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Space Vehicles Directorate

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SHOT II WORKSHOP USER'S GUIDE

UNIVERSITY NANOSAT-7 PROGRAM

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SIGNATURE PAGE

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REVISIONS

Revision	Description	Date	Approval
	Initial release for Nanosat-6. Much of the material contained herein is unchanged from the Nanosat-3/4/5 SHOT II User's Guides. The reader should be aware that any changes from those documents are unmarked.	2 Feb 04	
1	1.3 kg listed on page 5 should be 1.5 kg. Brass tube listed on page 10 replaced with non-metallic tube. Nuts on page 10 replaced with cotter pins.	3 Jun 05	
2	Incorporated NS-7 revisions. Minor changes throughout document. Added section 5: Recommended Payloads.	16 Dec 11	
3-5	Incorporated feedback from COSGC, and AFRL. Revised sections 5.3, 5.5	3 Feb 12	

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1. INTRODUCTION

1.1 Purpose

The purpose of this document is to identify specific interfaces and other accommodations available on the University of Colorado-Boulder (CU-Boulder) Colorado Space Grant Consortium (COSGC) Student Hands-On Training Workshop II (SHOT II) high altitude balloon, and to establish guidelines and requirements for qualifying a University Nanosatellite Experiment subassembly for use on the balloon. The University Nanosatellite (Nanosat) Experiment subassembly (payload) to be flown aboard the balloon will be selected by each university based on requirements of their University Nanosat-7 (NS-7) mission goals. This document also provides Experiment and Experiment-to-Balloon interface requirements.

1.2 Points of Contact

Program points of contact (POC's) are as follows:

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1.3 Applicable Documents/Links

- Colorado Space Grant Consortium SHOT website: http://spacegrant.colorado.edu/shot/
- University Nanosat Program Website: http://www.universitynanosat.org/
- UN7-0001, *AFRL Nanosat-7 User's Guide*

2. SHOT II WORKSHOP OVERVIEW

The SHOT II Workshop is a 3-day educational program conducted by the Colorado Space Grant Consortium at the University of Colorado at Boulder. AFRL will fund 4 students (excluding airfare and shuttle to Boulder) from each Nanosat team to attend the SHOT II Workshop. Universities wishing to participate in the Nanosat-7 Student Satellite Flight Competition are required to participate in the SHOT II workshop. This workshop will provide students an opportunity to launch a small payload on a high altitude balloon, in order to observe the effects of a near space environment on their flight experiment. The Experiment to be flown will be designed, constructed, and tested prior to the SHOT II Workshop by students participating in the NS-7 program and must meet the requirements set forth in this document. Participation in program events such as this will be part of the NS-7 Flight Competition evaluation criteria.

The Workshop will be a three day weekend event (Friday-Sunday), currently scheduled on June 29-July 1, 2012. Friday will consist of individual mission presentations and pre-launch requirements verification by each university. Saturday will be launch day and Sunday will be used for preliminary results presentations to the workshop sponsors and attendees. In the event of unacceptable weather conditions on Saturday, Sunday will serve as the alternate launch day.

The intent of this workshop is to provide an opportunity to test a specific subsystem or function of the NS-7 Student Satellite design. This testing should benefit the student team, and documentation of the testing and testing results will be considered during the Flight Competition Evaluation. COSGC and AFRL will provide feedback on each University's Shot II Experiment design, and how this relates to their specific satellite design. The Shot II website will be the main means for feedback, and this will be provided at specific progress report milestones in the Experiment design process (See schedule in Section 8).

3. BALLOON DESCRIPTION AND CAPABILITIES

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

3.1 Balloon Interface General Description

Each Experiment 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 NS-7 teams for their payloads. Each team must meet the 1.5 kg payload mass. Team exceeding this requirement 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 Experiment payload must stay clear of certain radio frequencies listed later in this document. Balloon and control payload cannot provide power or communication links to the NS-7 payloads.

NS-7 Experiment 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 (see Figure 1). The flight string will consist of a single 4.0 mm nylon braided cord. 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. Lateral attachments are possible but not recommended due to the forces the payload may experience upon burst. Access to Experiment payloads will be limited after attachment to flight string unless special considerations are made during the design of the payload structure. Each Experiment payload will be held by one team representative during the launch. External activation switches are recommended so that this individual can power on the payload just before liftoff.

