DemoSat User's Guide

Colorado Space Grant Consortium
High Altitude
Scientific Balloon Payload
Program

January 4, 2023
Revision: 3
Colorado Space Grant Consortium

Revisions

Revision	Description	Date	Approval
DRAFT	Initial release of new Guide, replacing previous document.	8/28/2017	BGG
2	Updating overall program details and adding limitations to experiment (no bugs)	8/24/2021	BGG
3	Update weight restrictions, flight tube diameter, and general document clean-up.	1/4/2023	BGG

INTRODUCTION

DemoSat Program

The DemoSat program is designed to provide COSGC student teams with access to high altitude balloon flights that carry student scientific payloads to the edge of space. Balloon payload projects are a great way to challenge students to design light-weight robust projects that help develop their science and engineering skills. DemoSat launches/flights are made possible through a collaboration with Edge of Space Sciences (EOSS). The organizers of the DemoSat program guide student teams through a design process throughout a single academic semester. Launches/flights occur near the end of the spring and fall semesters and the summer term. The process includes regular reviews including Preliminary, Critical, and Flight Readiness.

Participant Eligibility and Responsibility

The intent of the DemoSat program is to provide hands-on experiences to students and faculty advisors at COSGC institutions. Interested teams must work with the Affiliate Director on campus and submit an online Intent to Fly form in order to be considered for launch each semester.

Participation in the DemoSat program includes web conferences with COSGC leadership to complete regular design reviews.

BALLOON DESCRIPTION & CAPABILITIES

This document defines key interfaces between the Payloads and the Balloon for the purpose of establishing program responsibilities.

Balloon Capabilities: General Description

Each payload will be flown on a latex balloon designed to reach 30km (~100,000 ft) in altitude.

Each balloon will have at least one control payload that provides tracking information for the entire flight string as well as a parachute. Each balloon is equipped with an emergency cut-down device. This device is radio controlled and subject to radio interference. Each payload shall stay clear of certain radio frequencies listed later in this document. Balloon and control payloads do not provide power nor communication links to the DemoSat payloads.

Balloon Capabilities: Mass limitations

Each team must meet the mass limit depending on the number of payloads launching from the institution in any semester:

1 Payload/institution: 800g - 1kg*
2+ payloads/institution: 600g - 700g/payload

*Depending on the number of teams participating, the 1-payload limit could be lessened to 800g/payload and the 2+ payload limit could be 600g.

Teams exceeding their mass requirement without prior approval will not be launched.

IMPORTANT NOTE: The mass reported during the Flight Readiness Review (FRR) will be considered the final weight for flight. Teams MAY NOT add additional weight to their payloads following FRR, even if their reported weight is less than the weight allotted for the semester.

The number of payloads launched depends on 1) the total payload mass across all balloons; and 2) the percentage of cloud cover on launch day. In order to comply with FAA regulations, COSGC will baseline a manifest for 16kg of payloads – equating to launch of 4 "exempt" balloons carrying 4kg per balloon. This is the maximum number of balloons that may be launched per day with more than 50% cloud cover.

In any semester that there is more than 16kg of payloads, COSGC will consider additional payloads up to 27kg of total mass - equating to the launch of 3 – "heavy" balloons carrying 9kg of payloads each. Payloads added over 16kg, will be added to the baseline manifest with a "Contingency" designation. Contingency payloads will only launch in the event that there are clear skies or less than 40% cloud cover. DemoSat facilitators will liaise with EOSS to track cloud predictions and update Contingency teams about the status of launch.

Balloon Capabilities: Flight String Integration

DemoSat payloads will be attached to a single balloon flight string before launch. The flight string will pass through the center of the payload, through an appropriately integrated flight tube. A knot will be tied on each side of flight tube, figure 1. The flight tube shall be polyethylene tubing (or similar material) with a 3/8" *inner* diameter. The flight tube shall not be metal, or any material that may endanger the flight string, and shall be free of burrs and sharp edges.

