# Balloon Program Office

# Piggyback Handbook

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National Aeronautics and
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Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia

# Piggyback Handbook

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# 1 INTRODUCTION

## 1.1 PURPOSE

The NASA Balloon Program Office (BPO) provides high-altitude scientific balloon platforms for scientific and technological investigations, including fundamental scientific discoveries that contribute to our understanding of the Earth, the solar system, and the universe. A primary balloon mission may host between zero to several piggyback missions.

Piggyback missions are typically lightweight and must be able to operate on a non-interference basis with the primary mission and other piggybacks. NASA BPO coordinates with piggyback missions, primary missions, and with the Columbia Scientific Balloon Facility (CSBF) to ensure appropriate placement of piggyback missions.

This document provides background information, tips, and best practices for science teams working on a piggyback mission, or who are considering applying for a piggyback mission. For more information on piggyback opportunities, contact BPO Mission Operations Manager (contact information available at https://sites.wff.nasa.gov/code820/pages/about/about-staff.html)

This document has been developed with the help of previous piggyback teams. Feedback on your experiences and any additional suggestions for future teams are appreciated by BPO. As you go through the life of your piggyback mission, if you find additional information that you think would be beneficial to include in this document, please send it to christy.hales@nasa.gov or your mission manager.

## 1.2 SCOPE

This document covers piggyback opportunities for all missions operated under the auspices of NASA BPO.

## 1.3 REFERENCE DOCUMENTS

When no version is specified, the most recent release of a document should be used.

- 820-PG-1060.2.1, *Balloon Program Management Review and Reporting for Programs and Projects*
- 820-PG-8700.0.1, *Gondola Structural Design Requirements*
- GSFC-STD-8009, *Goddard Space Flight Center (GSFC) Wallops Flight Facility Range Safety Manual*
- NASA-STD-5002A, *Load Analysis of Spacecraft and Payloads*
- OF-300-12-F, *Balloon Flight Support Application*
- EL-100-10-H, *Long-Duration Ballooning Support for Science*

## 2 BACKGROUND

This section provides an overview of NASA Balloon Program Office operations and capabilities, with a focus on information relevant to piggyback missions. To learn more about scientific balloons at NASA, visit https://www.nasa.gov/scientificballoons/.

### 2.1 BALLOON CAPABILITIES

NASA uses two types of scientific balloons: Zero Pressure Balloons (ZPB) and Super Pressure Balloons (SPB). ZPBs can maintain altitude from a few days up to multiple months in locations where there is no diurnal cycle (i.e. sunset) and are capable of both short and long flight durations. To reach an equilibrium altitude, ZPBs utilize a channel duct, which vents gas into the atmosphere once the balloon is fully inflated. Because the balloon's pressure (at the base) matches that of the outside atmosphere during the balloon's flight, the balloon's altitude fluctuates with changes in the atmosphere. In order to provide a more consistent flight pattern, ballast is released (by command to a relay) to minimize altitude droops.

The standard ZPB volumes range from 1.1 million cubic feet (MCF) to 60 MCF (reference Figures 1 and 2). The balloon volume selected for flight correlates to both the size of the payload and the desired float altitude. Balloon float altitudes are typically between 120,000-130,000 feet but can vary depending upon science flight requirements and observed flight conditions.

SPB design and development has made long-duration missions in the stratosphere possible without the need for constant sunlight. These balloons are developmental and are designed to be pressurized during both day and night operations, allowing the balloon to maintain a near-constant altitude while at float. These balloons can carry up to 5,500 pounds of payload to 110,000 feet (24.6 miles) above sea level and reach sizes up to 18.8 million cubic feet when they reach their preferred altitude. They can stay aloft for months at a time.

Piggyback opportunities exist on both ZPB and SPB. For more information on balloon capabilities and BPO mission opportunities, please visit: https://sites.wff.nasa.gov/code820/pages/operations/operations-operational-capabilities.html.

