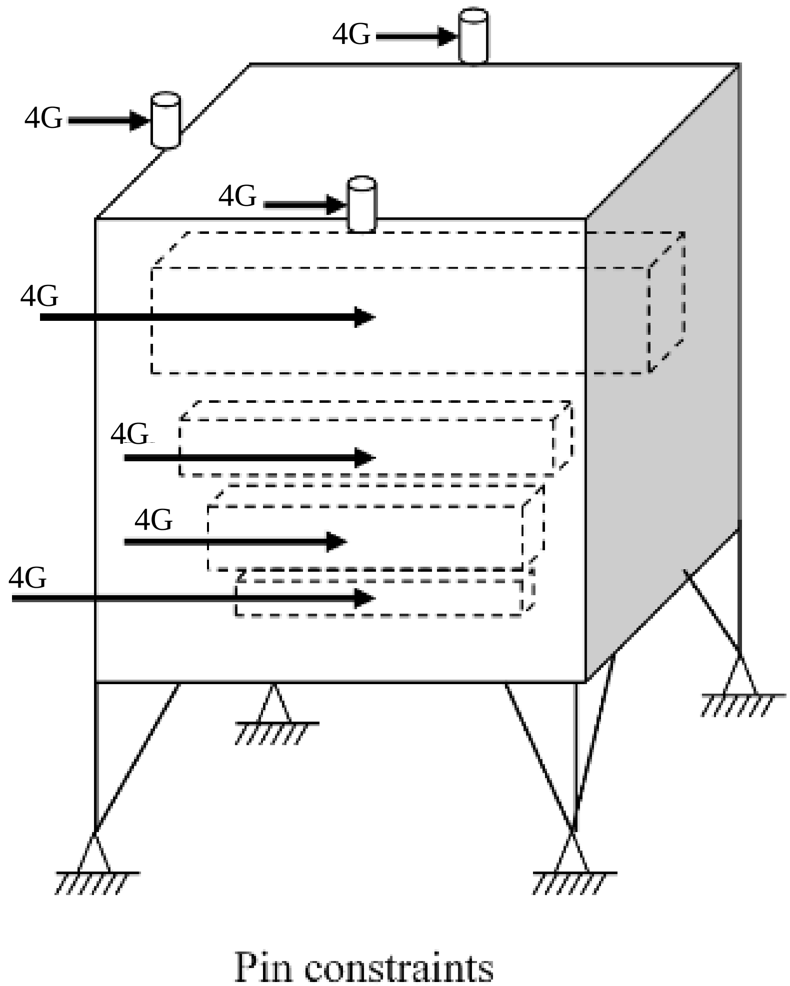


Figure 5: Load Case #4 – Gondola Lateral Loading

4.2.5 Load Case #5 – Flight Hardware to MGSE Interface Verification

A load 1.4 times the weight of the payload applied independently to the gondola in all three orthogonal directions. The mechanical ground support equipment (MGSE) (cart/casters/stand/etc) interface shall be pinned or fixed depending on the interface design.

4.2.6 Load Case #6 (Recommended – Not Required for Certification)

A horizontal pressure load of 125 psi (equivalent to sustained 16kt wind) should be applied on all externally mounted equipment including but not limited to antennas, solar panels, and baffles.

Rationale: Assumes that while the gondola is suspended during compatibility or launch, the structure is exposed to winds for considerable amounts of time.