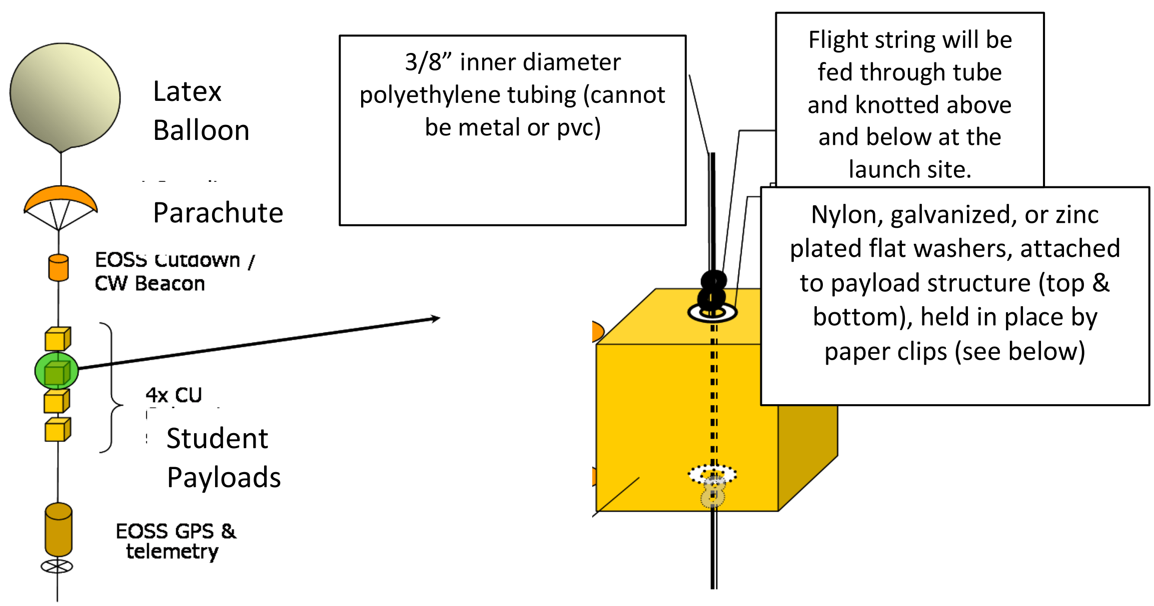

Figure 1: Payload Attachment Guidelines

Nylon, galvanized or zinc plated flat washers will be flush with and adhered to the payload surface. A paper clip shall be used to keep the flight tube in place (see figure 2). **Paper clips should not be hot glued or otherwise attached to the structure until the payload has been attached to the flight string.** The default spacing between the payloads is ~60cm. Additional, length of flight string may be added as requested by teams if necessary for experiment.

Figure 2: Structurally Integrated Center Tube for Flight String

Access to payloads is limited after attachment to flight string unless special considerations are made during the design of the payloads structure. These requests shall be made at each design review. Each payload shall be held by one team representative, the payload handler, during the launch. **External activation switches are recommended**, so that the designated payload handler can power on the payload just before liftoff.

Balloon Launch Timeline

Typically, when there are multiple balloons, launches occur 15 minutes apart, beginning at 6:50am. These times are subject to change due to wind or other weather conditions at the launch site. Payloads with time-critical events that are linked to launch time should be prepared to make adjustments to the payload at the launch site if launch is delayed. It is recommended that timers begin at switch activation, which will not occur until moments before launch.

Launches typically occur on early Saturday mornings. In the case that the launch must be scrubbed for any reason, an attempt will be made to launch the following Sunday. If that is not possible for some reason, a new launch date will be scheduled.

All DemoSat teams shall arrive at the launch site at least 60 minutes before the launch of the first balloon. Payloads will be attached to each balloon flight string 50 minutes before launch. Balloons will begin hydrogen inflation 20 minutes prior to launch. The designated payload handler will take possession of payload 20 minutes prior to launch. NOTE: The payload handler must be physically able to run for payload release.

