How to Fly with BPO & Requirements & Recommendations for Balloon Gondola Design

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Agenda

How to Fly with BPO

- Solicitation Requirements & Selection
- Mission Specific Pre-Campaign Reviews
- During and Post Campaign Specific Reviews
- Things to Think About

Requirements & Recommendations for Balloon Gondola Design

- Design Philosophy
- Structural Requirements
- Mission Assurance
- Staging and Gondola Pickup
- Recovery

How to Fly with BPO

Solicitation Requirements & Selection

Most Balloon Program Office missions are funded through Science Mission Directorate (SMD) research grants through NSPIRES. But we do support non-SMD funded missions as reimbursables.

Depending on the discipline, a Letter of Feasibility may be requested.

For Wallops Sub-Arc Pointing missions, a Letter of Support will be required.

Solicitations will likely require estimates for costs of cryogens and other high dollar consumables during integration and launch.

Selection of awards is then made by SMD. Once selected submit a Flight Support Application with CSBF.

Mission Specific Pre-Campaign Reviews

The BPO process now requires additional reviews for new missions working towards flight:

1. Mission Intake Review
   - Discuss science requirements and schedule for flight.
   - Introduction to Subject Matter Experts who will be later reviewers.
2. Mission Initiation Consultation (MIC)
   - What, why, how, and when for mission.
3. Operations Requirements Design Meeting (ORDM)
   - MIC delta + prelim gondola review and hazards review.
4. Operations Design Review (ODR)
   - ORDM delta + field training requirements, certification needs, and Foreign Nationals.
5. Pre-Flight Requirements Review
   - Confirms mission profile parameters.
6. Pre-Integration Review (PIR)
   - ORDM delta + NASA Panel Review of mission and Structural Analysis Package.

Re-flight missions will go through a tailored process at the discretion of the BPO.

During and Post Campaign Specific Reviews

Leading up to a campaign, there are several reviews that science teams will and will not participate.

1. Mission Readiness Review*
   - BPO presenting to leadership that all preparations are complete or in work.
   - Science Status Review for each mission.
2. Campaign Flight Readiness Review
   - Final closeout of all actions with Wallops Flight Facility (WFF) leadership.
3. Mission Flight Readiness Review*
   - Closeout of integration actions per mission after compatibility / hang test.
4. Approval to Proceed
   - Final WFF approval for flight.
5. Hot Wash / Lessons Learned*
   - Post flight review of the launch and all operations leading up to the flight.
   - Looking for ways to improve our processes for science.

* Science team participates.

Things to Think About

Planning for your cannot not be accomplished at the last minute, depending on what location you're a flying from, and there can be severe limitations.

- Antarctic flights are currently backlogged through '27 -'28 season.
- Antarctic bed space continues to be extremely limited.
- Increased scrutiny on foreign national team members coming to NASA facilities.
- Crane / lift operation training should be scheduled 1-2 years prior to deployment.
- Reviews and consultation with Subject Matter Experts (cryo, pressure, lifting, etc.) are happening much earlier.
- Lasers and radiological sources require minimum 6 months notice prior to first use at a NASA facility.