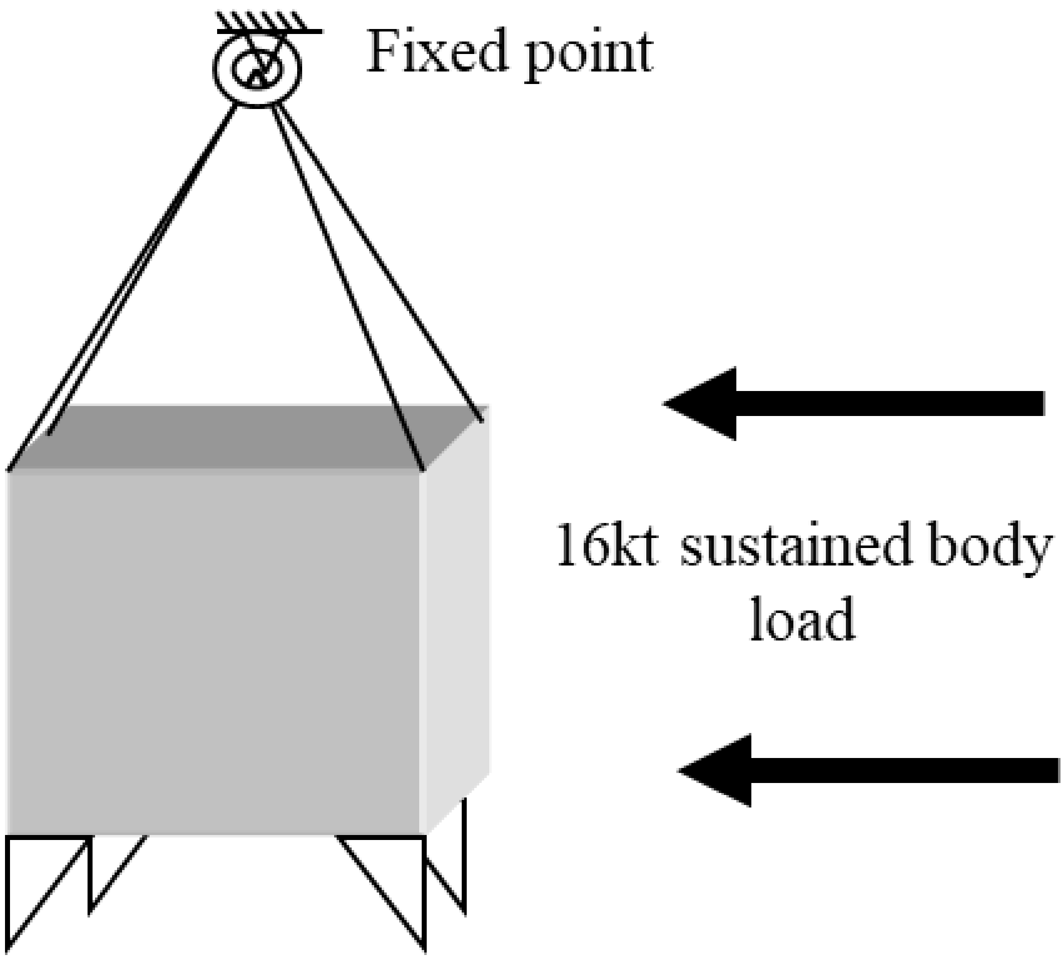


Figure 6: Load Case #6 – Sustained Wind Loading

4.3 Analysis Deliverables

The GP shall provide design drawings, CAD models, and a stress analysis of the gondola to the certifying authority in accordance with Table 1. The minimum requirements for drawings and stress analysis are as follows:

1. Drawings shall show the relative locations and dimensions of all structural and load-bearing gondola members;

2. Drawings shall identify all the materials used for the construction depicted by the drawing;

3. Material specifications shall be included in all drawings;

4. At least one complete assembly drawing shall be provided;

5. Working drawings and specifications for all purchased and fabricated mechanical components and assemblies that are part of the gondola (e.g., rotators, swivels, turnbuckles, clevises, rings, and universal joints) shall be provided;

6. A stress analysis of all major structural members, including decks and ballast attachment points shall be provided and shall identify the boundary conditions, components, equipment, and weights comprising the loads;

7. For critical or single-point failure items material certifications shall be provided in accordance with Section 4.4, Material Requirements for Critical Hardware;

8. A statement certifying that the aforementioned requirements have been met; the statement shall be signed by the principal investigator and the engineer responsible for the design and analysis of the gondola structure. Qualifications of the engineer responsible shall be submitted in the form of a brief résumé.

9. Any changes to analytical models following submittal of deliverable shall be submitted to NASA as soon as practical. Scope and timing of changes may impact review and certification for flight.

4.4 Material Requirements for Critical Hardware

For hardware determined to be critical (i.e., critical components) in accordance with Section 3.2.3, the Gondola Provider shall address the following sections and provide documentation as needed. It is incumbent upon the GP to interface with CSBF and NASA to ensure requisition of all stated requirements outlined below. Failure to provide information or address sections below may result in forfeiture of launch opportunities.

4.4.1 Certification of Materials

1. All parts or materials that provides critical functions shall be certified as to composition, properties, and requirements as identified by the procuring document. The minimal requirements for traceability should include material specification (AMS 4037), metal alloy (2024 Al), form (plate), temper (T351), dimension (0.250 thick x length x width), and unique identification number for tracking. (Reference examples from MMPDS Handbook, 10 Table 3.2.4.0.b2.).

2. For metallic materials, the alloy, heat treatment, product specification, product form, and thickness shall match the alloy, heat treatment, product specification, product form, and thickness in MMPDS Handbook.

