How NASA Can Exploit Low-Cost Access to Near Space: Recommendations from the April 2007 LCANS Workshop

August 1, 2007

EXECUTIVE SUMMARY

Over 60 members of academia, industry, and NASA's Science Mission Directorate met in Boulder, CO on April 26-28 to discuss low-cost access to near space (LCANS) and its applications for the future of scientific ballooning in general. We, the organizers and participants of the LCANS workshop, have written this document as the first product of that workshop. It consists of three parts:

- **Recommendations** by the workshop participants to help NASA exploit balloon-borne payloads.
- A summary of some of the unique **strengths of balloon experiments** (Appendix 1).
- **A Long-Term Vision** for balloon missions over the next 25 years (Appendix 2).

The recommendations are designed to promote several goals: (1) fast turn-around of missions, (2) sustained escape from 99.5% of the Earth's atmosphere, and (3) most importantly, optimum return per dollar across all of the SMD disciplines: Earth Science, Planetary Science, Heliophysics and Astrophysics. The overall focus of the recommendations is to *fly more missions, achieve more science*.

LCANS WORKSHOP OVERVIEW

The April 2007 LCANS workshop was organized by several scientists at Southwest Research Institute to achieve three objectives:

- Discuss recent technological advances that could lead to cheaper, lighter, more capable balloon experiments.
- Discuss "what-if" science that could be accomplished if scientists had routine access to near space, particularly in the context of NRC decadal surveys and the SMD science plan.
- Discuss strategies to make better use of LCANS by NASA and NSF.

A diverse program of speakers from NASA, academia and industry addressed these specific issues. The program and talks are online at http://www.boulder.swri.edu/LCANS/LCANS_SpeakerList.html. Several recurring themes emerged from the workshop, including the following:

- Balloons as low-cost/low-risk test-beds are stymied by the existing rules for TRL qualification. At present, balloon-borne instruments can be qualified only to TRL 4. A change in the TRL specifications to allow qualification to TRL 6 or higher would provide a fast-track avenue for instrument development.
- A gap exists between the 8000-lb payloads launched by NASA/CSBF and the 6-lb "BalloonSats" launched by Space Grant consortiums. Significant scientific research can be accomplished with

payloads in the 30-lb to 200-lb range. These payloads can be launched inexpensively using several demonstrated commercial launch systems. Furthermore, these payloads are small enough to take advantage of the long-duration capabilities of currently available super-pressure balloons.

- Large balloon payloads typically cost between \$3M - \$8M. Because NASA funds payload development strictly through its R&A programs, there is a bottleneck in funding payloads to take advantage of the near space environment. We therefore recommend a new class of smaller-than-SMEX funding opportunities.
- The three most common "wish-list" requests to the Balloon Program Office (BPO) are for flights with (a) longer duration, (b) higher altitudes, and (c) larger payloads, followed by requests for position control (e.g., stationkeeping for Earth observing applications) and more power for the experiments. Looking to the future, it was noted by BPO administrators that the BPO currently flies *all* payloads referred to it by NASA's R&A programs, but there is not much unused capability to support more long-duration flights at present. It was also noted that commonly available super-pressure balloons, with lifting capabilities of a few hundred pounds, motivate the development of lightweight payloads.

RECOMMENDATIONS

1. *Enable TRL 6 Qualification for Appropriate Balloon-Borne Instruments.* Balloon missions could provide fast, inexpensive test-beds to qualify potential spacecraft instrumentation. We recommend that sub-orbital platforms, which currently top out at TRL 4, be re-evaluated as avenues to qualify appropriate instrumentation TRL 6.
2. *Establish a New Tier of Cross-Division Opportunities for LCANS Payload Development*. It is widely recognized that a balanced program of tiered opportunities generally protects smaller programs from the funding demands by larger programs. Without separate opportunities for Flagship-, New Frontiers- and Discovery-class missions, it is likely that Flagship missions would use NASA's available resources to the exclusion of smaller missions.

   We recommend the formation of a new, cross-discipline *TEX* program for low-cost "Tiny Explorers" with total funding at the \$30M/yr level. Large balloon payloads typically cost between \$3M – \$8M to develop. A \$30M TEX program would support a dynamic variety of missions each year at a fraction of the cost of a single \$120M SMEX mission. Furthermore, the existence of a TEX program would make it possible to fund/build/fly balloon missions in a two-year cycle. In contrast, the current R&A funding model often requires that balloon payload development be spread out over 5+ years.
3. *Develop Separate Large and Small Opportunities within the Balloon Program Itself*. As recommended by the NRC, NASA flies a balanced program of large and small missions. We recommend that a cross-discipline TEX program be formally structured to support a balanced array of balloon missions of various sizes.
4. *Develop Multiple-Payload Missions*. By sharing power, telemetry, and the launch vehicle itself, experiments on a multiple-payload balloon mission will realize cost-savings and reduced development requirements relative to solo payloads. We recommend that infrastructure to support multiple-mission payloads be developed through competed proposals solicited through future TEX announcements.
5. *Formally Promote Rideshare (aka "Hitchhiker") Opportunities*. Some rideshare opportunities exist at present through the *ad hoc* efforts of the balloon program office to match up small ex-

periments with the PIs of large balloon missions. To provide fair and widespread access to rideshare opportunities, we recommend that the TEX announcement have a rideshare category, analogous to "snapshot" proposals on the Hubble Space Telescope. Rideshare proposals would be peer-reviewed along with regular TEX proposals and flown whenever possible with technical and scheduling oversight by the BPO.

