## Revisions

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1 BALLOON DESCRIPTION AND CAPABILITIES

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

1.1 Balloon Interface General Description

Each payload will be launched on one of two 3,000 gram latex balloons. Each balloon is designed to reach 30 km (100,000 feet) in altitude and can carry 9 kg (20 pounds) of payload which will be divided equally amongst all schools for their payloads. Each team must meet the 1.5 kg payload mass. Teams exceeding this requirement without prior approval will not be launched.

Each balloon will have a control payload that will provide 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 must stay clear of certain radio frequencies listed later in this document. Balloon and control payload shall not provide power or communication links to the DemoSat payloads.

DemoSat payloads will be attached to a single balloon flight string before launch. It is recommended that the flight string pass through the center of the payload. A knot will be tied on each side of the payload, figure 1. The flight string will consist of a single 4.0 mm nylon braided cord. The pass-through hole diameter should not exceed 6.4 mm and shall be free of burrs and sharp edges. It is recommended that a center tube be used for the flight string and that the tube is integrated to the payload structure, see figure 2. The tube shall not be metal.

The Experiment will be mounted to the Balloon via a flight string with a not on each end of payload. The flight string consists of a 4.0 mm diameter braided nylon/Dacron cord. Each university may use as much flight string as they need. The default spacing between the payloads will be 1 meter (3 ft).

Lateral attachments are possible but not recommended due to the forces the payload may experience upon burst. Access to payloads will be limited after attachment to flight string unless special considerations are made during the design of the payload 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.
Figure 1: Payload Attachment Guidelines

Figure 2: Structurally Integrated Center Tube for Flight String
1.2 Balloon Launch Timeline

There will be launches on April 14, 2012 at 7:00 AM and 7:30 AM and on August 4, 2012 at 7:00 and 7:30 AM. 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.

All DemoSat teams shall arrive at the launch site at least 75 minutes before launch. Payloads will be attached to each balloon flight string 70 minutes before launch. Balloons will begin helium inflation 20 minutes prior to launch. The designated launch day payload handler will take possession of payload 20 minutes prior to launch. The payload handler shall be able to run for payload release.

1.3 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 in June and July of 2003, see figures 3 and 4.

<table>
<thead>
<tr>
<th>Key Performance Parameter</th>
<th>Value</th>
<th>Note</th>
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<tr>
<td>Altitude</td>
<td>80,000-110,000 MSL</td>
<td>1</td>
</tr>
<tr>
<td>Payload spin rate about z-axis (flight string)</td>
<td>Less than 10 RPM</td>
<td>2,3</td>
</tr>
<tr>
<td>Rate of ascent, minimum</td>
<td>1,500-3,000 fpm</td>
<td>2</td>
</tr>
<tr>
<td>Rate of descent, maximum</td>
<td>1,000-9,000 fpm</td>
<td>2,4</td>
</tr>
<tr>
<td>Impact Speed</td>
<td>10-35 mph</td>
<td>2,4</td>
</tr>
</tbody>
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Notes for Table 1:
1 Problems do occur during flight that may prevent maximum altitude from 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
1.4 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. Descent velocities immediately after burst can momentarily exceed Mach 1.

1.5 Miscellaneous

Recovery of the payload(s) is not guaranteed. In the last 73 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 to ensure payload design will not separate from the flight string.

Contact information shall be clearly written on at lease one side of payload. Contact information should include: representative name, university 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.

Colorado Space Grant Consortium
University of Colorado at Boulder
Boulder, Colorado 80309
303-492-3141
2 ORGANIZATIONAL RESPONSIBILITIES

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

DemoSat-B 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.
- Ground handling and maintenance provisions for payloads (interfaces, mechanical and electrical ground support equipment [GSE] and related procedures).
- Payload operations (Ground, Flight)

Balloon and Balloon Lanyard (COSGC Responsibility)

- Balloon, Balloon control payload, cut-down device, and flight string.
- Balloon tracking and recovery

2.2 Ground Control

Each DemoSat team is responsible for the activation of their payload prior to launch. Each DemoSat team is also responsible for support and recovery as well. All tracking and recovery of the balloon/payloads as well as all commands to the control payload will be handled by COSGC in cooperation with the Edge of Space Sciences (EOSS).