Balloon Key Performance Parameters

See table 1 for Balloon Key Performance Parameters. For more detailed information on rates of ascent and descent for similar balloons launched on June and July of 2003, see figures 3 and 4.

Table 1: Key Performance Parameters

Key Performance Parameter	Value	Note
Altitude	80,000-110,000 MSL	1
Payload spin rate about z-axis (flight string)	Less than 10 RPM	2,3
Rate of ascent, minimum	1,500-3,000 fpm	2
Rate of descent, maximum	1,000-9,000 fpm	2,4
Impact Speed	10-35 mph	2,4

Notes for Table 1:

1 Problems do occur during flight that may prevent maximum altitude form being reached (leaks, icing, winds, etc.)
2 Based on previous balloon flight observations
3 Not actually measured during flight but number is good based on past flight images and video
4 Numbers assume parachute deploys and performs as designed. One flight parachute partially failed and descent rates reached 15,000 fpm and impact speed was over 100 mph

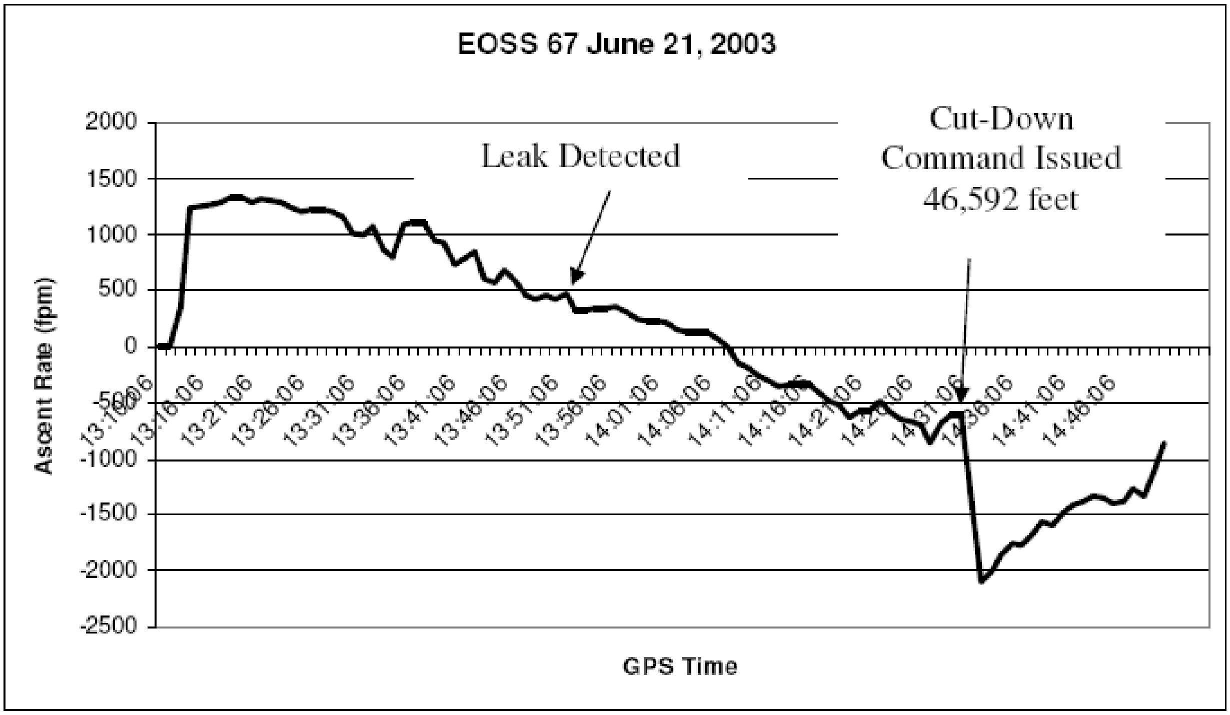