Requirements & Recommendations for Balloon Gondola Design

Design Philosophy

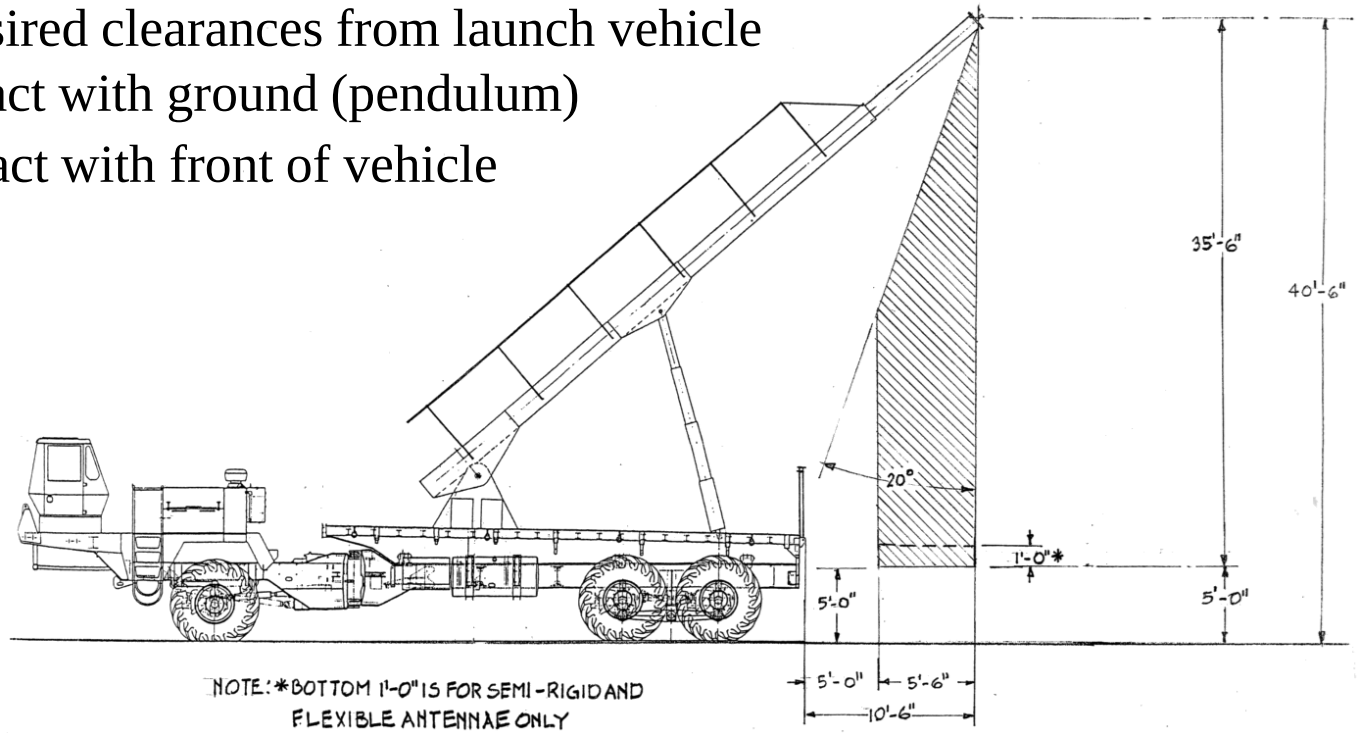
- Structural Integrity
  - Primarily to survive “termination event” (i.e. momentary free-fall followed by parachute opening)
    - Safety
    - Mission Assurance
  - Historically sufficient for landing, although not a requirement
- Mission Assurance
  - Important to prevent damage
  - Allows for less-than-ideal launch conditions
- Staging/Pickup
  - Must be able to fit inside existing high bays
  - Allows for hoist pickup and roll out to launch vehicle
- Recovery
  - Some existing recovery limitations (Antarctica)
  - Crucial to stay within limitations for critical components

Structural Requirements

- What is NOT changing?
  - Prescribed load cases for analysis
    - Inertial relief defined as preferred analysis method
  - Welded/Bonded joints discouraged (for critical structure)
    - See Section 3.6.1 for guidance on welded/bonded joints
- “Critical” Hardware
  - Components constituting a single point failure or whose failure may propagate to further component failures
  - Must be source-traceable and have certified material/mill test reports
- Re-Flights & Legacy Gondolas
  - Need visual inspection prior to every flight
  - Documentation to NASA regarding flight heritage, storage, and testing/inspection or replacement of structural components
  - Deviations (See Section 1.1)

Mission Assurance

- Payload Must Be Able to Survive Launch
  - Dynamic Launch: damage to antennae, solar panels, or other protruding objects
- Minimum Desired Distances From Launch Vehicle
  - “20 degree rule” – Assures minimum desired clearances from launch vehicle
  - 6 feet of ground clearance – avoids contact with ground (pendulum)
  - 5 feet of vehicle clearance – avoids contact with front of vehicle
  - New launch vehicle in development
- Other Observations
  - Width/Length of payload – rotation during launch
  - Wide sections near the boom (higher)
    - Risk contact with boom
  - “Sails” – mylar or solar panels



Staging & Gondola Pickup

- Facilities Limitations
  - Height & Width of Payload
    - Allow for weighing of payload inside high bay (Antarctica)
    - Allow for ease of roll in/out of building
- Carts/Wheels/Stands
  - Allows operations to work underneath gondola
  - Ideally allows for ballast hoppers and solar panels to stay attached for rollout
    - BIG time saver
  - Must be big enough for easy rollout
  - Must allow rotation of payload for vehicle pickup

Recovery

- Gondola Disassembly
  - Focus on ease/speed of disassembly
    - Allows for quicker recovery (Antarctica)
  - Accessibility of data vaults and other critical components
    - Trade-off between access and protection
- Transport
  - Critical components to stay within a certain allowable size and weight
  - Limited by recovery vehicle
    - Helo
    - Twin Otter & Bassler (Antarctica)
    - Land Vehicles
    - Reference drawings available on CSBF website

Questions?

I have often marveled at the thin line which separates success from failure.

