SHOT II WORKSHOP
USER’S GUIDE
UNIVERSITY NANOSAT-3 PROGRAM

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SIGNATURE PAGE

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## REVISIONS

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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) Student Hands-On Training Workshop II (SHOT II) high altitude balloon, and to establish guidelines and requirements for qualifying a University Nanosatellite subassembly for use on the balloon. The University Nanosatellite (Nanosat) Experiment subassembly to be flown aboard the balloon should complement University Nanosat-3 (NS-3) program goals. This document 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
- University Nanosat Program Website: http://www.universitynanosat.org/
- SHOT II Workshop Website: http://spacegrant.colorado.edu/shot
- Edge of Space Sciences (EOSS) Website: http://www.eoss.org
- UN-0001, AFRL ICU User’s Guide
- UN-0002, Nanosat-3 Configuration Management Plan
- UN-SPEC-12311, Stress Analysis Guidelines

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 AIAA Student Satellite Flight Competition are encouraged 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 payload to be flown will be designed, constructed, and tested prior to the SHOT II Workshop by students participating in the NS-3 program and must meet the requirements set forth in this document. Participation in program events such as this will be part of the NS-3 Flight Competition evaluation criteria.

The Workshop will be a three day weekend event (Friday—Sunday), currently scheduled on June 4 – 6, 2004. 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. In the event of unacceptable weather conditions on Saturday, Sunday will serve as the alternate launch day.

3. BALLOON DESCRIPTION AND CAPABILITIES

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

3.1 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 NS-3 teams for their payloads. Each team must meet the 1.3 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 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-3 payloads.

NS-3 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 2.5 mm black nylon/Dacron 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 Y). 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. Each 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.
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 on June 5, 2004. The first launch will occur at 7:00 AM MDT. The second launch will occur at 7:30 AM MDT. These times are subject to change due to wind or other weather conditions at the launch site. Experiments 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.

All NS-3 teams will arrive at the launch site 90 minutes before launch. 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.

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

Table 3-1: Key Performance Parameters

<table>
<thead>
<tr>
<th>Key Performance Parameter</th>
<th>Value</th>
<th>Note</th>
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<tbody>
<tr>
<td>Altitude</td>
<td>80,000-110,000' MSL</td>
<td>1</td>
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<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, maximum</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>
</table>

Notes for Table 3-1:

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

EOSS 67 June 21, 2003

Leak Detected
Cut-Down
Command Issued
46,592 feet

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

SHOT I: July 12, 2003

Burst
100,180 feet
3.4 Environmental Conditions
The environmental conditions that the 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. 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 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 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. 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.

Nanosat Payload Experiment (University Responsibility)
- Payload experiment and support systems, power to operate systems.
- Mechanical interfaces with the balloon flight string, on the Experiment side of the interface, 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)

Balloon and Balloon Lanyard (AFRL/CSGC Responsibility)
- 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 Payload 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 CSGC in cooperation with the Edge of Space Sciences (EOSS).

5. PAYLOAD DESIGN REQUIREMENTS

5.1 Payload Physical Envelope, Mass, and Center of Gravity Requirements
The following paragraphs provide the basic physical requirements for the Nanosat SHOT II Payload Experiment.

5.1.1 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. Schools must notify AFRL/CSGC if this is the case.

5.1.2 Mass Properties
The mass of the Payload shall not exceed 1.3 kg (2.86 lbs). The payload mass includes all components required by the NS-3 team, including the box and the fasteners used to attach the payload to the Balloon flight string. The balloon flight string is not included in the payload mass. Each team must meet the 1.3 kg payload mass requirement. 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.

5.1.3 Center of Gravity
The center of gravity (CG) for the Nanosat payload experiments 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.