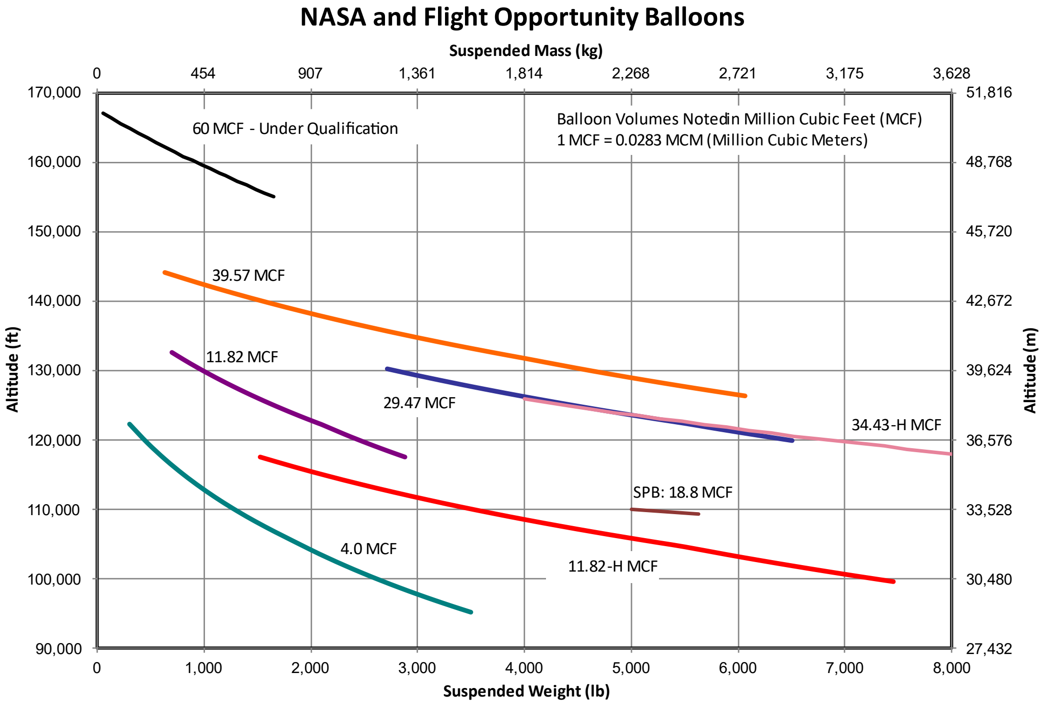


**Figure 1 – NASA Standard Zero Pressure Balloons**

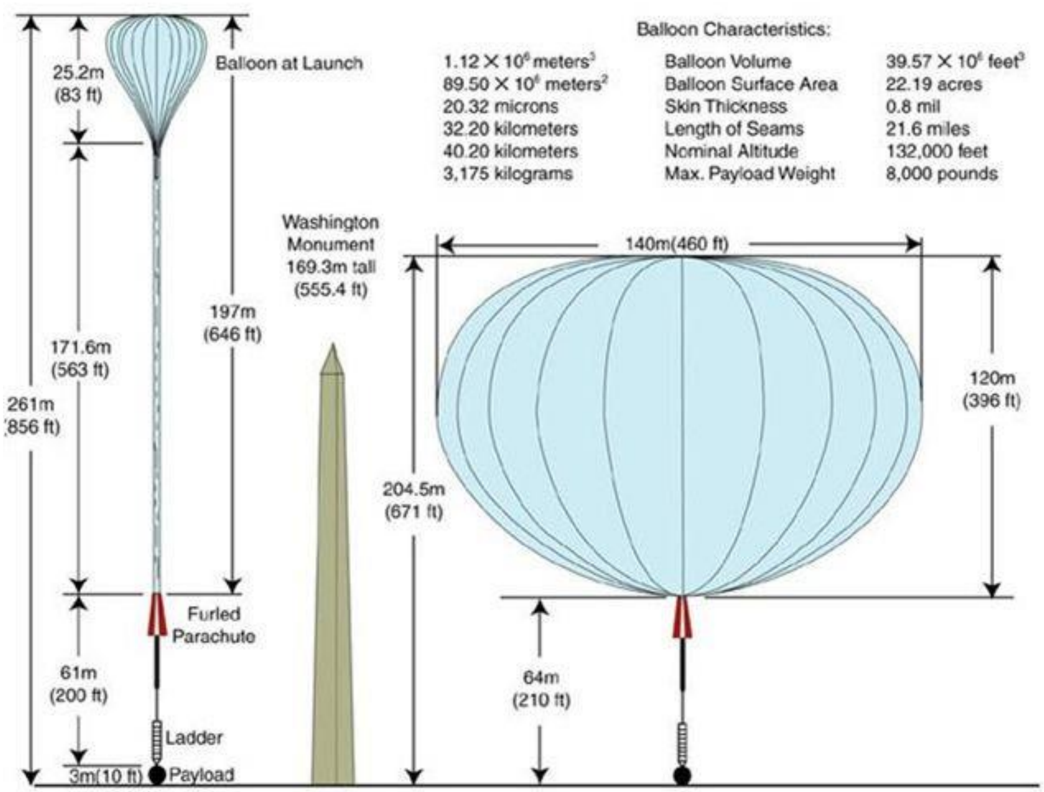


**Figure 2 – NASA Balloon Size Comparison**

## 2.2 LAUNCH LOCATIONS

Piggyback opportunities depend upon availability and finding a suitable primary mission, but can be supported from all of the Balloon Program Office's current launch sites:

- Fort Sumner, NM
- Palestine, TX
- Esrange, Sweden
- Wanaka, New Zealand
- Alice Springs, Australia
- McMurdo Station, Antarctica

More information on each of the launch sites, including environment, campaign type and timing, operational details, and facility descriptions are available at https://sites.wff.nasa.gov/code820/pages/operations/operations-facilities.html.

# 3 REQUIREMENTS

Piggyback missions adhere to all relevant BPO requirements. Reviews, schedules, integration activities, launch and recovery operations, and other activities are tailored to specific missions and environments. Balloon missions are highly dependent upon weather and local conditions and the timelines and typical operations listed below are subject to change.