Figure 3: Ascent and Descent Rates for June 21, 2003 Flight

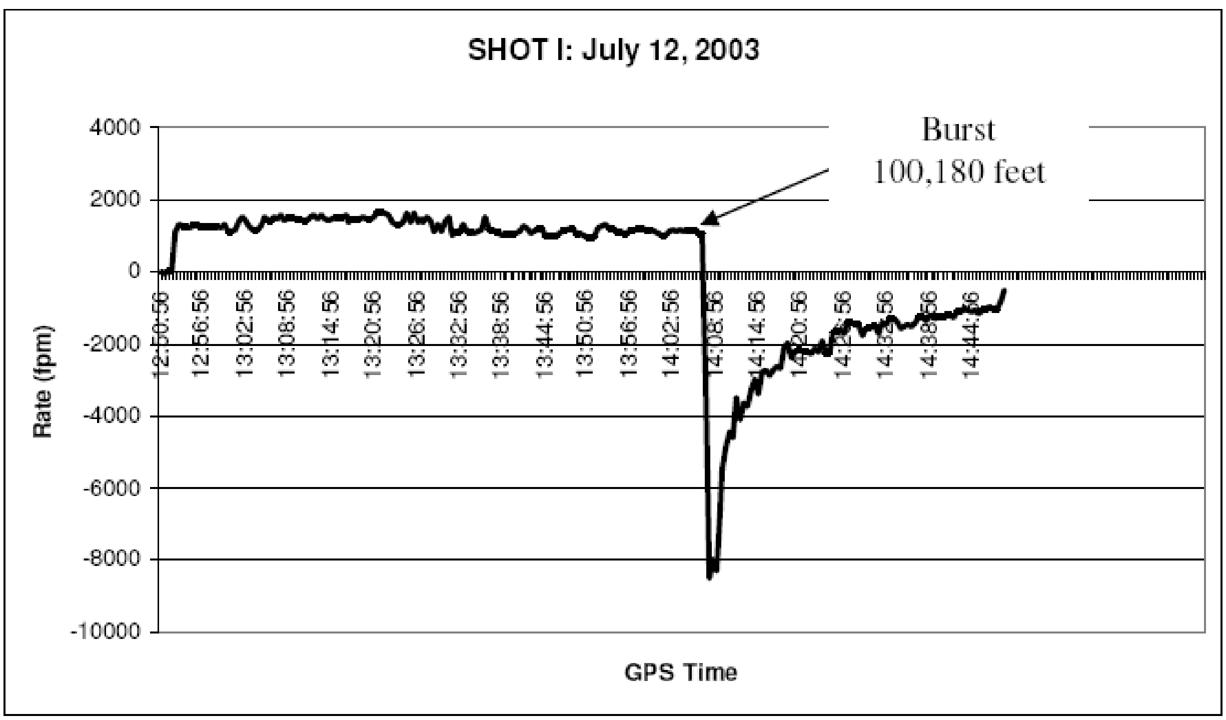

Figure 4: Ascent and Descent Rates for Flight July 12, 2003

Environmental Conditions

The environmental conditions that each payload will experience during the flight will be extreme. Teams should take these conditions into consideration while designing, constructing, and testing the payload.

Temperatures can reach -80 C during the ascent and descent through the Troposphere. Payloads will experience near vacuum conditions at maximum altitude. Condensation may occur during ascent and descent through Troposphere and Stratosphere.

Miscellaneous

Recovery of the payload(s) is not guaranteed. In the last 300+ flights in Colorado all Balloon Control Payloads and flight strings have been recovered. Due to poor interface design, several individual payloads have been lost and never recovered. Great care should be taken in string interface design (integration of flight tube) to ensure payload design will not separate from the flight string.

