“Current Outlook for Scientific Research with Super Pressure Balloons”

W. Vernon Jones and David L. Pierce
Science Mission Directorate
NASA Headquarters
Washington, DC, 20546
w.vernon.jones@nasa.gov; david.l.pierce@nasa.gov
1-202-358-0885; 1-202-358-3708
History of NASA Long-Duration Balloon Flights

• 50 “polar” Long-Duration Balloon (LDB) flights have been conducted since the first successful launch in 1991 by the NASA - NSF Office of Polar Programs partnership

• 39 Antarctic flights (*)
  - 27 single circumpolar flights with durations of 8 - 20 days
  - 6 double circumpolar flights with durations of 20 - 32 days
  - 4 triple circumpolar flights with durations of 35 - 42 days
  - 2 super-pressure balloon (SPB) test flights: 54 days; 22 days

• 2 flights from Fairbanks, Alaska to Canada over Russia with durations of 13 days

• 9 Flights from Kiruna, Sweden to Canada with durations of 4 - 6 days

(*) 2 science payloads, CREST & STO, and an 18 MCF SPB test flight with a piggyback payload are planned for December 2011 launches.
• Antarctic flights have increased the float duration significantly.
• Increase in recent years is due to multiple circumnavigations, and flying 2 – 3 instead of 1 – 2 payloads per Antarctic season.
• Next major increase will come from super-pressure ballooning.
Super-Pressure Balloons (SPB) Required for Ultra-Long-Duration Balloon (ULDB) flights

- Vented “Zero Pressure” balloons used in Antarctica are in equilibrium with the atmosphere, so the altitude changes with air temperature and pressure.
- Super-pressure “Constant Volume” balloons maintain altitude stability, thereby enabling long-duration flights, even at mid-latitudes.

Successful SPB Test Flight

7 MCF At Float

54 days (12/28/08 – 2/20/09)
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.”
• Three major submissions to Astro2010 by the Cosmic Ray Program Assessment Group (CRPWG)* supported scientific research ballooning.
  – White Paper entitled “Balloon and Space Based Cosmic Ray Astrophysics” was sent to the Program Prioritization Panel (PPP), 13 February, 2009.
  – Response to Astro2010 Request for Information (RFI) showed great promise of super pressure ballooning, aka ULDB, for Particle Astrophysics 1 April, 2009.
  – Invited Briefing, 8 June, 2009, to the Particle Astrophysics and Gravitation Panel (PAG) requested, in addition to Particle Astrophysics, information on:
    o ULDB application for broad field of Astrophysics.
    o ULDB Frontier Particle Astrophysics research if resources were available
    o Supporting instrumentation and new technology needed to develop ULDB.
  – ULDB is currently defined as super pressure balloon; >110,000 ft; 60 days minimum, 100 days desired; 1000 Kg science instrument; higher altitudes with smaller instruments.

(*) The CRPWG was organized and chaired by Jonathan Ormes, University of Denver.
  – Don Ellison, North Carolina State University was Point-of-Contact for Astro2010.
  – Invited Oral Briefing to Astro2010 made by Peter Gorham, University of Hawaii.
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. A growth in the budget by $15 million per year is recommended.

Summary Page 7-27: To increase the launch rate by about 25 percent, it is recommended that the R&A program be augmented by $5 million per year to accommodate the selection of additional balloon and rocket payloads. In addition, $10 million per year will be needed to support the additional launches and improvements in infrastructure.

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 panel estimates that the cost for this capability requires an augmentation to the balloon program of about $250 million over the next decade.
Supporting Technologies needed for LDB/ULDB potential

- The Wallops Arc Second Pointer (WASP) under development for conventional and LDB payloads is scheduled for flight Demonstration in October 2011.
- A Trajectory Control System (TCS) needed to fully enable ULDB science missions is behind SPB development in the funding queue.
  - No study has been adequately funded.
- A TCS system with at least 1 m/s control authority would enable missions to stay over Antarctica for multiple orbits with tight orbit control.
  - 3 - 4 circumnavigations routinely.
- A mid-latitude launch site is needed to enable global ULDB flights 30-50° S.
  - Avoid highly populated regions.
  - Fly around the globe.
  - Facilitate recovery if possible.
• 14.9 MCF SPB flew for 22 days over Antarctica with 4,000 lb suspended.
• The goal was to fly as long as possible, but stay over the Antarctic continent to facilitate recovery of high valued program assets, including portions of the balloon.
• The flight performance was exactly as predicted.
Super-Pressure Balloons enable:
- Stable-altitude 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

2 Antarctic 2011 LDB flights

Representative Average Float Altitude Variation for ~9 Days for 61SN BLAST and 616NT Super Pressure Balloon

Days from launch

GPS Altitude Variation From Average Float Altitude ft

-6000  -4000  -2000  0  2000  4000  6000

61SN BLAST, +/-4,688 ft/6,267 ft
616NT Super Pressure Balloon, +/-964 ft/997 ft
Concluding Remarks

• Zero-pressure LDB flights have a history of scientific discovery.
  - Many high priority projects are proposing multiple Polar LDB Missions.

• Super-pressure balloons are a major technological advance.
  - They offer an order of magnitude increase in flight capability.
  - They enable Ultra Long Duration Balloon (ULDB) flights (60-100 days).
  - They open areas of exploration closed to zero-pressure balloons.

• Cost impacts of converting LDB payloads for ULDB are modest.
  - Most LDB payloads can be upgraded for ULDB flights.
  - LDB and ULDB together form a science opportunity continuum.
  - Balloons can help get more science done in the current budget climate.

• ULDB missions can be adapted quickly to new challenges.
  - They are ideally suited as a Small Explorer (SMEX) mission equivalent.
  - They offer significant science at a fraction of the cost of a space mission.
Acknowledgements

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• 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 Aerostar, Inc. in Sulphur 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.

• The Sweden-Canada flights from Kiruna would not be possible without the outstanding service provided by the Swedish Space Corporation.