In order to initiate a mission, piggybacks are required to complete and submit a flight application for every desired flight. The current flight application can be found on the CSBF website[1]. For clarification of specific terms, there is guidance also available on the CSBF website. Once a flight application is submitted, a BPO Mission Manager (MM) will be assigned to you. This MM is your Point Of Contact (POC) for all questions and information.

## 3.1 REVIEW SCHEDULE

The schedule of reviews for inside the Continental United States (CONUS) and Outside of the Continental United States (OCONUS) missions can be found in 820-PG-1060.2.1, *Balloon Program Management Review and Reporting for Programs and Projects,* and are summarized here in Table 1. All reviews will be scheduled by the mission manager and will be facilitated by teleconference or web conference. In some cases, it can be beneficial to have reviews earlier than required for OCONUS missions.

## 3.2 LOAD INTEGRATION

Once in the field, the piggyback mission will need to be integrated into the primary mission. Your mission manager will facilitate logistical coordination between CSBF, the primary mission science team, and the piggyback mission science team. Integration should be completed in accordance with the agreed-upon location and orientation from the PIR.

Mechanical integration of the structure to the main gondola should be completed by CSBF using approved science-provided fasteners (generally aircraft hardware). For campaigns within the continental United States, a science team member is advised to be onsite to facilitate ease of integration and installation of all hardware. If a science team member cannot be present, sufficient detail should be provided (in the form of a procedure) for installation to be completed. Approval of all installations should be given via email or in person.

Your team will be responsible for providing any tools necessary to prepare your payload for flight, as well as all necessary Personal Protective Equipment (PPE) for any team members onsite. Required PPE includes high visibility vests, hardhats, and safety shoes for anyone who will be near the payload while any lifts are being performed during integration or launch proceedings. Additional PPE may be required based on the hazards associated with the piggyback or primary missions.

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[1] https://www.csbf.nasa.gov/docs.html

**Table 1 - Required Operations Review Schedule**

| Meeting | CONUS Timeline | OCONUS Timeline | Key Topics |
|---|---|---|---|
| Project Initiation Conference (PIC) | N/A | 1 year prior to campaign start | • Review CSBF and Science requirements<br>• Discussion on operation support plans and schedules<br>• Identify open action items |
| Mission Initiation Consultation (MIC) | Application submission | Application submission | • Discussion on structural requirements, typical hazards, overview of campaign operations, overview of BPO review schedule |
| CSBF Pre-Flight Requirements | L-6 months | L-6 months | • Review science requirements<br>• Discussion of operational plans, balloon, ballast, and hazards<br>• Review travel plans |
| Operations Requirements Design Meeting (ORDM) | L-5 months | L-5 months | • Discussion on structural requirements, critical hardware, support hardware<br>• Discussion on hazardous operations, integration |
| Operations Design Review (ODR) | L-4 months | L-4 months | • Discussion on structural requirements met, are being met, or are being addressed<br>• Discussion on mass availability and deltas<br>• Discussion on information for NASA data request |
| Pre-Integration Review (PIR) | L-4 months | L-4 months | • Presentation on structural analysis package<br>• Operations, integration, schedule<br>• Review of information for NASA data requests |
| Mission Readiness Review (MRR) | L-2 months | L-5 months | • Readiness Reviews for Science, Operations, Safety, and BPO |
| Delta MRR (as required) | N/A | L-1 month | • Changes since MRR |
| Campaign Flight Readiness Review (FRR) | L-7 days | L-7 days | • BPO presents campaign readiness to WFF leadership |
| Mission Flight Readiness Review (mFRR) | L-1 days | L-1 days | • Gondola certification and compatibility test results<br>• Flight requirements review<br>• Confirm receipt of Approval to Proceed with flight |
| Hotwash | L+1 day | L+1 day | • Solicit lessons learned from launch, flight, and/or recovery<br>• Discuss issues encountered<br>• May be delayed if required by operations |
| Post-Campaign Lessons Learned (PCLL) | NLT L+3 months | NLT L+3 months | • Review lessons learned and opportunities for improvement |

Coordinate with your mission manager if you have any foreign nationals who will be participating in integration or launch activities onsite; additional documentation (and in some cases an escort, which incurs a science-paid cost to support) will be required.

If the piggyback payload has any electrical or software cables which are required to interface to CSBF or main gondola systems, those cables need to be connected by science personnel or their designated representative. All requirements should be agreed upon during the ORDM and PIR prior to arrival in the field. For more details about piggyback design, please refer to Section 4.

The compatibility test includes putting the science payload and CSBF/NASA systems in mission confirmation and is required prior to a flight attempt. Often called a “hang test”, the main gondola and all piggyback missions are powered on and set in operational modes. Then the gondola is suspended, either from an overhead crane in a high bay, or using the launch vehicle outside the hanger. Command and control protocol are completed per standard CSBF procedures for all flight equipment, followed by all specific instructions for piggyback missions. The primary goal is to identify any electromagnetic interference or other unintended interference or cabling/system issues. After, the payload is powered off and brought inside for storage until flight day. It is expected that all piggybacks be operational for this test with no further changes to the piggyback post-test.