Contact information shall be clearly written on at least one side of payload. Contact information should include: representative name, institution name, phone number, email, and "Reward if found." A United States flag decal should also be clearly visible on the payload.

In addition to the above said contact information, teams shall also place COSGC's contact information on the satellite.

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ORGANIZATIONAL RESPONSIBILITIES

Hardware/Interface Responsibilities - Component and functional design responsibilities are as listed below.

DemoSat Teams (Member Schools)

- Payload experiment and support systems, power to operate systems.
- Mechanical interfaces with the balloon flight string, on the payload side of the interface, as specified in this document.
- Safety features for payload-related hazards (shall not endanger other payloads, flight string, or environment).
- Ground handling and maintenance provisions for payloads (launch-site tools/supplies).
- Payload operations (Ground, Flight)
- **LIVE EXPERIMENT LIMITATIONS:** Biological experiments are limited to bacteria, algae, yeast, and other cellular organisms. No larger living organisms are allowed including any type of insects. **If flying a biological payload, teams must address possible contamination dangers and their environmental safety precautions.**

Balloon and Balloon Lanyard (COSGC/EOSS Responsibility)

- Balloon, fill gas, balloon tracking payload, cut-down device, and flight string.
- Flight tracking and recovery

Ground Control

Each DemoSat team is responsible for the activation of their payload prior to launch. DemoSat teams must provide their own equipment for in-flight telemetry. Each DemoSat team is responsible for participating in tracking and recovery as part of the group (all tracking and recovery done together with teams and facilitators). All tracking and recovery of the balloon/payloads as well as all commands to the control payload will be handled by Edge of Space Sciences (EOSS) in collaboration with COSGC.

PAYLOAD DESIGN REQUIREMENTS

Payload Physical Envelope, Mass, and Center of Gravity Requirements - The following subsections provide the basic physical requirements for DemoSat payloads.

Physical Envelope

There are no strict requirements on physical size or volume. It is recommended that volume be minimized for heating and aerodynamic reasons.

Absolutely no part of the payload may separate from the payload, unless it remains tethered to the flight string.

Mass Properties

Scenario A: One payload at institution

- The mass of the Payload shall not exceed 800g - 1kg. (Summer payloads may be heavier)

Scenario B: Two or more payloads at institution.

- The mass of each Payload shall not exceed 600g - 700g.

The payload mass includes: the payload, any housing/box, and fasteners/hardware required to integrate to the flight string. The balloon flight string is not included in the payload mass. Each team shall meet the payload mass requirement. Teams exceeding this requirement will not be launched. The heaviest payloads shall be on the bottom of the flight string for stability reasons during descent.

Teams may apply for additional mass if necessary. To do so, a team representative should email bgarcia@colorado.edu and provide the following information 1) additional mass required; 2) details about steps the team has made to cut mass; and 3) limitations facing team should it be kept initial weight allotment.

IMPORTANT NOTE: The mass reported during the Flight Readiness Review (FRR) will be considered the final weight for flight. Teams MAY NOT add additional weight to their payloads following FRR, even if their reported weight is less than the weight allotted for the semester.

Center of Gravity

The center of gravity (CG) for the payload shall be as close to the balloon flight string tube as possible. Balloon flight string tubes should be designed to pass through the center of the payload, figure 5. Adherence to this requirement will ensure a stable flight for all payloads attached to the flight string.

Payload Interfaces

Mechanical Interface:

Each payload will be mounted to the balloon via a flight string with a knot on each end of flight tube. The flight string consists of a 4.0 mm diameter braided nylon/Dacron cord. Each payload team may use as much flight string as needed. The default spacing between the payloads shall be 60cm.

