Planetary Ballooning Pre-Workshop Virtual Meeting

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“NASA Balloon Capabilities and Outlook for the Coming Decade”

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Overview of the NASA Balloon Program

- Large helium-filled balloons provide access to near-space at a fraction of the cost of a satellite.
- They currently support cutting-edge observations in Astronomy and Astrophysics, Solar Physics, and Upper Atmospheric Research.
  - They train young scientists and develop new technologies for subsequent space flight.
- Flights last from a few hours to several weeks, with possibility of flying up to 100 days using super-pressure balloons under development.
- NASA launches balloons from New Mexico, Texas, Sweden, Australia, and Antarctica.
  - A 42-day record-breaking flight went three times around the South Pole in 2004 - 2005.
- Science payloads are solicited via annual ROSES AO’s, and competitively funded by grants.
  - The Balloon Program does not fund payloads.
Antarctica is the Center Piece of NASA Ballooning

- NASA-NSF/OPP Long-Duration Ballooning (LDB) provides:
  - NASA’s lowest cost access to space (>= stratosphere).
  - Spacecraft-scale payloads (1000 - 2000 kg science instruments).
  - Recoverable/Re-usable payloads increase exposure at low cost.

- The Balloon Program has focused on expanding the highly successful LDB flights around Antarctica.
  - Flight durations of up to 4-6 weeks.
  - Flight support to 3 payload flights every year.

- Frontier Astrophysics on Super-Pressure Balloons (SPB) will justify Ultra-Long Duration Balloon (ULDB) flights from Antarctica in the coming decade.

- ULDB flights from Antarctica yield long exposure: 60 days now; 100 days soon.
  - NASA is working with NSF/OPP to enable flights to leave Antarctica for recovery in South America, New Zealand, Australia, etc.
History of NASA Long-Duration Balloon (LDB) Flights

- 37 Antarctic Science Long-Duration Balloon (LDB) flights have been conducted since the first successful launch in 1991 by the NASA - NSF Office of Polar Programs partnership.

- Since 1991, historical average LDB flight is 17.5 days.


- Since 2002, 10 flights have requested double orbits:
  - Of those, 7 of 10 achieved 30 day or greater duration.

![Flight Duration Frequency (Days)]

- Triple circumpolar LDB flight of 42 days Dec.-Jan. 2004-05
Duration of LDB Science Missions

- Decadal “Polar” LDB Flight History (Antarctica)
  - Over course of last decade (2002-2012)

- 20* long-duration balloon (LDB) Antarctica science flights since December 2001
  * Does not include Engineering Science or Vehicle Test Flights
  - Average Duration is ~ 23 days
  - 1 Balloon Failure – Wefel(ATIC) Dec 2005
  - 1 Instrument Failure – Rust (SBI) Dec 2006
Multiple Flights Are The Norm
Six CREAM Flights in Antarctica: ~ 161 days Cumulative Exposure

CREAM-I
12/16/04 – 1/27/05
42 days

CREAM-II
12/16/05-1/13/06
28 days

CREAM-III
12/19/07-1/17/08
29 days

CREAM-IV
12/19/08 – 1/7/09
19 days 13 hrs

CREAM-V
12/1/09 – 1/8/10
37 days 10 hrs

CREAM-VI
12/21/10 – 12/26/10
5 days 16 hrs
Reliability of LDB Science Missions

- Decadal “Polar” LDB Flight History (Antarctica & Sweden)
  - Over course of last decade (2002-2012)

Vehicle Success Rate: \[
\frac{\text{Total Flights} - \text{Vehicle Failures}}{\text{Total Flights}} = \frac{29 - 1}{29} = 96.5\%\]

Instrument Success Rate: \[
\frac{\text{Total Flights} - \text{Instrument Failures}}{\text{Total Flights}} = \frac{29 - 1}{29} = 96.5\%\]