The compatibility test is usually scheduled for the day prior to the first launch attempt and may begin very early in the morning. Therefore, all integration should be planned to be completed at least 2 days prior to the first anticipated launch opportunity. Your mission manager can help you coordinate with the primary mission to determine when to arrive onsite for integration.

## 3.3 LAUNCH DAY

Launches in Fort Sumner most often occur between 7-11 a.m. local time, and personnel may arrive to begin preparing for launch sometime between midnight and 3 a.m., so be prepared for a very early start to the day. There is typically a daily weather briefing on days when the team does not show for a launch to discuss launch opportunities over the next several days. A Teams notice will be sent out so that people offsite can also participate in the weather briefings and key campaign information will also be shared via email.

The following is a rough sequence of events surrounding pre-launch, launch, flight, and landing. Due to the variability in mission requirements and meteorological conditions, these times are approximations. Table 2 shows an example for a one-day mission launched from Fort Sumner.

**Table 2 - Example Timeline for Launch Day for a Fort Sumner Launch**

| Time | Event | Description |
|---|---|---|
| L-18 hours | Show notification | Notification is given of a show, or launch attempt, the following day. This is generally at a weather brief and disseminated via email. Show and pickup times are determined. |
| L-4.5 hours | Show time | All Principal Investigators (PIs) and support personnel for the main mission and all piggybacks are required to show at the launch site. |
| L-4 hours | Pickup time | The main payload and piggybacks are all powered on and nominal status is set. The gondola is rolled out of the hanger and picked up using the launch vehicle. Typically, the gondola is hands-off post-CSBF pickup. No further interaction with the payload can occur after this point. |
| L-3 hours | Rollout time | The gondola is moved to the flight line and positioned for flight. Main balloon and flight support systems are attached. |
| L-1.5 hours | Inflation begins | Balloon inflation begins. |
| L-5 minutes | Inflation ends | Balloon inflation ends. |
| L-0 minutes | Launch | Gondola launch is conducted. |
| L+3 hours | Float reached | The gondola is declared to be "at float", with stable altitude and quiescent conditions. |
| L+24 hours | Termination | The mission is terminated. The payload begins descent to the ground on the parachute. |
| L+26 hours | Landing | The gondola lands on the ground. |
| L+30 hours | First contact | The recovery team arrives on site and powers off the gondola and all equipment. |

Note that the timings above are based on a Fort Sumner flight requiring overnight duration. A test flight duration from Fort Sumner can be as short of a duration as two hours. For Antarctic flights, ascent can take upwards of six hours and termination can occur as many as 55 days post-launch.

## 3.4 RECOVERY

The recovery operation is complicated, messy, and requires considerable coordination. Often times, recovery is done over two days. The first event is termed "first contact" and meant to safe and secure the payload. The second event is the actual time when the payload is picked up using the mobile crane and transported back to the launch site.

At first contact, the piggyback missions need to be disconnected and powered off. Clear power off instructions should be provided. On pickup and return, if the entire gondola cannot be returned in the flight configuration, then instructions need to specify the critical aspects for recovery and return. Note that recovery and return loads can be significant, therefore design consideration should be given to transportation loads (Table 1 in NASA-STD-5002A, *Load Analysis of Spacecraft and Payloads*, can be helpful when assessing likely transportation loads).

On landing, the gondola has a high likelihood of tipping over.  Further, there is a good chance that a gondola will impact an object (e.g., tree) upon landing, especially in Fort Sumner and Canada. Piggybacks which are exposed (i.e., no protective cover) are at an increased risk to Foreign Object Debris (FOD) upon landing, such as dirt, branches, and rocks.  Further, for landing events in the southern hemisphere or Canada, there is also an additional risk of snow, ice, and water. It is advisable to design your payload to withstand these environments to the extent possible, and to protect essential hardware and data.

In most cases CSBF can ship your payload to you after recovery if you provide a shipping label and have relatively simple payload.  Coordinate through your mission manager if you would like to discuss this possibility.

# 4 DESIGN

## 4.1 PARADIGM

A piggyback payload is meant to be small, easy to integrate, and flown on a non-interference basis. Most piggyback missions are flown on a test flight gondola from Fort Sumner, NM, with about half of the PIs in-person for the launch. Thus, the piggyback design needs to focus on being simple to integrate and operate, robust to accommodate changes, and considerate of the recovery process. In short, the more standalone the piggyback payload is, the greater the chance of science success. Even if you plan to have a science representative onsite, it can be helpful to have a simple payload with clear procedures. Some missions are flight-ready for weeks while waiting for favorable launch conditions and/or launch priority.