- Ernest Shackleton

How to Fly with BPO Back-Up

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Important Links

NASA NSPIRES:
https://nspires.nasaprs.com/external/

NASA SMD Astrophysics:
https://science.nasa.gov/astrophysics/

NASA Balloon Program Office:
https://sites.wff.nasa.gov/code820/

CSBF Science User Documentation:
https://www.csbf.nasa.gov/docs.html

Gondola Structural Design Requirements 820-PG-8700.0.1:
https://www.csbf.nasa.gov/documents/gondola/820-PG-8700.0.1%20Gondola%20Structural%20Design%20Requirements.pdf

NASA Earth Observatory Notes from the Field:
https://earthobservatory.nasa.gov/blogs/fromthefield/category/balloon/

National Science Foundation Office of Polar Programs:
https://www.nsf.gov/div/index.jsp?div=OPP

Mission Intake

- When it happens:
  - Immediately after award of grant.
- What is covered:
  - The science requirements and schedule for flight.
  - Overview of the required BPO reviews.
  - Introduction to the assigned MM.

Attendees:

- PI and Science Team
- NASA Mission Management Team
- NASA Wallops Arc Second Pointer (WASP) or Super Pressure Balloon (SPB) Team (if applicable)
- CSBF Flight Project Team

Why:

- Introduce PI to the working team at Wallops Flight Facility (WFF) and CSBF.
- Review requirements and develop a plan to support.

Mission Initiation Consultation (MIC)

- When it happens:
  - After award for primary missions.
  - For reimbursable / piggybacks when Flight Application is received.
- What is covered:
  - Science Team
    - Science Requirements Review (SRR)
      - What: High-level Payload and Flight Overview
      - Why: Scientific Goal Overview
      - How: Operations Overview (Power, Telemetry, Hazards, Etc.)
      - When: Timeline
  - BPO
    - Hazardous Operations and Procedures Review
  - CSBF
    - Operations and Integration Overview

Attendees:

- PI and Science Team
- NASA Discipline and Project Scientists
- NASA BPO Leadership and Mission Management Team
- NASA WASP or SPB Team (if applicable)
- NASA Safety Office Analysts
- NASA Engineering Representative
- CSBF Flight Project and Engineering Teams

Why:

- Have an open forum to discuss the proposed mission with the appropriate subject matter experts.
- Begin discussing the requirements set for the Program and how they impact the mission.

Operations Requirements Design Meeting (ORDM)

- When it happens:
  - Launch (L) -27 months for primary missions
  - L-5 months for hand launch and piggyback missions
- What is covered:
  - Science Team
    - Science Configuration Review (SCR) – Preliminary review of the gondola structural configuration.
    - Ground and Flight Operations Update – Has anything changed?
  - BPO
    - Hazardous Operations Requirements Review

Attendees:

- PI and Science Team
- NASA BPO Mission Manager
- NASA Engineering Representative
- CSBF Flight Project and Engineering Teams

Why:

- Discuss how the 820-PG-8700.0.1 is applicable to the gondola.
- Discuss any operational changes from MIC.
- Discuss what requirements will be required for working with known hazardous systems.

Operations Design Review (ODR)

- When it happens:
  - L-15 months for primary missions
  - L-4.5 months for hand launch and piggyback missions
- What is covered:
  - Science Team
    - Science Critical Configuration Review (SCCR) – Presentation of the appropriate load cases from 820-PG-8700.0.1 requirements.
    - Will any science team members need crane operator certification?
    - Any equipment that will need NASA certification? Lifting? Pressure?
    - Piggyback accommodation.
    - Ground and Flight Operations Update – Has anything changed?
  - BPO
    - Initiate Safety Data Forms

Attendees:

- PI and Science Team
- NASA BPO Mission Manager
- NASA Engineering Representative
- CSBF Flight Project and Engineering Teams

Why:

- Review compliance with 820-PG-8700.0.1 requirements and assign any open actions.
- Begin compiling data for Ground / Flight Safety review, BPO Power Systems Review, Radiation (ionizing and non-ionizing).

Pre-Integration Review (PIR)

- When it happens:
  - L-6 months for primary missions
  - L-4 months for hand launch and piggyback missions
- What is covered:
  - BPO
    - 820-PG-8700.0.1 Structural Analysis Package (SAP) – Accepted
    - Hazardous Procedures – Submitted
    - Safety Data Forms – Submitted

Attendees:

- PI and Science Team
- NASA BPO Mission Manager
- NASA Safety Office Analysts
- NASA Engineering Representative
- CSBF Flight Project and Engineering Teams

Why:

- Review for ensuring total documentation compliance prior to preparation for flight.
- Discuss any changes that may impact the Safety Plans for the proposed campaigns.