- 29 polar long-duration balloon (LDB) science flights since December 2001
  - 9 LDB science flights from Sweden to Canada
  - 20 LDB science flights from Antarctica
  * - Does not include Engineering Science flights or Vehicle test flights
  - 1 Balloon Failure – Wefel(ATIC) Dec 2005
  - 1 Instrument Failure – Rust (SBI) Dec 2006
2008-09 Super Pressure Balloon Test Flight

- 54 days of flight: Longest large NASA balloon flight ever
- Balloon remained pressurized - no apparent gas loss. Balloon could have flown indefinitely
- MIP functioned flawlessly
- 2011: Test flight of 14MCF successfully flown (22 days)
14.9 MCF Super Pressure Balloon Test Flight

- Launched: January 9, 2011
- Terminated: February 1, 2011
- Flight Time: 22 days

<table>
<thead>
<tr>
<th>Volume</th>
<th>Launch Date</th>
<th>Suspended Weight</th>
<th>Altitude</th>
<th>Duration</th>
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<tbody>
<tr>
<td>7 MCF</td>
<td>Dec 28, 2008</td>
<td>1,500 Lbs</td>
<td>110 KFT</td>
<td>54 days</td>
</tr>
<tr>
<td>14.9 MCF</td>
<td>Jan 9, 2011</td>
<td>4,000 Lbs</td>
<td>110 KFT</td>
<td>22 days</td>
</tr>
<tr>
<td>18 MCF</td>
<td>2012</td>
<td>5,000 Lbs</td>
<td>110 KFT</td>
<td></td>
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The 14 MCF Super Pressure Balloon (SPB) Test Flight successfully validated design changes made in scaling up from the 7MCF balloon, demonstrated deployment, pressurization to near the 155 Pascal design pressure, and to maintain constant float altitude.
Super Pressure Balloon Test Flight (14MCF) – January 2011
Super Pressure Balloon Test Flight (14MCF) – January 2011

- Super-Pressure Balloons enable:
  - Stable-altitude Long-duration Balloon (LDB) flights in non-Polar regions
  - Ultra Long Duration Balloon (ULDB) flights at any latitude

Super-Pressure ULD Balloon maintains altitude

Zero-Pressure LD Balloon droops at night

ZPB variations include up to 40% change in volume

These data are from Antarctic flights—effect is even more dramatic in mid-latitudes
Launch Site Near McMurdo
LDB/ULDB Operational Control Center

- Located at CSBF in Palestine, Texas
- Can support 3 LDB payloads in flight simultaneously
- Receipt and processing of telemetry
- Flight management
- Transferring experiment data to users
- Communications
- FAA Airspace coordination
The ULDB & WASP System

Super Pressure Balloon

Inflated Dimensions
Height 163.61 ft
Diameter 271.60 ft

Payload:
Telemetry & Support Systems

Communications Systems

Payload: Gondola & Instrument

Solar Arrays

Photo taken by Mike Smith

WASP Gondola
Wallops Arc Second Pointer (WASP)

- Development Approach
  - Refine Coarse Sun Sensor to +/- 1 degree
  - Design, build and test fly a control system capable of pointing balloon-borne telescopes at inertial targets with arc second accuracy
  - Provide a flexible design which can accommodate a variety of science instruments
  - Designed based on Elimination of Static Friction
    - Bearing Shaft with Constant Rotation
  - Pitch and Yaw capability

- 2010 - Ground Tests with Mock Telescope
  - 24 foot long, 1500 lbs.
  - Pitch and Yaw Torque Motors
  - Full Scale Gimbal (1 meter spacing)
  - New Flight Processor, Software
- Sub-Arcsecond Pointing Achieved
  - Jitter less than 0.75 arcseconds RMS
Wallops Arc Second Pointer (WASP) Project

2011- Project developed WASP Flight System

The WASP test flight was conducted from Ft. Sumner, N.M. on October 7, 2011. The flight duration was ~ 5 hours.