## 4.2 MECHANICAL

### 4.2.1 Structural Design

All piggyback payloads need to meet the requirements within 820-PG-8700.0.1, *Gondola Structural Design Requirements*. Most of the specified load cases are meant to envelope loading encountered during the termination event, which is always seen during flight. Verification of the design can be done by Finite Element Analysis or by proof testing. The PI will also need to provide to CSBF and the primary gondola a Computer Aided Design (CAD) model of your payload. Note that 820-PG-8700.0.1 is also the standard used for primary missions, and Sections 4.2.2 (Load Case 2) and 4.2.5 (Load Case 5) do not apply for piggybacks. Contact your mission manager with any questions.

Mounting will depend upon the primary mission and plans should be coordinated through your mission manager. Often a plywood surface is used on the CSBF gondolas, and it is beneficial to have easy mounting holes on the payload. Rachet straps will be used in some cases, especially for those with foam enclosures. In general, bolted joints and through fasteners are preferable to welds or friction fasteners.

### 4.2.2 Enclosures

It is recommended that piggybacks be self-contained within a box, either plastic or metal. Self-contained missions are easy to mount, generally have a clean interface to power and data, and are able to easily withstand the termination loads. Additionally, boxes protect internal electronics from the dirt, wind, brush, and sand commonly seen during recovery operations. Obtaining the material properties of the box is essential and known electronics enclosures with an Ingress Protection (IP) rating are good choices.

### 4.2.3 External Interfaces

For all piggybacks, actuation switches shall have a mechanical interface on the outside of the gondola. For example, if data is passed by Ethernet cable to a computer inside the piggyback, then either an Ethernet port or Ethernet cable accessible from the exterior is suggested. Panel mounted switches or ports for Ethernet and DB connectors are advised. Locking connectors are suggested for all critical connections. It is a good practice to make sure it is clear whether a switch is in the ON or OFF position. A key or switch with a “Remove Before Flight” tag can also be useful. Do not assume internal access to a payload is available on the morning of flight (especially if secured via rachet strap).

## 4.3 ELECTRICAL

### 4.3.1 Voltage

Power is the main concern for piggybacks. For payloads using CSBF-provided or science-provided power, most power systems for balloons will run on 28 VDC potential, leading to a requirement for a voltage converter. When applicable, take measures to prevent the conversion of Direct Current (DC) voltage to Alternating Current (AC) voltage, especially when voltage is simply converted back to DC voltage. This often occurs when using Commercial Off-The-Shelf (COTS) consumer computers with wall plugs meant for 110 VAC 50-60 Hz inputs, which can lead to arcing and result in loss of payload and mission.

### 4.3.2 CSBF-Provided Batteries

Most piggybacks will use batteries as the primary power source. CSBF can provide a battery pack as an option for flight: a Saft Lithium Sulfur Dioxide (LiSO2) battery pack. These packs are non-rechargeable with a typical capacity of 50 Ah and nominal voltage of 29.7 VDC. Each battery comes fabricated with a locking connector on a 3-foot cable lead. Modifications to this configuration are generally not allowed due to safety concerns, so science teams need to be prepared for field integration. Use of these batteries requires coordination with CSBF and the primary mission.

Talk to your mission manager if you have any questions about batteries or other electronic support that CSBF can provide.

### 4.3.3 Piggyback-Provided Batteries

Without CSBF-provided batteries, the piggybacks are left to provide their own batteries, unless they can coordinate use of power from the primary mission. All batteries must comply with GSFC-STD-8009, *Goddard Space Flight Center (GSFC) Wallops Flight Facility Range Safety Manual*. The approval process is simplest for UL-certified batteries. Either UL certificates or a description of how the batteries meet the requirements within GSFC-STD-8009 must be provided as part of the NASA Safety approval process. Rechargeable batteries must also have the charging infrastructure, protection items (e.g. fire-proof bags), and a charging procedure provided by the time of integration. 820-SCI-Battery-01, *Non-UL Certified Battery Charge and Discharge Procedure*, is an approved generic charging procedure applicable for both UL-certified and non-UL certified batteries. Your mission manager can help you determine whether its use would be beneficial for your mission.

In general, CSBF will only switch on or plug in batteries for compatibility tests or launch attempts. CSBF will not recharge batteries for PIs or integrate batteries into piggyback systems. Thus, if a science representative is not to be onsite during integration or flight, the piggyback batteries must be contained within the piggyback or have a power cable clearly marked with the matching battery plug.

Once the piggyback is integrated into the gondola and compatibility has been completed, the piggyback should not be de-integrated. Thus, if a battery needs to be charged or replaced, then an access port needs to be present. This could be a power plug on the outside of an enclosure, or a hinged lid that opens for electronics access. Keep in mind that the piggyback could be placed within the gondola in a hard-to-access point, so charger cables should be long and access ports should be easy to access.

When making battery plans, be sure to account for turning on the batteries several hours (4-8, depending on the mission) prior to launch, as well as the potential for multiple launch attempts (5 or more). There is a lot of uncertainty and dependence upon the weather in ballooning and being conservative when making these arrangements can be the difference between a successful mission and collecting no data.