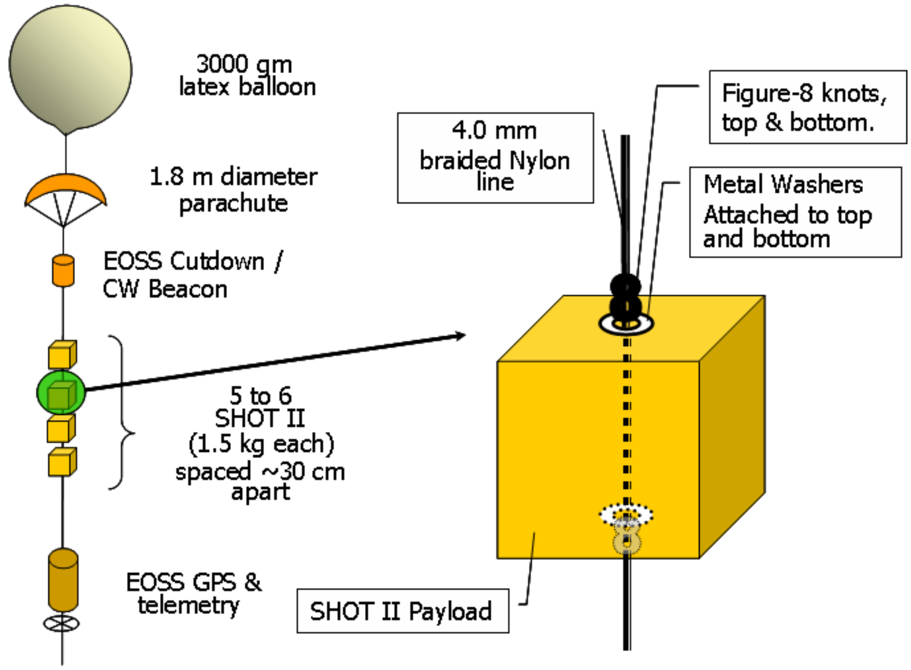

Figure 1: *Payload Attachment Guidelines*

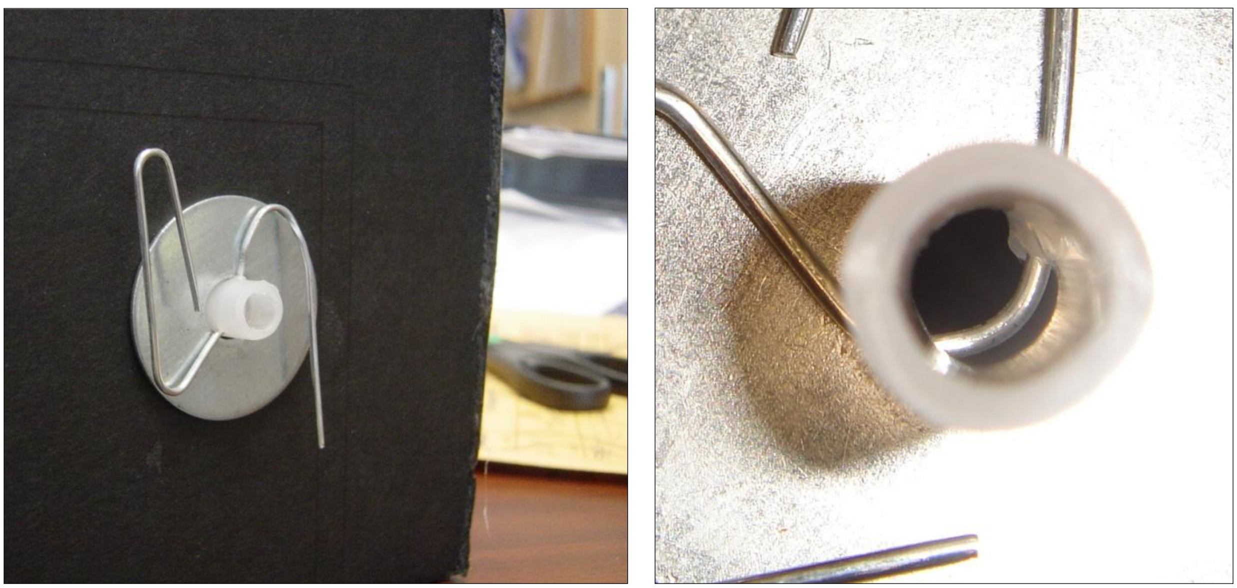

Figure 2: *Structurally Integrated Center Tube for Flight String*

Separation distance between payloads on the flight string can be of any length up to 3 meters (10 feet).

3.2 Balloon Launch Timeline

There will be two launches scheduled on June 30, 2012. The first launch will occur at approximately 6:50 AM MDT. The second launch will occur at approximately 7:20 AM MDT. These times are subject to change due to wind or other weather conditions at launch site. Experiment payloads with critical timed events that are linked to launch time should be prepared to make adjustments to the payload at the launch site if launch is delayed such as remove before flight (RBF) pins or external payload switches.

All NS-7 teams will arrive at the launch site 90 minutes before launch. Experiment payloads will be attached to each balloon flight string 70 minutes before launch. Balloons will begin Helium inflation 20 minutes before launch. Designated team representative responsible for launch of payload will take hold of payload 10 minutes prior to launch. This representative must be able to run with their university's Experiment payload in-hand.

3.3 Balloon Key Performance Parameters

Specific details about the balloon characteristics of the Experiment payload environment are provided in Table 1***:*** *Key Performance Parameters* below. For more detailed information on rates of ascent and descent for similar balloons launched during past workshops, see Figures 3 and 4.