Each payload team shall provide the interface and hardware for attaching the payload to the flight string. Recommended hardware includes (see Figure 2):

- Straight-through **non-metallic** tube with an inner diameter of 3/8”
- Nylon or Metal Washers (adhered to the structure)
- Paper clip pushed through tube so that it rests on top of the metal washers. **

** Paper clip shall hug the inside wall of the tube to allow the flight string to pass through.

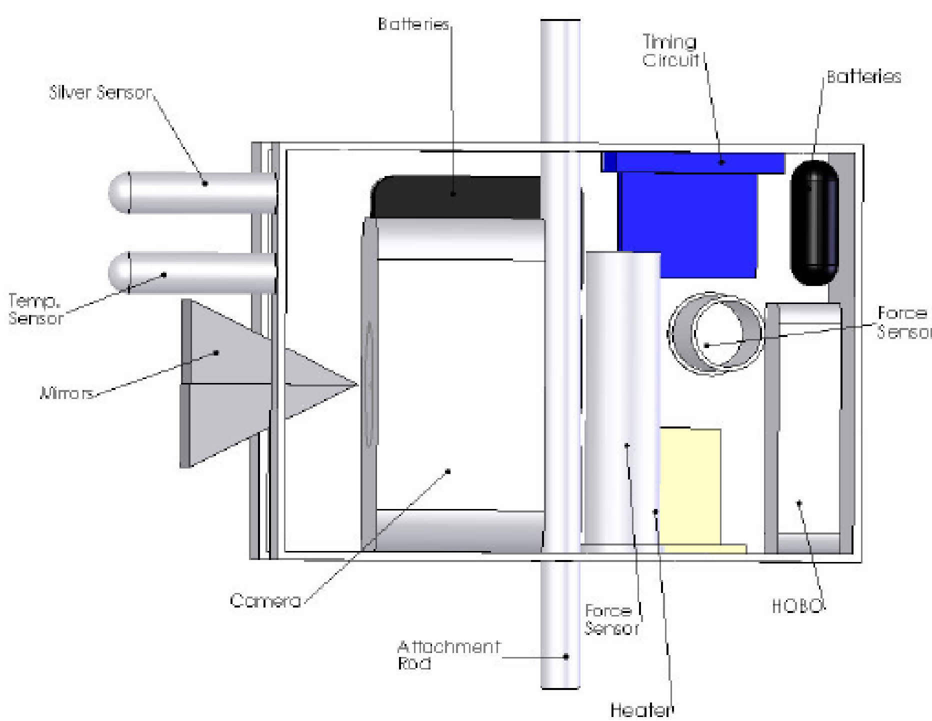

Figure 5: Example of Structurally Integrated Center Tube (rod) for Flight String

Electrical Interface

The payload shall be electrically self-contained. Each DemoSat team is responsible for all telemetry and control functions of their payload, including the activation of the power source prior to launch. No power will be provided to payloads during flight. There is no power at the launch site. It is recommended that all electrical switches be on the outside of the payload for easy activation moments before launch, figure 6. Payloads utilizing high voltage must consider and

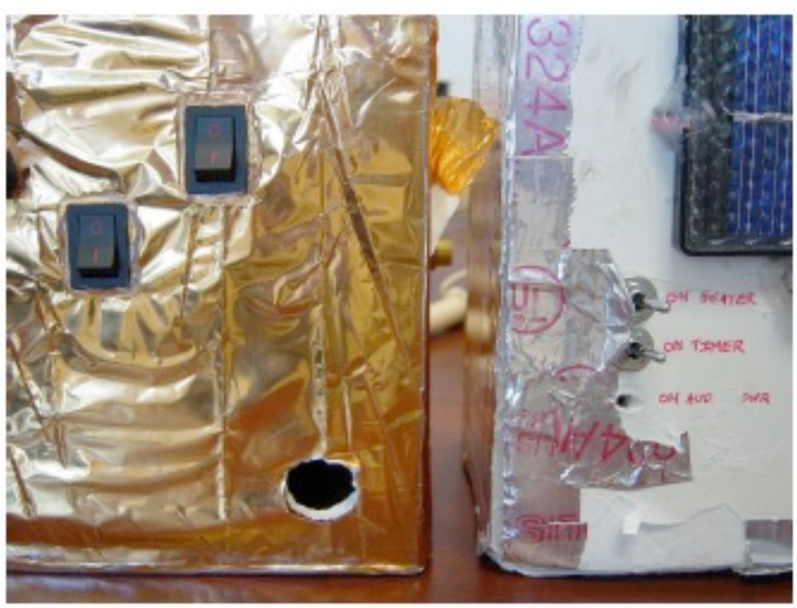

Figure 6: External Electrical Activation Switches

eliminate the potential for coronal arcing, which could cause failure to the flight string.