The project team exercised the proto-type WASP system for ~ 2hrs at float altitude of 102K FT. (32 Km)

- Demonstrated sub-arc second pointing stability with the mock telescope and in a typical flight environment (Uncage mock-instrument and point inertially)
- Inertial target offsets were issued from the ground to demonstrate science operations mode and target acquisition dynamics.
- System was able to maintain arc-second pointing stability during discrete ground-commanded gondola azimuth adjustments
- Demonstrated ops concept for long duration target observation
During the >20 minute "stay on target" test, the Pitch Error RMS was 0.24 arc-sec, and the Yaw Error RMS was 0.22 arc-sec.
Wallops Arc Second Pointer (WASP) Project

WASP Status and Next Steps:

• Payload has been returned, disassembled, and inspected.
  • Some damage to hubs; will be repaired in next few months.
  • New Torque Motors have been received, shaft motors, gear heads, resolvers in process
  • Hub drawing package will be updated and released for fabrication.
• Software Integration of Star Tracker will be implemented
• Plans call for another Test Flight of longer duration, with night time and a representative instrument payload in the FY2013 timeframe.
The 2008 NASA Authorization bill from Congress required a National Research Council (NRC) study of the Suborbital Program.

**Recommendations**

- **No. 1:** “NASA should undertake the restoration of the suborbital program as a foundation for meeting its mission responsibilities, workforce requirements, instrumentation development needs, and anticipated capability requirements. To do so, NASA should reorder its priorities to increase funding for suborbital programs.”

- **No. 4:** “NASA should make essential investments in stabilizing and advancing the capabilities in each of the suborbital program elements, including the development of ultra-long-duration super-pressure balloons with the capability to carry 2 to 3 tons of payload to 130,000 feet, etc.”
**ASTRO and Planetary Decadal Studies**

**Summary Page 1-9:** The balloon and sounding rocket programs provide fast access to space for substantive scientific investigations and flight testing of new technology. The balloon program in particular is important for advancing detection of the cosmic microwave background and particles for the principal investigators of tomorrow’s major missions.

**PAG Panel Report Page 8-28:** For this panel’s purposes, it recommends that the development of technologies needed for ULDB be completed and a ULDB program of one or two flights per year be supported, including their payloads, possibly replacing some LDB flights.

**The Planetary Science Decadal Survey for 2013-2022:**

Significant planetary work can be done from balloon-based missions flying higher than 45,000 ft. This altitude provides access to electromagnetic radiation that would otherwise be absorbed by Earth’s atmosphere, and it permits high spatial resolution imaging unaffected by atmospheric turbulence. These facilities offer a combination of cost, flexibility, risk tolerance and support for innovative solutions that is ideal for the pursuit of certain scientific opportunities, the development of new instrumentation, and infrastructure support. Given the rarity of giant planet missions, these types of observing platforms (high altitude telescopes on balloons and sounding-rockets) can be used to fill an important data gap. (7-33)
Concluding Remarks
Natural Evolution for Ballooning to Support Planetary Science

• NASA’s investment in super pressure balloons promises an order of magnitude increase in capability.
  – Capable of carrying 4000-6000 lb payloads to 110 KFT for upwards of 100 days.
  – Providing a high precision, arc second pointing system to support astronomy, and planetary investigations from balloons.

• As Scientific ballooning continues to increase its capabilities, this platform can play an important role in planetary science.
  – *SMD needs input from the planetary science community on what balloon-borne capabilities are needed to enable future investigations.*
Acknowledgements

• Executive oversight of the NASA Balloon Program is provided by the Astrophysics Division, Science Mission Directorate, NASA Headquarters

• Implementation of the Balloon Program is delegated to the Goddard Space Flight Center Wallops Flight Facility (WFF) at Wallops Island, Virginia http://www.wff.nasa.gov/balloons

• Balloon flights are conducted by the Columbia Scientific Balloon Facility (CSBF) in Palestine, Texas http://www.csbf.nasa.gov/

• The CSBF is managed by the Physical Science Laboratory, New Mexico State University, under contract with WFF

• The balloons are manufactured by Raven Industries, Aerostar Division in Sulfur Springs, Texas

• The Antarctic LDB program would not be possible without the crucial contribution of the U.S. National Science Foundation Office of Polar Programs and Raytheon Polar Services Company