Table 1: *Key Performance Parameters*

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

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

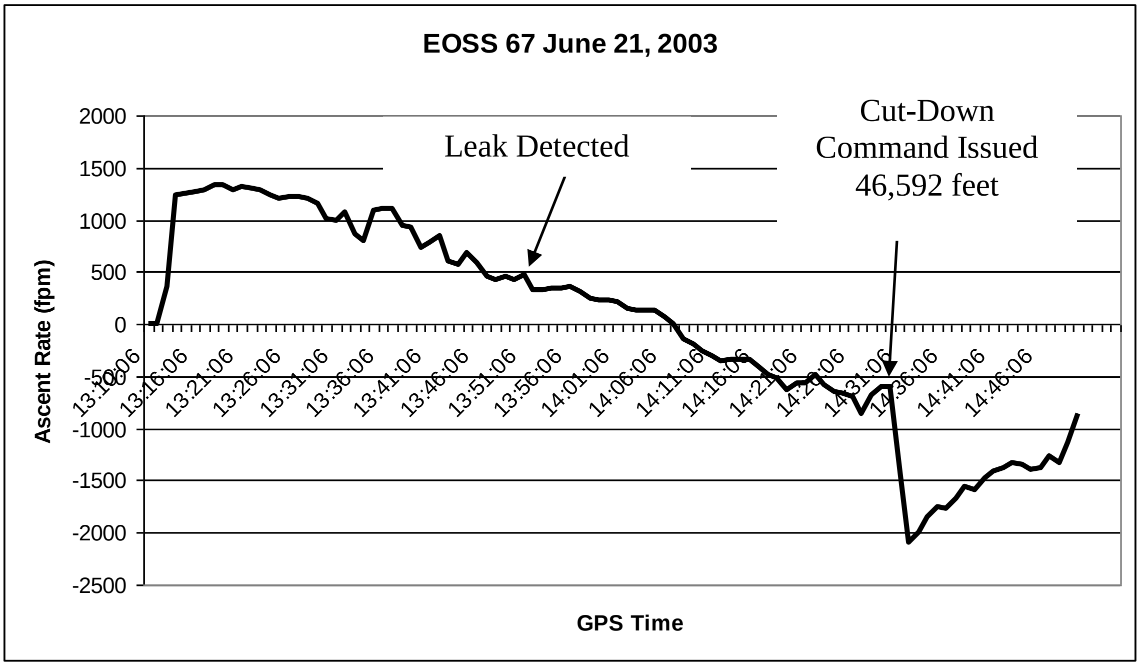

Figure 3: *Ascent and Descent Rates for COSGC June 21, 2003 Flight*

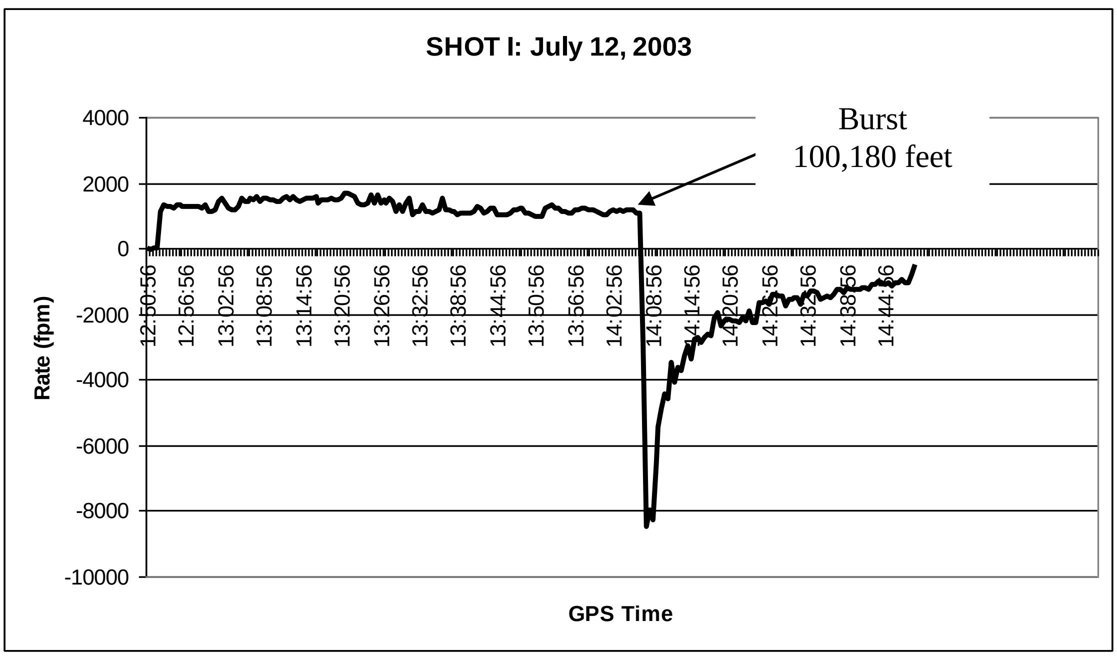

Figure 4: *Ascent and Descent Rates for NS-3 SHOT I Flight July 12, 2003*

3.4 Environmental Conditions

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

Temperatures can reach -80 C during the ascent through the Troposphere. Experiment 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.

3.5 Miscellaneous

Recovery of the Experiment payload(s) is not guaranteed. In the last 100 flights in Colorado all Balloon Control Payloads and flight strings have been recovered. However, due to poor interface design, several individual payloads have been lost and never recovered. Great care should be taken to ensure payload design will not separate from the flight string.

Contact information should be clearly written on side of payload in the event a payload is lost during the flight and recovered externally. Additionally, a United States flag decal should be clearly visible on the payload.

4. ORGANIZATIONAL RESPONSIBILITIES

4.1 Hardware/Interface Responsibilities

Component and functional design responsibilities are as listed below.

<u>Nanosat Experiment Payload (University Responsibility)</u>

- Payload experiment and support systems, power to operate systems
- Mechanical interfaces with the balloon flight string as specified in this document
- Safety features for Experiment-related hazards
- Ground handling and maintenance provisions for Experiments (interfaces, mechanical and electrical ground support equipment [GSE] and related procedures)
- Payload Operations (Ground, Flight)

<u>Balloon and Balloon Lanyard (COSGC/AFRL Responsibility)</u>

- Balloon, Balloon control payload, cut-down device, and flight string
- Ground handling and maintenance provisions for Balloon (Interfaces, GSE, related procedures), including GSE and procedures for the transport and handling of the integrated balloon/Nanosat Experiment system
- Balloon tracking and recovery

4.2 Ground Control

In general, universities are responsible for the activation of payload prior to launch and to support recovery of all the payloads. All tracking and recovery of the balloon and associated payloads as well as all commands to balloon control payload will be handled by COSGC in cooperation with the Edge of Space Sciences (EOSS).