3. With the exception of off-the-shelf parts, parts and materials used in critical applications, such as life-limited materials and/or safety and fracture critical parts, shall be traceable through all processing steps defined in the engineering drawing to the end-item application.

4. The lowest of the A, B, or S-basis statistical values for mechanical properties of materials shall be utilized for the design and analysis of hardware for all applications where structural analysis is required.

5. A, B, or S-basis statistical methods shall be defined by, and values for mechanical properties in their design environment taken from MMPDS Handbook or SAE CMH-17, *Composite Materials Handbook*.

6. The 5000-series aluminum alloys containing more than 3 percent magnesium shall not be used in hardware that provides critical functions where the temperature exceeds 66 °C (150 °F).

7. Steels shall not be used below their ductile-brittle transition temperature.

8. Corrosion-resistant metals used in hardware that provides critical functions shall be passivated after machining.

9. All parts that provides critical functions shall have a part number and serial number that uniquely identifies the part to trace the flight history.

Note: For materials intended for use by the GP that are not characterized in MMPDS, another recognized standard may be used in its place provided a proper reference.

4.4.2 Certification of Fasteners

1. All fastening hardware that provides critical functions shall be aviation grade (Military Standard (MS), Army-Navy (AN), or National Aerospace Standard (NAS)). Ultimate tensile and shear strengths for each size are based on shank area and can be found in Chapter 8 of MMPDS Handbook.

2. A Certificate of Conformance (COC) shall be obtained from the manufacturer or distributor selling the fasteners and is required for every fastener lot to the applicable fastener specification. *A COC is a document that is signed by the fastener supplier to affirm that the product has met the requirements of the relevant specification(s), contract(s), and any other applicable regulations.*

3. Regardless of the magnitude of preload, each threaded fastening system for structural joints shall incorporate a minimum of one locking feature that does not depend upon preload to function.

4. When a threaded fastening system for structural joints incorporates a prevailing torque locking feature, the fastener length shall be sufficient for fully formed threads to engage the locking feature.

5. If a liquid-locking compound is used as a locking feature for structural joints where rotational loosening or disengagement would result in a critical or catastrophic hazard, its use shall comply with the design and quality requirements and best practices in NASA-STD-5020, Requirements for Threaded Fastening Systems in Spaceflight Hardware, Sections 5.5 and 7.6 and Appendix C.

6. Users should consider NASA-STD-6008, NASA Fastener Procurement, Receiving Inspection, and Storage Practices for Spaceflight Hardware for fastening system hardware that joins or retains components or structural elements.

4.4.3 Quality Assurance Report

Process specifications for hardware that provides critical functions shall define process steps at a level of detail that ensures a repeatable/controlled process that produces a consistent and reliable product.

4.4.4 Nonconformance Reports

Any nonconformance to the material or fastener specifications for critical hardware shall require written notification to NASA to review and dispose of nonconformance issue.

4.5 Analysis Guidelines

The Gondola Provider (GP) shall produce a structural analysis package (in English) that documents and addresses each of the following sections. It is incumbent upon the GP to interface with NASA and CSBF to ensure requisition of all stated requirements. Failure to provide information or address sections below may result in forfeiture of launch opportunities.

Delivery schedule of the structural analysis package shall be in accordance with Table 1 (i.e. 6 months prior to anticipated launch date), or an alternative date agreed to by NASA and CSBF.

Format of the structural analysis package may be in report form or slide decks, so long as all requested information is provided. A compliance checklist is provided below. It shall be included in the GP's package submission, indicating ("x") each section that has been provided. Reply "N/A" if appropriate.

Section 1 – Introduction	**Check for Completion**
A. Provide a brief description of the gondola, and indicate any previous flight history (i.e. have any major mechanical subsystem designs flown on previous balloons missions?).	
B. Provide documentation of any mechanical subsystems are being reused or rebuilt from previous balloon flight(s) in compliance with Section 3.6 and Table 3. **Note:** For re-flights of the same or similar gondola design, detail any significant changes from previous mission(s); particularly changes in mass or critical hardware.	
C. Provide drawing(s)/rendering(s) of gondola displaying major dimensions (height, width, length), inclusive of any CSBF provided systems (i.e. ballast hopper(s), PV arrays, antenna(s), antenna boom(s), etc.).	
D. Provide drawing(s)/rendering(s) of gondola inclusive of any CSBF provided systems (on launch vehicle) in launch configuration detailing compliance to EL-100-10-H, Section 5.7 (i.e. "20 degree rule").	
E. Provide an estimated mass budget table, inclusive of any CSBF provided systems, indicating total expected mass and mass of major subsystems and components.	
Section 2 – Materials and Critical Hardware Identification	
A. Indicate or list any critical structural members, fasteners, or welded joints.	
B. Provide a table of prominent structural materials used in the gondola design and associated properties used in calculation of margins of safety. Cite material properties source (i.e. MMPDS, MTRs, Hardness Testing, etc.).	
C. Provide a table of any GP provided suspension cabling, slings, etc. and associated properties used in calculation of margins of safety. Cite materials properties source.	
Section 3 – Stress Report	
A. Indicate design loads used for structural analysis (i.e. what is the total mass the gondola is being certified for?). **Note:** It is suggested to analyze gondolas for the total expected mass plus margin.	
B. List any significant assumptions with regard to the structural analysis.	
C. Provide a summary table of minimum margins of safety for each load case listed in Sections 4.2.1 thru 4.2.6.	