Mission Readiness Review (MRR)

- When it happens:
  - L-2 months for domestic campaigns
  - Prior to sea shipments for international campaigns
- What is covered:
  - Science Status Review (SSR)
    - Deployment and Integration Schedule
    - Operational Requirements
    - Integration Requirements
    - Current status of payload
    - Risks and mitigations
  - NASA
    - Full Operational Readiness Review
      - BPO
      - Safety Office
      - CSBF

Why:

- Full readiness review prior to campaign start.

Attendees:

- PI and Science Team
- NASA Program Executive, Discipline and Project Scientists
- NASA BPO Leadership and Mission Management Team
- NASA WASP or SPB Team (if applicable)
- NASA Safety Office Chief Engineer, Campaign RSO, and Analysts
- NASA Engineering Representative
- CSBF Flight Project and Engineering Teams

Integration and Test

- When it happens:
  - L-2 days
- What is covered:
  - CSBF
    - Science/Support Compatibility Test (SSCT)
      - CSBF Hang Test
      - Mechanical Certification
    - Flight Readiness Review
  - WFF Leadership
    - Approval to Proceed (ATP)

Attendees:

- PI and Science Team
- NASA WFF Leadership
- NASA BPO Mission Manager
- CSBF Campaign Manager, Engineering and Technician Teams

Why:

- Final check on mission compliance with stated requirements.
- Integration complete and ready for launch.

Post Launch / Campaign

- When it happens:
  - L+7/14 days
- What is covered:
  - Lessons Learned Documentation Captured
  - Campaign Lessons Learned Review (CLLR)
  - Mission Management Close-out Documentation

Why:

- Formal closeout documentation following flight.

Attendees:

- PI and Science Team
- NASA BPO Mission Manager
- CSBF Campaign Manager, Engineering and Technician Teams

Launch Site Matrix

Goddard Space Flight Center — Wallops Flight Facility

Launch Site	Fort Sumner, NM	Palestine, TX	Alice Springs AUS	Kiruna SWE	McMurdo ANT	Wanaka NZ
Flight Season	Aug - Oct every year	May - July	March - May odd years [1]	May - July odd years	Dec - Jan every year	April - Aug even years
Campaign Duration	July - Oct	May - July	Feb - May	April - July	Oct - Feb	Feb - May
Launch Time	Morning	Morning / Afternoon	Morning	Anytime	Anytime	Morning
Lat/Long	34.4731° N, 104.2422° W	31.7786° N, 95.7144° W	23.80° S, 133.89° E	67.8833° N, 21.1167° E	77.8500° S, 166.6667° E	44.7222° S, 169.2455° E
Trajectory	West / East / Turnaround	West	West / East / Turnaround	West	West	East
Latitude Range	29 N - 38 N	29 N - 38 N	17 S - 29 S	60 N - 80 N	Continent	20 S - 65 S (nominal) 10 S - 80 S (possible)
Longitude Range	94 W - 117 W	94 W - 117 W	116 E - 140 E	23 E - 120 W	Continent	South Hemisphere
Float Wind Speed Range	0 - 70kts	20 - 70kts	0 - 70kts	10 - 30kts	5 - 30kts	10 - 120kts
Balloon Type	Zero Pressure	Zero Pressure	Zero Pressure	ZP / SPB	ZP / SPB	Super Pressure
Max Science Mass	6000 lbs	6000 lbs	6000 lbs	6000 lbs (ZP) 3674 lbs[2] (SPB)	6000 lbs (ZP) 3674 lbs[2] (SPB)	3674 lbs [2]
Comm Package	CIP / MiniSIP / MIP	CIP / MiniSIP / MIP	CIP / MiniSIP / MIP	CIP / MiniSIP / MIP	SIP / MIP	SIP / MIP
Ready to Ship	August	May	January	March	August	December
Building door constraints	NASA Building 30' h x 15' w (Hook Height 29.5 ') Airport Hangar 20' h x 13' w (Hook Height 20')	29.5' h x 18' w (Hook Height 30 ')	31.5 ' h x 23.6' w (Hook height 27.4 ')	Multiple	30' h x 18' w (Hook Height 25.5 ')	13.7' h x 20' w (Hook Height 11.2 ')
Launch vehicle envelope	Suspension ht is 40', ground clearance is 6 '	Suspension ht is 40', ground clearance is 6 '	Suspension ht is 40', ground clearance is 6 '	Suspension ht is 40', ground clearance is 6 '	Suspension ht is 40', ground clearance is 6 '	Suspension ht is 40', ground clearance is 6 '

Antarctica Long Duration Balloon Campaign

Goddard Space Flight Center — Wallops Flight Facility

Launch Site	**McMurdo Station, Antarctica**
Flight Season	Dec – Jan (every year)
Campaign Duration	Oct - Feb
Launch Time	Anytime
Lat/Long*	77.8500° S, 166.6667° E
Trajectory	West
Latitude Range	Continent
Longitude Range	Continent
Float Wind Speed Range	5 - 30kts
Balloon Type	ZP / SPB
Max Science Mass	6000 lbs (ZP) 3674 lbs[2] (SPB)
Comm Package	SIP / MIP

* Launch location Lat and Long change year to year.