5. RECOMMENDED PAYLOADS

5.1 Objective

The objective of SHOT II is to provide the opportunity and demonstrate the complexity of flying a real subsystem in the near space environment. To this effect, considerable thought should be given to the payloads flown during SHOT II. It is the intent of the program office that schools fly subsystems that provide some utility to the overall NS-7 program objectives. By no means is a school limited to the recommendations below; however, the program office expects each school to clearly document the link between the high altitude SHOT II payload and each school's NS-7 spacecraft.

5.2 Communication Systems

Communication systems are a natural candidate for a high altitude balloon launch to test details like the link budget. When using a high altitude balloon launch to validate a link budget, be sure to take into consideration the following:

- Antenna design: Verify the antenna being used on the ground and the antenna being used on the SHOT II BalloonSat are electrically similar to the anticipated flight unit. This includes the method of attachment to your "spacecraft structure" (that is your balloon structure). A light weight RF replica should be flown that will allow for accurate representation of how the antenna pattern will look on the spacecraft.
- Signal loss: Although 100,000 ft is high it still does not represent the free space loss of a LEO spacecraft. Also, losses due to splitters, and cable length can increase the signal loss in the actual spacecraft. RF attenuators should be used on either the balloon segment or the ground segment to account for these additional losses.
- Be sure to create a balloon link budget that can be directly correlated to your space segment link budget.

5.3 Deployment and Free-Fall Experiments

The most stable portion of the flight is in the altitude range of 70,000 to 100,000 feet. Any SHOT II payload that intends to have deployable tests such as solar arrays or tethers, those tests should be conducted prior to burst. The balloon burst creates a flight environment that produces extreme loads on the BalloonSats. Additionally, BalloonSats will be highly unstable as they free-fall from ~100,000 feet to the start of the troposphere around 40,000 feet. Due to the risk of entanglement with the flight string during descent, all deployment tests should be completed before burst.. Free-fall experiments are permitted but nothing may free-fall untethered from the flight string without a waiver from the FAA.

5.4 Attitude Determination and Control System

It is difficult to demonstrate useful attitude control information; however, a demonstration of a spacecrafts magnetometer may be useful. Using this information to determine the payload pointing vector would be a beneficial exercise for the AD&C team. A more sophisticated effort may be performed by using an engineering reaction wheel to resist the spin of the payload.

5.5 Sensor, Instrument, Subsystem Demonstrations

The flight environment of a high altitude balloon (prior to burst) is ideal for sensor, instrument, and subsystem (i.e. power, command and data handling) demonstrations. While there is still gravity, the flight environment provides pressure, temperature, science and radiation environments similar to low-earth orbit. It is acceptable for SHOT II payloads to demonstrate one or more of their spacecraft's sensors, instruments and/or subsystems. Numerous examples of past SHOT II payloads can be found on the SHOT website (spacegrant.colorado.edu/shot).

6. PAYLOAD DESIGN REQUIREMENTS

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

The following paragraphs provide the basic physical requirements for the Nanosat SHOT II Payload Experiment.

6.1.1 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.

6.1.2 Mass Properties

The mass of the Experiment payload shall not exceed 1.5 kg (3.31 lbs). The payload mass includes all components required by the NS-7 team, including the box and the fasteners used to attach the Experiment payload to the Balloon flight string. The balloon flight string is not included in the payload mass. Teams exceeding this requirement will not be launched. The heaviest payloads will be on the bottom of the flight string for stability reasons during descent.

6.1.3 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 through the center of the payload (see Figure 5). Adherence to this requirement will ensure a stable flight for all the other payloads attached to the flight string.

6.2 Payload Interfaces

6.2.1 Mechanical Interface

The Experiment 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 they need. The default spacing between the payloads will be 1 meter (3 ft).