Note: If needed or appropriate, major mechanical subsystems can be analyzed independently of the gondola assembly. Rationale: situations may arise when this is needed due to processing capability, or there is a need for a higher fidelity FEA output.	
D. Provide drawing(s)/rendering(s) for each load case indicating boundary conditions used for analysis.	
E. Provide drawing(s)/rendering(s) for each load case indicating stress plots and location of maximum stresses. **Note:** Where effects of stress concentrations shall be considered (Section 4.1.2.1), include in renderings mesh details (overlay mesh or indicate element size) for FEA, or provide applicable stress concentration factor details used to solve for stress result.	
F. For critical structural members, fasteners, or welded joints, provide similar plots and results for stress analysis above, to include margins of safety.	
Section 4 – Analysis Deliverables (Section 4.3)	
A. Drawings or CAD models showing relative locations and dimensions of all structural and load-bearing gondola members.	
B. Drawings or CAD models identifying all materials used for the gondola construction.	
C. At least one complete assembly drawing or CAD model shall be provided.	
D. Working drawings and specifications for all purchased and fabricated mechanical components and assemblies that are part of the gondola.	
Section 5 – Conclusions	
A. Provide a statement certifying that the aforementioned requirements have been met; **the statement shall be signed by the principal investigator and the engineer responsible for the gondola structure.**	

Appendix A– Definitions

A.1 Critical - A classification for structures, components, procedures, etc., whose failure to perform designed or produce the intended results would pose a safety risk or threat to personal injury or loss of life.

A.2 Factors of Safety (Safety Factors) - Multiplying factors to be applied to limit loads or stresses for purposes of analytical assessment (design factors) or test verification (test factors) of design adequacy in strength or stability

A.3 Failure - Rupture, collapse, excessive deformation, or any other phenomenon resulting in the inability of a structure to sustain specified loads, pressures, and environments or to function as designed.

A.4 Fitting Factor for Fitting Analysis: In accordance with FAA requirements, a fitting factor of at least 1.15 (15%) must be used in the analysis of fittings in the critical load path.

A.5 Limit Load - The maximum anticipated load, or combination of loads that a structure may experience during its design service life under all expected conditions of operation.

A.6 Margin of Safety (MS) - MS = [Allowable Load (Yield or Ultimate)/Limit Load*Factor of Safety (Yield or Ultimate)] - 1.

A.7 Proof Test -A test performed on flight hardware to screen for defects in workmanship and material quality, and to verify structural integrity.

A.8 Ultimate Strength - The maximum load or stress that a structure or material can withstand without incurring failure.

A.9 Yield Strength - The maximum load or stress that a structure or material can withstand without incurring detrimental yielding.

Appendix B – Acronyms

AN	Army-Navy
AIAA	American Nation Standards Institute
ANSI	American Institute of Aeronautics and Astronautics
AR	Aviation Research
ASM	American Society for Metals
BPO	Balloon Program Office
CAD	Computer Aided Drafting
COC	Certificate of Conformance
CSBF	Columbia Scientific Balloon Facility
DLL	Design Limit Load
DOT	Department of Transportation
FAA	Federal Aviation Association
FS	Factor of Safety
GSFC	Goddard Space Flight Center
GP	Gondola Provider
MGSE	Mechanical Ground Support Equipment
MMPDS	Metallic Materials Properties Development and Standardization
MS	Margin of Safety
MS	Military Standard
NAS	National Aerospace Standard
NASA	National Aeronautics and Space Administration
NBOC	NASA Balloon Operations Contract
NDT	Non-Destructive Testing
PVS	Pressure Vessel and Pressurized Systems
SSOPD	Suborbital and Special Orbital Projects Directorate
TIM	Technical Interchange Meeting
WFF	Wallops Flight Facility

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	November 5, 2019	Initial Release