## 4.4 SOFTWARE

Software should be as autonomous as possible. For example, if running a microcontroller or small computer, that computer should run startup scripts on boot when powered on. Commands sent from a user to the piggyback should be minimized unless a team member will be present on-site for launch. Power-on times should be minimized; for example, 5 minutes is a good limit for power on and initialization.

Data storage is an important consideration for piggybacks. Hard drives should be capable of operating in the low-density low-convection environment. Secure Digital (SD) cards must be sized to be large enough to hold all data. For telemetry (which is rare for piggybacks), the data stream must conform to the CSBF-provided science stack format EL-100-10-H, *Long-Duration Ballooning Support for Science*, or to the science-provided interface.

## 4.5 SENSORS

Sensors are mission-specific; however, there are some shared concerns to consider. First, Global Positioning System (GPS) units need to have the high Capcom limits (or the limits removed) to meet the altitude requirement (some hobby-grade GPS units use the lower limits). Second, the transmitting antennas used by CSBF can cause interference with some GPS receivers. You will need to coordinate with your mission manager to ensure that any sensors you plan to use will not interfere with CSBF or primary mission equipment.

## 4.6 HAZARDS

Hazards (both for use in-flight or on the ground) must be approved by NASA Safety and may require supplemental information, procedures, and conversations with NASA Safety as part of the review process. Below is a non-comprehensive list of hazards:

- Pressurized or vacuumed systems
- Chemical and flammable substances
- Cryogenic systems
- Ordnance
- Transmitters
- Lasers
- Ionizing radiation
- High voltage (>50 V)
- Batteries
- Lifting devices and equipment

Contact your mission manager if you are unsure whether something qualifies as a hazard. They will help you through the review process.

# 5 BATTERIES

## 5.1 GROUND CONSIDERATIONS

Often, CSBF batteries are located for thermal management and can be ~15 feet from the piggyback. Thus, if science teams use a CSBF-provided battery, then teams need to fabricate/bring an extension cable from the battery to the main piggyback power point. For science-provided batteries, extension cords, surge protectors, and voltage adapters (if outside of the country) are all good items to bring to the field. Do not assume CSBF has the infrastructure to charge or wire a battery in the field.

## 5.2 FLIGHT CONSIDERATIONS

Each phase of flight provides unique challenges. The launch phase is often hot and humid, especially for contained payloads. Thermal design needs to account for the batteries when considering overheating. The ascent and float phases of flight are calm, with low payload rotations and an ambient air temperature of approximately -30 ºC. Radiation protection is important to prevent loss of heating to space; 1" blue building insulation foam (as found in a commercial hardware store, e.g. Polystyrene Board Insulation) may work well for this protection. However, thermal analysis depending on power consumption is desired (insulation may not be appropriate if significant power is generated in the piggyback). Finally, termination and landing are violent with significant shock and rotation. Locking connectors for battery connections are recommended. If the battery has significant mass, structural reinforcement for the battery is recommended to prevent the battery from moving.

## 5.3 RECOVERY CONSIDERATIONS

The recovery operation presents the most unknowns. Often, science team members do not accompany the recovery team. Thus, the power connections need to be well-marked for ease of disconnection. Recovery will be dirty, allowing dirt, dust, and brush to potentially enter the battery enclosure. Finally, transport back to the hanger can be violent due to travel off-road to get the gondola. Similar guidance to termination and landing is suggested.

# 6 TIPS

This section contains additional suggestions and advice from BPO and previous piggyback teams.

## 6.1 FORT SUMNER

Since most BPO piggyback missions fly from Fort Sumner, this section describes the area, lodging, and airports.

Most people who travel by air to Fort Sumner fly into either the commercial airport in Albuquerque, NM (2.5 hours by car to Fort Sumner) or Lubbock, TX (2.75 hours to Fort Sumner). There are several hotels in Fort Sumner and houses available for short-term rentals. There are also restaurants in Fort Sumner but limited grocery and entertainment options. Some people choose to stay in Santa Rosa, NM (1.75 hours from Albuquerque, 45 minutes from Fort Sumner) or Clovis, NM (1.75 hours from Lubbock, 1 hour from Fort Sumner), which have more entertainment, dining, and grocery options. Clovis also has hardware stores which can be useful if you need last minute purchases for your payload or personal protective equipment.

Integration and launch operations occur at the Fort Sumner Municipal Airport. The hangars are generally available 24 hours per day, 7 days per week, unless a balloon launch is imminent or in progress (in which case roads may be blocked temporarily). CSBF and NASA personnel are required to abide by NASA work hour rules and have to rest from work at least one day per week and 12 hours per day. Support during off-hours or rest days can be coordinated through the NASA mission manager and CSBF campaign manager and typically requires 1-2 days advance notice.

Figure 3 includes a red X on each of the hangars used by NASA and a yellow path to the parking area (top right) from the airport entrance (left side of image). Note that the some of the roads on this path are unpaved. Do not drive on the light gray concrete areas around the hangars or on runway. This is an active airport.