The universities shall provide the interface and hardware for attaching the Experiment to the balloon at 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 should hug the inside wall of the tube to allow the flight string to pass through.

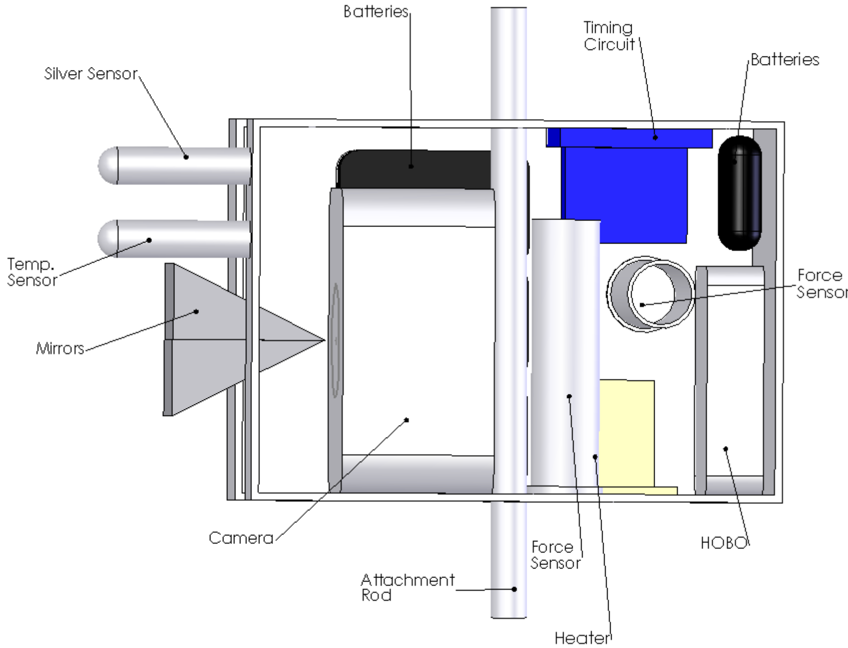

Figure 5: *Example of a Structurally Integrated Center Tube for Flight String*

6.2.2 Electrical Interface

The Experiment payload shall be electrically self-contained. NS-7 teams are responsible for all telemetry and control functions to their Experiment, including the activation of the power source prior to launch. No power is supplied from the balloon. 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 (see Figure 6). In experiments where high voltage may be used, considerations must be made to prevent coronal arcing which may cause a catastrophic failure of the entire balloon string.