New Zealand Long Duration Balloon Campaign

Goddard Space Flight Center — Wallops Flight Facility

Launch Site	Wanaka, New Zealand
Flight Season	April – Aug, even years
Campaign Duration	Feb - May
Launch Time	Morning
Lat/Long	44.7222° S, 169.2455° E
Trajectory	East
Latitude Range	20 S - 65 S (nominal) 10 S - 80 S (possible)
Longitude Range	South Hemisphere
Float Wind Speed Range	10 - 120kts
Balloon Type	Super Pressure
Max Science Mass	3674 lbs [2]
Comm Package	SIP / MIP

Sweden Long Duration Balloon Campaign

Goddard Space Flight Center | Wallops Flight Facility

Launch Site	**Kiruna, Sweden**
Flight Season	May - July, odd years
Campaign Duration	April - July
Launch Time	Anytime
Lat/Long	67.8833° N, 21.1167° E
Trajectory	West
Latitude Range	60 N - 80 N
Longitude Range	23 E - 120 W
Float Wind Speed Range	10 - 30kts
Balloon Type	ZP / SPB
Max Science Mass	6000 lbs (ZP) 3674 lbs[2] (SPB)
Comm Package	CIP / MiniSIP / MIP

Australia Conventional Balloon Campaign

Launch Site	**Alice Springs AUS**
Flight Season	March - May odd years [1]
Campaign Duration	Feb - May
Launch Time	Morning
Lat/Long	23.80° S, 133.89° E
Trajectory	West / East / Turnaround
Latitude Range	17 S - 29 S
Longitude Range	116 E - 140 E
Float Wind Speed Range	0 - 70kts
Balloon Type	Zero Pressure
Max Science Mass	6000 lbs
Comm Package	CIP / MiniSIP / MIP

Fort Sumner Conventional Campaign

Goddard Space Flight Center | Wallops Flight Facility

Launch Site	**Fort Sumner, NM**
Flight Season	Aug – Oct, every year
Campaign Duration	July - Oct
Launch Time	Morning
Lat/Long	34.4731° N, 104.2422° W
Trajectory	West / East / Turnaround
Latitude Range	29 N - 38 N
Longitude Range	94 W - 117 W
Float Wind Speed Range	0 - 70kts
Balloon Type	Zero Pressure
Max Science Mass	6000 lbs
Comm Package	CIP / MiniSIP / MIP

Requirements & Recommendations for Balloon Gondola Design Back-Up

Structural Requirements

- Requirements Have Changed
  - Effective 5 November 2019
  - OM-220-10-H has been superseded by 820-PG-8700.0.1
    - https://www.csbf.nasa.gov/documents/gondola/820-PG-8700.0.1%20Gondola%20Structural%20Design%20Requirements.pdf
- Notable Changes

Design Limit Loads (DLL) G's		
Vertical	@ 45°	Horizontal
10	5	5

Design Factor of Safety	
Yield	Ultimate
N/A	1.0

Design Limit Loads (DLL) G's		
Vertical	@ 45°	Horizontal
8	4	4

Design Factor of Safety	
Yield	Ultimate
1.25	1.4

  - Metallic materials with failure strain of 5% or less, at worse case temperature limit shall be considered brittle (previously 10% at -60 °C)
  - Deliverables and review schedule better defined
    - Review Schedule: See Table 1, Section 2.0
    - Deliverables Checklist: See Section 4.5

Structural Requirements

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			

Common Pitfalls and Recommendations

- Early Interface with CSBF
  - Aim to follow deliverables/review schedule
  - Pointing systems & critical hardware
    - Source traceable w/ certs
    - Placement of CSBF equipment
      - Thermal considerations
      - Antennae
      - Launch straps
      - Ballast hoppers
    - Gondola dimensions
      - “20 degree rule”
- Structural Analysis Margin
  - Final weights are usually higher than predicted!!
- Protective Cage for SIP
- Non-appropriate casters/tires
  - Hard to maneuver