6. *Relax Restrictions/Accept Higher Risk for a Class of Balloon Missions*. Balloon payloads should not have to jump through the same hoops as spacecraft missions, since the cost, risk and turnaround period are much less for balloon missions. We recommend that balloon missions serve as a low-cost, high-risk seed farm to test novel instrumentation prior to the expense of a spacecraft mission. (Note that "high-risk" refers to a willingness to fly novel instruments, not a decrease in safety procedures.)

7. *Change the Language in R&A Solicitations to Make Investigators Aware of LCANS Opportunities*. Most NASA-funded scientists do not realize that balloon missions are (a) selected through individual ROSES R&A programs and (b) supported virtually without exception by NASA's BPO office once selected. To increase awareness of the BPO's capabilities, we recommend that NASA's individual program managers should, when appropriate, add text to their respective NRAs stating that balloon-borne science would fall under the auspices of their research programs. We also recommend that the NRAs suggest alternative ways to fund balloon payload development (such as the SR&T, PME or PIDDP programs) in the likely event that a specific R&A program award might fund data analysis efforts but not the actual payload development.

APPENDIX 1: ADVANTAGES OF BALLOON PAYLOADS

Balloon payloads have specific advantages over ground-based and spacecraft facilities. We give a few examples here to provide some motivation for balloon-borne missions.

- *Diffraction-Limited Seeing*. There is no atmospheric distortion at altitudes routinely achieved by balloon payloads (e.g., 70 to 120 thousand feet). A 1-m telescope in the Earth's stratosphere has a diffraction limit of 0.1″ at 5000 Å. For ground-based observatories, turbulence at CCD wavelengths (shortward of around 1 micron) is notoriously hard to correct with adaptive optics; large ground-based telescopes with adaptive optics only approach their diffraction limits longward of 1.2 μm. For UV- and visible-wavelength imaging, a 16-inch balloon-borne telescope will outperform current 8-m and 10-m ground-based telescopes every night of the year.
- *Rapid Development Cycles*. Balloon-borne missions can be developed and launched much more quickly than a spacecraft with similar capabilities. A real-life example occurred after supernova 1987a was detected. At that time there were no high-resolution germanium spectrometers in space (like INTEGRAL). Balloon missions GRIS and HEXAGONE quickly filled the gap, paving the way for the INTEGRAL satellite.
- *Low-Cost Daylight Observations*. The diffuse component of the daylight sky is a combination of Raleigh scattering by N_2 molecules and scattering by suspended particulates. At 0.5 μm, the one-way optical depth above 100,000 ft due to N_2 is around 0.0025; at 2.5 μm, this optical depth drops to 4×10^{-6}. For many applications, such as infrared imaging, daytime observations can be made of targets that are angularly close to the Sun.
- *Ability to Launch Physically Large Payloads*. Some payloads have extremely long dimensions that would be difficult to launch by rocket but can be straightforwardly lifted by balloon. For example, the inFOCuS balloon-borne hard X-ray experiment was designed with an 8-m focal length

(necessitated by grazing incident optics). The 9-m telescope would have been challenging to launch by rocket, but was easily launched by balloon in September 2004.

- *Low-Cost X-Ray, Gamma-Ray, Cosmic Ray, UV, IR and Submillimeter Observations*. Recent balloon payloads have taken advantage of the atmospheric transmission at 90,000 - 120,000 ft to observe radiation from X-rays to the thermal IR. Payloads built to observe radiation at many important energy regimes have been a traditional strength of NASA's balloon program.
- *Test-beds for Potential Planetary Missions*. Stratospheric balloons can serve as important shake-down exercises to test hardware, software, and especially operations for potential planetary balloon missions to Mars, Titan, or Venus.

APPENDIX 2: BALLOONS IN 25 YEARS – A LONG-TERM VISION

The long-term vision for near space is a rich topic that could benefit from serious discussion. We mention a few examples here which we believe are reasonable and worthwhile for NASA to develop over the next quarter century.

- *Medium to very large observatory-class telescopes in near space*. Apertures up to many meters for gamma-ray through sub-mm observations would achieve image resolutions of a few milli-arcseconds (mas). We envision balloon-borne telescopic facilities that accept competed proposals for their usage, like ground-based observatories, with the potential for instrument reconfiguration (if necessary) between re-flights.

- *Capability to support massive instruments*. Some applications, like the detection of rare, very energetic cosmic rays, require massive detectors.