**Figure 3 - Fort Sumner Municipal Airport**

The airport has a refrigerator and small kitchen area that you are welcome to use. Beware of local wildlife, which includes poisonous snakes, scorpions, spiders, insects, etc. Fort Sumner is in a desert, and can get quite hot during the day and cold at night. Be sure to drink enough water.

## 6.2 OTHER CAMPAIGN LOCATIONS

BPO also regularly launches from Palestine, TX, McMurdo Station, Antarctica, Esrange, Sweden, and Wanaka, New Zealand. Launches from Palestine occur at the CSBF facility and generally have similar operations and cadence as Fort Sumner (See Section 6.1).

In most cases, piggyback teams do not send representatives to OCONUS locations for integration and launch support. Instead, at least one team member will travel to Palestine, TX for integration at CSBF approximately 6 months prior to launch. You will need to coordinate travel timing and plans with the primary mission and CSBF through your mission manager. After integration, CSBF will pack and send everything to the launch location. Very clear procedures for operations (including powering on and off the system, battery recharging if necessary, recovery requirements, etc.) will be required. In addition, since people who are not as familiar with your systems as you are will be operating them, it is extremely important to make sure that access is easy for any troubleshooting that may become necessary. Having a simple, accessible payload with clear operating instructions will increase the likelihood of having a successful mission. Shipping instructions and a shipping label will also be required. Return of your payload after recovery may take a long time for international campaigns.

Let your mission manager know if a piggyback team member needs to travel to an OCONUS location to support integration and/or flight. They will help with logistical requirements and can provide tips unique to your launch location.

# Appendix A Previously Flown Equipment

The items listed in this appendix are included as examples of hardware that have successfully been approved to fly on previous Balloon Program Office (BPO) balloon missions. It is not meant to be an exhaustive list, or an endorsement of any company or product, but to provide helpful context and history. Documentation is required in order to fly any hazards, including batteries, and is subject to approval by the Wallops Flight Facility (WFF) Safety Office. Contact your mission manager with any questions and for copies of the necessary forms.

## A-1 Batteries

**Table 3 – Previously Flown Batteries**

| Chemical Makeup | Manufacturer | Model Number |
|---|---|---|
| LiFePO4 | AA Portable Power Corp | |
| Lithium Ion | AA Portable Power Corp. | |
| Silver-Oxide | Any domestic battery manufacturer: Duracell, Energizer, Rayovac, etc. | CR2032 |
| Blackvue pack | Blackvue | B-112 |
| Lithium Ion Polymer | Clyde Space 3G | 01-02686 |
| Lithium Iron Phosphate | Dakota Lithium | |
| Li-ion from Sparkfun (3.7V 6A-hr) | Data Power Technology Ltd | DTP605068-3P |
| Li-SOCl2 | Eagle Picher | |
| Lithium Bromine Chloride | Electrochem BCX85, 3B0076 | |
| Lithium/Iron Disulfide (Li/FeS2) | Energizer | L91 AA |
| NiMH | GPI International Ltd | |
| Lithium oxides | MaxAmps | |
| Sealed Lead Acid, Pb-H2SO4 | Odyssey | PC370, PC625, PC100, PC1700 |
| Nickel-Metal Hydride | Panasonic | BK-3HCDE |
| Lead-acid | Power Sonic | |
| Polymer LiFePO4 | Powerizer | |
| Lead-acid | Power-Sonic | |
| Lead Acid | PowerStar | PS12-200 |
| LiNiCoAlO2 | SAFT | MP 176065 ise |
| [2]Lithium-Ion | SAFT | B7901-10 |
| LiSO2 | Saft cells assembled into pack by Battery Giant | |
| Lithium Ion | Tenergy | ICR14500 |
| LiMnO2 | Ultralife U9VL-J-P | |

[2] CSBF-provided if requested on the flight application

| Chemical Makeup | Manufacturer | Model Number |
|---|---|---|
| LI POLYMER | Voltaic Systems | V88 |
| Lithium Polymer | Voltaic Systems | V50 |
| LI POLYMER | VOLTAIC SYSTEMS INC. | V88 |

## A-2 COMPUTERS

**Table 4 – Previously Flown Computers**

| Name | Vendor | Model | Notes |
|---|---|---|---|
| Raspi | Raspberry pi foundation | 3B+ | Flown out-of-the-box |
| Raspi | Raspberry pi foundation | 4 | Flown out-of-the-box |

## A-3 SENSORS

**Table 5 – Previously Flown Sensors**

| Name | Vendor | Model | Notes |
|---|---|---|---|
| Vectornav IMU | VectorNav | VN-200 | Flown out-of-the-box |
| 9-DOF breakout | Adafruit | ST 9DoF | Hobby-grade IMU |
| Thermistor | OMEGA | SA1-TH-44006-40-T | Temperature sensor |

# Appendix B Example Piggybacks

The Balloon Program Office and Columbia Scientific Balloon Facility (CSBF) have successfully facilitated hundreds of successful piggyback missions. Some examples are listed below.