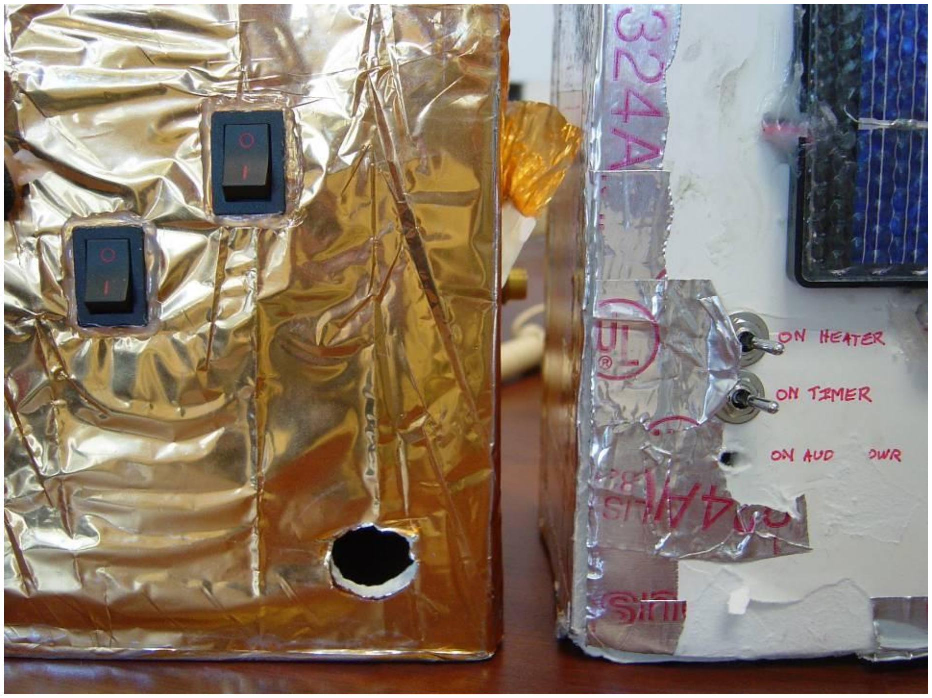

Figure 6: *External Electrical Activation Switches from Two Previous Payloads*

6.2.3 Communication Interface

The balloon tracking and recovery as well as the emergency cut down device are heavily dependent on clear communication channels. Therefore, all Experiments must adhere to the following guidelines.

- The following frequencies are off-limits during all launch and recovery day activities: 144.340 MHz (±15 kHz), 147.555 MHz (±15 kHz) and 445.975 MHz (±100 kHz).
- The following frequencies are available and clear of interference in launch and recovery area: 145.600 MHz and 446.050 MHz. There are likely to be many other usable frequencies in the area but EOSS has not yet confirmed them to be interference-free.
- Each transmitter must be controlled by a licensed ham operator and identified per Part 97 of the FCC Rules.
- Effective Isotropic Radiated Power (EIRP) must be no more than 0.4W (26 dBm).
- Each transmitter must 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. Experiments using communications links to the ground should notify COSGC as soon as possible during the design phase, so that placement of the payload in the balloon string can be coordinated.

6.3 Structural Design Requirements

The Experiment 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 showed loads exceeding 15 g’s. Barring a parachute failure, landing loads should not exceed 5 g’s. Pre-launch testing of the Experiments (discussed later) should validate the typical loads that the payloads will experience. (An interesting experiment might be a high-fidelity characterization of the 3D shock and vibration environment.)

6.3.1 Materials

When designing the structure for the Experiment payload, there are many materials that may be used. Previous flights have shown that aluminum and foam core work the best. 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 Experiments try to avoid using materials that are pressurized or contain embedded air pockets, fluids, etc.

6.3.2 Structural Loading

The Experiment payload is not expected to see accelerations above 1.5 g’s during launch. Accelerations after burst can be very severe but should not exceed 15 g’s. Landing shock is generally in the neighborhood of 5 g’s. These loads take into account the worst case launch and landing load environment barring parachute failure.

6.3.3 Mechanical ground support equipment

Universities shall provide any required mechanical ground support equipment (MGSE) for use in the Experiment/Balloon integration operations. There is no power at the launch or recovery site. It is highly recommended that the University design their Experiment to be highly rugged.

6.4 Thermal Design Requirements

Universities are responsible for providing adequate thermal heating for the payload. Heaters are highly recommended for all balloon payloads. Environmental conditions during the flight can be extreme. See Sections 3.3 - 3.4 for more details.

6.5 Electrical Design Requirements

6.5.1 General

Experiments must address standard electrical/power system safety hazards including:

- Shorting, which may lead to fire or ignition sources
- Routing of wiring such that failures in one circuit will not affect safety features in physically adjacent circuits
- Battery hazards, such as shorting
- Temperature and pressure related failures
- Inadvertent activation of hazardous subsystems

Table 2 provides the design approach for Nanosat power and electrical systems, required by the SHOT II program.

Table 2: *Recommended Battery Design Features*

Design Feature	Comments
1. Power is provided through batteries.	Solar cells may be used to supplement battery power.
2. Electrical switches should be placed between batteries and experiment.	Switches should be externally accessible
3. Batteries should be insulated and kept warm during flight	The heater design from SHOT I may be used, but the thermal design must be tested and verified so as to prevent damage to the experiment hardware.

6.5.2 Electromagnetic Compatibility (EMC)

The Experiment payload should be designed and tested for EMC with the balloon communications frequencies listed in Section 5.2.3. Any and all test data should be provided to COSGC no later than 1 June, 2012, in order to give the University time to mitigate any potential conflicts. If you have an EMI sensitive payload it is recommended to place an Al-Mylar or other conductive material on the exterior of your package (Faraday cage) to help mitigate the interference from the number of transmitters in the balloon stack.