5.2 Payload Interfaces

5.2.1 Mechanical Interface (located as close as possible to payload centerline and CG)
The Experiment will be mounted to the Balloon via a flight string with a knot on each end of payload. The flight string consists of a 2.4 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 brass finish threaded tube with an inner diameter of 6.4 mm (¼ inch) maximum
- Metal Washers (attached to structure)
- Nuts (Should bear down on the washer)

![Figure 5: Example of a Structurally Integrated Center Tube for Flight String](image)

Figure 5: Example of a Structurally Integrated Center Tube for Flight String
5.2.2 Electrical Interface

The payload shall be electrically self-contained. NS-3 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 for coronal arcing which may cause a catastrophic failure of entire balloon string.

![Figure 6: External Electrical Activation Switches from Two Previous Payloads](image)

5.2.3 Communication Interface

The balloon tracking and recovery as well as the emergency cut down device are heavily dependent on the 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, 147.555 MHz and 445.975 MHz.

The following frequencies are available and clear of interference in launch and recovery area: 145.600 MHz and 446.050 MHz. There are quite 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 and ID'ed 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.

Payloads using communications links to the ground must notify ARFL as soon as possible.

5.3 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 showed loads exceeding 15 g’s. Barring a parachute failure, landing loads should not exceed 5 g’s. Tests discussed later should validate the typical loads that the payload will experience.

5.3.1 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 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.

5.3.2 Structural Loading
The Experiment 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.
5.3.3 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 rugged.

5.4 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 section 7.2 for more details.

5.5 Electrical Design Requirements

5.5.1 General

Experiment designs should resemble UNP nanosatellite designs based on the guidance given in the User’s Guide, and 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, and inadvertent activation of hazardous subsystems.

Table 5-1 provides a recommended design approach for Nanosat power and electrical systems. This approach is mandatory.

<table>
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<th>Design Feature</th>
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<tr>
<td>1. Power provided through batteries.</td>
<td>• Solar cells may be used</td>
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<tr>
<td>2. Electrical switches should be placed between batteries and experiment.</td>
<td>• Switches should be external</td>
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<tr>
<td>3. Batteries should be insulated and kept warm during flight</td>
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5.5.2 EMI/EMC (Electromagnetic Interference/Electromagnetic Compatibility)

The Experiment should be designed and tested for EMI/EMC susceptibility to Balloon transceiver radiated emissions.
5.5.3 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 will 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.

5.5.4 Frequency Coordination and Licensing

All Experiments incorporating RF will coordinate their intended frequencies of operation with AFRL to ensure noninterference with other Experiments and the Balloon telemetry package. Universities shall be responsible for obtaining the necessary licenses for operation, and shall ensure compliance with operations regulations.

6. PAYLOAD HARDWARE INTEGRATION

The University shall furnish a complete and functioning payload to 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. AFRL/CU-Boulder will give guidance to the University to assist in the integration of the subassembly to the balloon.

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

7. PAYLOAD ANALYSIS & TEST REQUIREMENTS

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

7.1 Structural Testing

The Experiment box or superstructure should undergo sufficient testing to demonstrate containment and survivability of contents. It is the University’s responsibility to ensure safety to other Experiments. 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.

7.1.1 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, knots on each end. Begin...
to 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.

7.1.2 The Drop Test

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.

7.1.3 The Stair Pitch Test

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 parachute.

7.2 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.

7.2.1 Cooler Test

This may be the single most important test of the 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. Return in 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.

7.2.2 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.

7.3 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 should be performed before the cooler test.
8. SCHEDULE

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

- 02-20-04 SHOT II User’s Guide Released
- 03-05-04 Payload Input Form submitted spacegrant.colorado.edu/shot website
- 03-19-04 On-line progress report is due
- 04-02-04 Payload design complete
- 05-07-04 Payload subsystems complete
- 05-14-04 On-line progress report is due
- 05-23-04 SHOT II registration Deadline
- 05-28-04 Testing Complete
- 06-01-04 Final On-line progress report is due
- 06-03-04 Travel to Boulder
- 06-04-04 SHOT II Workshop Begins
- 06-05-04 SHOT II Launch
- 06-06-04 SHOT II Workshop Concludes