Communication Interface

Balloon tracking and recovery, as well as the emergency cut down device, are dependent on the clear communication channels. All payloads shall adhere to the following guidelines.

The following frequencies are off-limits during all launch and recovery day activities: 144.340 MHz, 147.555 MHz and 445.975 MHz.

The following frequencies are available and clear of interference in the launch and recovery area: 145.600 MHz and 446.050 MHz. Other usable frequencies may be available, but EOSS has not confirmed them to be free of interference. **Each transmitter shall be operated by a licensed HAM and ID'ed per Part 97 of the FCC Rules.**

Effective Isotropic Radiated Power (EIRP) shall not exceed 0.4W (26 dBm).

Each transmitter shall be capable of being shut down in flight in the event of interference with essential EOSS channels or other users.

There should be no problem if teams wish to use Part 15 devices, or HAM bands other than 2m and 70 cm, e.g. 29, 50, 220, 905 MHz or higher bands, although the EIRP should be no more than 30 dBm (1W) to avoid possible de-sense to balloon receivers. This should be more than enough to maintain a narrow-band link out past 100 miles down to below 20,000 ft in descent, but the Part 15 (e.g. WiFi) devices may not work beyond 20 or 30 miles even with gain antennas on the ground.

Payloads using communications links to the ground should notify COSGC by PDR. EOSS must review and approve transmission hardware before CDR.

Structural Design Requirements

The payload will experience minimal loads during launch. Upon burst of the balloon, the payload can experience severe loading. Some crude measurements have been made in previous flights that indicated loads can exceed 15 g’s. In the event of a parachute failure, landing loads could exceed 5 g’s. Tests discussed later should validate the typical loads that the payload will experience.

Materials

When designing the structure for the payload, there are many materials that may be used. Nearly a decade of previous flights have proven that foam core works well. Foam core is inexpensive, light weight, and easy to use. *Due to the low pressure at altitude, it is highly recommended that payloads avoid using materials that are pressurized or contain embedded air pockets, fluids, etc.* Aluminum may not be used as a structural material unless it is critical to mission success. In this case, teams must receive pre-authorization from Bernadette Garcia in order to use aluminum. Aluminum tape is allowable to help stabilize structure joints.

Structural Loading

Each payload is not expected to see accelerations above 1.5 g's during launch. Accelerations after burst can be severe but should not exceed 15 g's. Landing shock is approximately 5 g's.

Mechanical Ground Support Equipment

Payload teams shall provide any required mechanical ground support equipment for use in payload integration operations (tools/supplies). There is no power at the launch or recovery site.

Thermal Design Requirements

Payload teams are responsible for providing an adequate thermal system for their payload. Environmental conditions during the flight can be extreme. Testing can determine whether heaters are necessary depending on payload design. See section 1.4 for more details.

Electrical Design Requirements

General

Experimenters shall address standard electrical/power system safety hazards including shorting, which may lead to fire. Payloads shall be designed such that failure in one subsystem will not propagate to others and cause: loss in safety circuitry, shorts, battery shorting, or inadvertent activation of hazardous subsystems.

Table 2 provides a recommended design approach for power and electrical systems. This approach is mandatory.

Table 2: Recommended Battery/Electrical System Approach

Design Feature	Comments
1. Electrical switches should be placed between batteries and experiment.	Switches should be external
2. Batteries should be able to withstand temperatures without failure.	Determine whether heaters are necessary.