6.5.3 Electrical Bonding and Grounding

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

6.5.4 Frequency Coordination and Licensing

All Experiment payloads incorporating RF will coordinate their intended frequencies of operation with COSGC to ensure non-interference with other Experiments and the Balloon telemetry package. Universities shall be responsible for obtaining the necessary licenses for operation and shall ensure compliance with all applicable operations regulations.

7. PAYLOAD HARDWARE INTEGRATION

The University shall furnish a complete and functioning Experiment payload to COSGC/AFRL that meets all the requirements of this document. This payload will be inspected prior to flight for compliance with requirements of this document. A pre-launch review and inspection will be conducted during day 1 of the SHOT II workshop. Teams will be expected to demonstrate payload functionality at this time. COSGC/AFRL will give guidance to the University to assist in the integration of the subassembly to the balloon.

It is highly recommended that all subsystems be tested independently before being integrated into a functioning Experiment.

8. PAYLOAD TEST REQUIREMENTS

Testing of the Experiment payloads should be performed by each University to ensure payload survivability and mission success. All tests shall be documented and/or recorded and provided to COSGC/AFRL at the Second Full Mission Simulation Test (see delivery dates below).

8.1 Structural Testing

The Experiment box or superstructure should undergo sufficient testing to demonstrate containment and survivability of payload contents. It is the university's responsibility to ensure safety to other Experiments. Each team should build a test structure and load it with mass models of experiment hardware. This test structure will be used for all three structural tests. University documentation of this testing shall be delivered via a SHOT II website submission.

8.1.1 The Whip Test (required)

A crude "whip test" simulates the post burst environment in which maximum g's are experienced. Attach the test structure to a similar flight string cord, knots on each end. Spin the payload above the tester's head, 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.

8.1.2 The Drop Test (required)

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

8.1.3 The Stair Pitch Test (required)

Pitch the same structure down a full flight of concrete steps. This test will crudely simulate the worst case effects of the payload being dragged across a field after landing, due to high winds re-inflating the parachute.

8.2 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. University documentation of this testing shall be delivered via a SHOT II website submission.

8.2.1 Cooler Test (required)

This may be the single most important test of the Experiment payload. Take fully functional and integrated flight payload. Prepare it as it would be 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 onto non-conductive material. Shut lid of cooler. Operate the payload for at least three hours. Begin planned deactivation and recovery efforts. 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 of the payload. Run payload in the same configuration as launch (i.e. if a heater is intended for launch than have heater in the payload)

8.2.2 Vacuum Test (Optional)

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. This test is very good for weeding out poor electronic component designs.

8.3 Functional Tests (required)

The Experiment 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 should be performed before the cooler test. University documentation of this testing shall be delivered via a SHOT II website submission.

9. SCHEDULE

The following are key dates that each team should follow during the completion of the flight payload.

02-03-12	SHOT II 2010 User's Guide Released
02-22-12	Submit Payload Input Form on-line
03-07-12	Preliminary Payload design complete
03-07-12	SHOT II Registration Begins
03-14-12	1st On-line Progress Report submitted
04-04-12	Final Payload design Complete
04-11-12	2nd On-line Progress Report submitted
04-12-12	SHOT Telecon: 2 PM MDT (4 PM EDT) (877-820-7831, then enter 434477#)
05-16-12	Subsystems build and testing Complete
05-23-12	3rd On-line Progress Report submitted
05-30-12	SHOT II Registration Deadline
06-06-12	Subsystem Integration and testing complete
06-13-12	Full Mission Simulation Test Complete

06-14-12	SHOT Telecon: 2 PM MDT (4 PM EDT) (877-820-7831, then enter 434477#)
06-20-12	Second Full Mission Simulation Test Complete
06-27-12	Presentations for Friday (06-29-12) Review submitted
06-28-12	Travel to Boulder
06-29-12	Presentations to AFRL and COSGC in Boulder
06-30-12	Launch Day
07-01-12	Post Launch Presentations to ARFL and COSGC
07-01-12	Workshop concludes mid day