## B-1 Cubes in Space

Principle Investigator: Amber Agee-DeHart, www.cubesinspace.com

STEAM-based outreach program that enables students ages 11-18 to engage in authentic, experiential, hands-on learning to design scientific research and technology development experiments.

Flight History: Fort Sumner, NM in 2015, 2016, 2018, 2019, 2021, 2022, and 2023

## B-2 Wallops Ambient Light Radiometer and Ultraviolet Sensor Suite (WALRUSS)

Principle Investigator: Evan Youngberg, NASA Wallops Flight Facility

Sensor package measuring total UV (UVA, UVB and UVC wavelengths) seen by the gondola during ascent, float, and descent phases of flight. It also measures ozone concentration.

Flight History: Fort Sumner, NM in 2021, 2022, and 2023
Wanaka, New Zealand in 2023

## B-3 Sensor Package for Attitude, Rotation, and Relative Observable Winds (SPARROW)

Principle Investigator: Christopher Yoder, NASA Wallops Flight Facility

SPARROW captures relative wind measurements using an ultrasonic anemometer designed for the balloon float environment. Objectives are to measure relative wind speeds using an ultrasonic anemometer, and to measure the gondola dynamics including gondola rotation.

Flight History: Fort Sumner, NM in 2021, 2022, and 2023

## B-4 Infrared Channeled Spectro-Polarimeter (IRCSP)

Principle Investigators: Jaclyn Amber John, Jeremy C. Parkinson, and Meredith K. Kupinski, University of Arizona

IRCSP seeks to produce long wave infrared spectro-polarimetric measurements of cirrus clouds to improve the retrievals of the microphysical properties of cloud ice particles. This data will be crucial in constraining global climate models. Previous flights have demonstrated the instrument's operation at high-altitude and during IRCSP's first flight it produced the first known measurements of downward viewing polarized thermal radiation from Earth's atmosphere.

Flight History: Fort Sumner, NM in 2022 and 2023

## Appendix C Frequently Asked Questions

This appendix includes a selection of common questions from new piggyback teams.

Q-1. My payload is small but has very specific altitude or timing requirements. Is it suitable for a piggyback flight?

A. Availability of piggyback flights is contingent upon finding a primary mission with compatible requirements, payload, and operations. In some cases, a hand launch on a 1.1 MCF balloon may be a good alternative if your requirements are unique or your payload is likely to interfere with nearby instruments.

Q-2. Do I have to travel to the launch location in order to participate in flight?

A. Generally teams send at least one team member to CONUS launch sites to support integration and any necessary troubleshooting. If you are not able to travel, we may be able to make arrangements to have CSBF perform the integration, but this will require a very straightforward payload and detailed instructions on integration, turning on power, etc.

For OCONUS launch locations, piggyback teams typically attend integration activities in Palestine, TX approximately 6 months prior to launch but do not travel to the launch site. Clear instructions for operation, recovery, and shipping are required.

Q-3. How long should I plan to be onsite for integration, launch, and recovery?

A. You will need to consider how long integration will take for your payload and coordinate with the primary mission to determine when to arrive onsite for integration. If you plan to stay until launch occurs, keep in mind that sometimes teams wait several weeks for a launch opportunity. If you will not be staying onsite for launch and/or recovery, you will need to provide clear instructions on operating your unit, as well as shipping instructions and a shipping label.

Q-4. Our team does not have experience with structural analysis. How can we ensure we meet the requirements in 820-PG-8700.0.1, *Gondola Structural Design Requirements*?

A. Many teams hire an engineer or organization with finite element analysis experience to perform their structural analyses. For simple payloads, a proof test may also be appropriate.

Q-5. Does my payload quality as a re-flight in Section 3.4.5 of 820-PG-8700.0.1, *Gondola Structural Design Requirements*? Parts of my payload have flown before. (Or: we have made some design changes since our last flight.)

A. Any payloads with design changes will need to go through the structural review process again. However, it is useful to note any heritage hardware and in some cases you may be able to benefit from previous analyses if they envelope your current design.

# Appendix D Acronyms

| | |
|---|---|
| **AC** | Alternating Current |
| **BPO** | Balloon Program Office |
| **CAD** | Computer Aided Design |
| **CONUS** | Continental United States |
| **CSBF** | Columbia Scientific Balloon Facility |
| **DC** | Direct Current |
| **GPS** | Global Positioning System |
| **GSFC** | Goddard Space Flight Center |
| **Hz** | Hertz |
| **IP** | Ingress Protection |
| **MCF** | Million Cubic Feet |
| **MM** | Mission Manager |
| **OCONUS** | Outside the Continental United States |
| **PI** | Principal Investigator |
| **POC** | Point of Contact |
| **PPE** | Personal Protective Equipment |
| **SD** | Secure Digital |
| **SPB** | Super Pressure Balloon |
| **WFF** | Wallops Flight Facility |
| **VAC** | Volts of Alternating Current |
| **VDC** | Volts of Direct Current |
| **ZPB** | Zero Pressure Balloon |