Electrical Bonding and Grounding

All external or exposed faces must be grounded wherever possible to the negative terminal of the payload power source. Elements such as antennas or high-voltage experiments shall incorporate automatic inhibit ("turn-off") measures to prevent interference with other payloads in the event of structural failure.

Frequency Coordination and Licensing

All payloads incorporating RF shall coordinate their intended frequencies of operation with COSGC by PDR to ensure non-interference with other payloads and the balloon telemetry package. Teams shall be responsible for obtaining the necessary licenses for operation, and shall ensure compliance with operations regulations.

PAYLOAD HARDWARE INTEGRATION

Each Payload team shall furnish a complete and functional payload to COSGC that meets all the requirements of this document. This payload shall be inspected prior to flight for compliance with requirements of this document. A pre-launch review and inspection will be conducted the week of launch (Flight Readiness Review – FRR). Teams will be expected to demonstrate payload functionality at this time. COSGC will give guidance to the DemoSat teams to assist in the integration of the subassembly to the balloon.

It is recommended that all subsystems be tested independently before integrated.

PAYLOAD ANALYSIS & TEST REQUIREMENTS

Analysis and test of the payload shall be performed by each payload team to ensure survivability and mission success. All tests shall be documented and/or recorded and made available at the flight readiness review.

Structural Testing

The Experiment box, or structure, should undergo sufficient testing to demonstrate containment and survivability of contents under conditions described under section 3.3.2. It is the Payload team's responsibility to ensure safety to other payloads. Each team must build a test structure and load it with mass models of experiment hardware. This test structure will be used for all three structural tests:

1. **The Whip Test**
   This crude test will simulate the post burst environment where maximum g's will be experienced. Attach the test structure to a similar flight string cord with knots on each end. Spin the payload overhead, spinning the payload as fast as possible. At some point, try to impart a directional change to the payload, the more abrupt, the better. This test will take some practice. It is important to complete this test once the payload is fully integrated in order to identify any integration failure that may result in components coming loose during post-burst chaos. [It is suggested this test be done away from windows in case the payload detaches from the test string.]

2. **The Drop Test**
   Another crude test for the landing environments the payload will experience can be simulated in the Drop Test. Drop a test structure from a height of 15 to 20 feet onto a hard surface. This will represent a worst-case parachute landing.

3. **The Stair Pitch Test**
   Pitch a test structure down a full flight of concrete steps. This test will crudely simulate the worst-case conditions of the payload being dragged across a field after landing due to high winds re-inflating parachute.

Environmental Testing

The environmental conditions the payload will experience during the flight will be extreme. The following tests simulate some of the worst-case environmental conditions the payload will experience.

Cold Test

Take a fully functional and integrated flight payload, and get it to a state that it would be in on flight day. Place 7 to 10 pounds of dry ice into a medium to large cooler. Distribute dry ice uniformly in the cooler. Place a non-conductive material (Styrofoam, wood, etc) in the center. Activate payload, and place the payload onto the non-conductive material, and shut the lid. Return in three hours. It is highly recommended that a temperature recorder be used during this test. Place a sensor inside the payload and one outside the payload but still in the cooler. Typically, this test must be repeated due to failures.

Vacuum Test (were possible)

If a bell jar or other vacuum chamber is available, a vacuum test on the operating flight payload would be beneficial. If the payload has a high voltage device, this test is required.

Functional Testing

Payload should be operated as an integrated payload for the entire mission time, typically 90 minutes during ascent and 45 to 60 minutes during descent. This test will ensure that all systems are functional for the mission life. Recorded data and failures should be noted. Multiple successful tests should be conducted to ensure mission success. A summary of this testing and the recorded data and failures shall be presented at the FRR.

This test should be performed before the cooler test. If significant failures occur during the cooler test, it may be necessary to carry out more functional testing once the failures have been resolved.