- *Stationkeeping capability*. Justifications for stationkeeping capabilities include terrestrial observations, lightweight/low power communications, and observations of specific phenomena (e.g., eclipses, occultations and gravitational lensing events).

- *Capability to reach very high altitudes*. Balloon deployment to 160,000 ft (and higher) opens up some important UV, X-Ray and cosmic ray regimes that are unavailable from 120,000 ft. A long-duration, high-altitude, super-pressure balloon is a worthwhile long-term goal. Current super-pressure balloons typically reach altitudes of 70,000 - 100,000 ft.

- *Distributed networks of balloon-borne observatories*. Applications include interferometers with very high spatial resolutions, observations that vary over short distances (e.g., occultations or gravitational lensing events), or densely sampled *in-situ* observations of terrestrial phenomena.

- *Large antennas in support of space missions*. Parabolic inflatables have been deployed from the space shuttle. Very large radio-reflective antennas could be deployed to achieve high bandwidth communications with remote, low power spacecraft on an *ad hoc* basis as needed for specific spacecraft missions.

- *Modular pointing infrastructure*. In the short term (around 5 years), we would like to see the development of standard, mature, modular units (including star trackers and configurable control systems with standard reaction wheel sizes). These would greatly reduce overall cost for pointed missions and also reduce barriers to entry for new instruments and/or PIs. These two effects would enable a new wave of instrument development and exploratory science using balloons.

LCANS WORKSHOP ORGANIZERS AND PARTICIPANTS

Organizers

Eliot Young, SwRI-Boulder
Robert Grimm, SwRI-Boulder
William Gibson, SwRI
Craig DeForest, SwRI-Boulder
I. Steve Smith, SwRI

Participants

John Andrews, *SwRI – Boulder*
Danny Ball, *Columbia Scientific Balloon Facility*
Alberto Behar, *NASA Jet Propulsion Laboratory*
Bob Blackington, *Near Space Corporation*
Bill Brown, *High Altitude Research Corp.*
Mark Bullock, *SwRI - Boulder*
Russell Chadwick, *NOAA/ESRL/GSD*
Philippe Crane, *NASA Headquarters, SMD*
D. Stefan Dancila, *Dancilla LLC*
Dan Durda, *SwRI - Boulder*
Dennis Ebbets, *Ball Aerospace & Technologies Corp*.
Ed Friedman, *Ball Aerospace & Technologies Corp*.
Joseph Gauthier, *United States Air Force, Space Command*
Larry Germann, *Left Hand Design Corporation*
T. Gregory Guzik, *Louisiana State University*
Keith Harrison, *SwRI - Boulder*
Don Hassler, *SwRI - Boulder*
Deborah Husby, *Aerostar International, Inc*.
W. Vernon Jones, *NASA Headquarters, SMD*
David Kaufmann, *SwRI - Boulder*
David Klumpar, *Montana State University - SSEL*
Jerry Knoblach, *Space Data Corp*
Tim Lachenmeier, *Near Space Corporation*
Derek Lamb, *University of Colorado*
Ralph Lorenz, *JHU/APL*
Michael Manes, *Edge of Space Sciences, Inc*
Robert Martin, *Composite Mirror Applications*
Reinhard Meller, *Max-Planck-Institute for Solar System Research*
Curtis Miller, *Space Grant, University of Colorado*
R. Gilbert Moore, *Project Starshine*
Todd Neff, *Daily Camera*
Peter Nelson, *High Altitude Observatory*
Cathy Olkin, *SwRI - Boulder*
Jonathan Ormes, *Denver University*
Thomas Parnell, *University of Alabama, Huntsville*
William Perry, *Southwest Research Institute*
David Pierce, *NASA GSFC, Balloon Program Office*
Scot Rafkin, *SwRI - Boulder*
Jonathan Rall, *NASA Headquarters, SMD*
Randy Rose, *Synthsys-D Inc*
John Sample, *UC Berkeley Space Sciences Lab*
Orlando Santos, *NASA Ames Research Center*
Brian Sanders, *Space Grant, University of Colorado*
David Schiminovich, *Columbia University*
Cindi Schmitt, *ASRC Aerospace*
Kevin Shoemaker, *Shoemaker Labs, Inc*.
Michael Smith, *Aerostar International, Inc*.
Dale Sommerfeldt, *Scientific Instrumentation Ltd*
Alan Stern, *NASA Headquarters, SMD*
Guy Stringfellow, *CASA, University of Colorado*
Henry Throop, *SwRI - Boulder*
Feng Tian, *NASA postdoctoral program*
Erin Tucker, *Space Grant, University of Colorado*
L. Paul Verhage, *NearSys*
Ted von Hippel, *University of Texas*
Jonathan Weinberg, *Ball Aerospace & Technologies Corp.*
Mark West, *Aerostar International, Inc*.
Bill Wood, *The Skunk Works, Lockheed Martin Aeronautics*
Leslie Young, *SwRI - Boulder*