3 PAYLOAD DESIGN REQUIREMENTS

3.1 Payload Physical Envelope, Mass, and Center of Gravity Requirements

The following subsections provide the basic physical requirements for DemoSat-B payloads.
3.1.1 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.

3.1.2 Mass Properties

The mass of the Payload shall not exceed 1.5 kg. 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 1.5 kg 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.

3.1.3 Center of Gravity

The center of gravity (CG) for the payload shall be as close to the balloon flight string tube as possible. It is recommended that all balloon flight string tubes 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.

3.2 Payload Interfaces

3.2.1 Mechanical Interface

Each payload will be mounted to the balloon via a flight string with a knot on each end of payload. The flight string consists of a 4.0 mm diameter braided nylon/Dacron cord. Each university may use as much flight string as needed. The default spacing between the payloads shall be 1 meter (3 ft).

Each university 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 6.4 mm (¼ inch) maximum
- Metal Washers (attached to structure)
- Cotter pin (paper clip) pushed through tube so that it rests on top of the metal washers. **
** Cotter pins shall hug the inside wall of the tube to allow the flight string to pass through. 

![Diagram of structural tube for flight string]

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

### 3.2.2 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 from COSGC. 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 eliminate the potential for coronal arcing, which could cause failure to the flight string.

![External electrical activation switches from two previous payloads]

Figure 6: External Electrical Activation Switches from Two Previous Payloads
3.2.3 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 dBi).

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 as soon as possible.

3.3 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.

3.3.1 Materials

When designing the structure for the payload, there are many materials that may be used. Previous flights have shown that aluminum and foam core work well. Foam core is inexpensive and easy to use. Aluminum is strong but heavier and harder to insulate. 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.

### 3.3.2 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.

### 3.3.3 Mechanical ground support equipment

Universities shall provide any required mechanical ground support equipment (MGSE) for use in payload integration operations. There is no power at the launch or recovery site.

### 3.4 Thermal Design Requirements

Universities are responsible for providing adequate thermal system for their payload. Heaters are recommended for all balloon payloads. Environmental conditions during the flight can be extreme. See section 1.4 for more details.

### 3.5 Electrical Design Requirements

#### 3.5.1 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 Nanosat power and electrical systems. This approach is mandatory.

<table>
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<tr>
<th>Design Feature</th>
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<tr>
<td>1. Electrical switches should be placed between batteries and experiment.</td>
<td>Switches should be external</td>
</tr>
<tr>
<td>2. Batteries should be insulated and kept warm during the flight.</td>
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Table 2: Recommended Battery/Electrical System Approach
3.5.2 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.

3.5.3 Frequency Coordination and Licensing

All DemoSats incorporating RF shall coordinate their intended frequencies of operation with COSGC to ensure noninterference with other payloads and the balloon telemetry package. Universities shall be responsible for obtaining the necessary licenses for operation, and shall ensure compliance with operations regulations.

4 PAYLOAD HARDWARE INTEGRATION

Each University 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 day before launch. 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 recommend that all subsystems be tested independently before integrated.

5 PAYLOAD ANALYSIS & TEST REQUIREMENTS

Analysis and test of the payload shall by performed by each University to ensure the payload survivability and mission success. All tests shall be documented and/or recorded and made available at pre-launch review and LRR.

5.1 Structural Testing

The Experiment box or superstructure should undergo sufficient testing to demonstrate containment and survivability of contents under conditions described under section 3.3.2. It is the University’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.
5.1.1 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.

5.1.2 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.

5.1.3 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.

5.2 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.

5.2.1 Cooler Test

Take a fully functional and integrated flight payload, and get it to a state that it would be in on launch 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 such as a HOBO data logger 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.

5.2.2 Vacuum Test (Where 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.

### 5.3 Functional Tests

Payload should be operated on the bench 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 LRR.

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.