AN OVERVIEW OF THE NASA SOUNDING ROCKETS AND BALLOON PROGRAMS

P. J. Eberspeaker, *Chief, Sounding Rocket Program Office*
D. D. Gregory, *Mission Operations Manager, Balloon Program Office*
National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337 USA

ABSTRACT

The U. S. National Aeronautics and Space Administration (NASA) Sounding Rockets and Balloon Programs conduct a combined total of 40 to 50 missions per year in support of the NASA scientific community and other users. The NASA Sounding Rockets Program supports the science community by integrating their experiments into the sounding rocket payloads, and providing both the rocket vehicle and launch operations services. Flight operations have been conducted at Andoya Rocket Range, Poker Flat Research Range, Whites Sands Missile Range and Wallops Flight Facility. Development efforts include the Mesquito and Terrier-Improved Malemute launch vehicles as well as new attitude sensors and systems. The NASA Balloon Program provides balloons, data acquisition, and launch and flight operations support to the science community. Flight operations have been conducted in Antarctica; Sweden (Esrange); Palestine, Texas; and Ft. Sumner, New Mexico. Flights have included conventional and long duration balloons as well as a successful demonstration flight of the NASA Super Pressure Balloon. Technology initiatives include the development of parachute shock attenuation systems and an upgraded gondola automatic parachute release system.

1. INTRODUCTION

The balloon and sounding rocket operations offer a unique approach to space flight for the purpose of addressing scientific and technical problems inherent in space-based investigations. The overall objectives for balloon and sounding rocket flights are low cost and frequent access to space in order to:

- Address diverse scientific problems in a wide range of scientific disciplines including physics, astronomy, astrophysics, geophysics, and earth sciences.
- Flight-test new technologies and techniques relatively inexpensively.
- Provide hands-on training for students on time scales consistent with university schedules.

Sounding rockets and balloon investigations are characterized by the diversity in the number and types of scientific investigations. In a typical year they support 40 to 50 flights involving about 200 scientists from more than 60 different institutions, including about 40 U.S. universities in about 30 states and 10 to 12 other countries.

Sounding rockets and balloons support cutting-edge, world class science for instruments weighing several kilograms to several thousand kilograms. Sounding rockets and balloons continue to provide the quick response and relative low-cost solution for instrument development destined for on-orbit science (i.e. COBE). Sounding rockets and balloons also serve as the ultimate vehicle of choice for low-cost near space applications (i.e. BOOMERANG and JOULE-2).

In addition, sounding rockets and balloons continue to be a primary hands-on learning and applications venue for experimentalists that form the foundation of the NASA space science missions. Graduate student involvement is at the very core of the program. In many cases the graduate students lead the efforts to create, develop, and fly the experimental hardware for scientific investigations. Many experiments also involve undergraduates, who may go on to careers unrelated to space, but their contribution to space activities is enduring and is essential to society's advancements in science and technology.

2. SOUNDING ROCKET PROGRAM

The Sounding Rocket Program launches approximately 20 missions annually, with payload masses ranging from 23 kg (~50 lb.) to 700 kg (~1500 lb.). Sounding rockets provide a cost-effective way to make *in situ* observations in the altitude regime of 50 to 1500 km above the near-earth environment. They uniquely cover the altitude regime between 50 km and 130 km above the Earth's surface, which is not accessible by either balloons or satellites. Flight times are typically 5 to 20 minutes in duration. Launch vehicles range from single stage rockets

Proc. '19th ESA Symposium on European Rocket and Balloon Programmes and Related Research, Bad Reichenhall, Germany, 7–11 June 2009 (ESA SP-671, September 2009)

capable of lifting a 9 kg (20 lb) payload to an altitude of 100 km to a four-stage vehicle capable of carrying a 114 kg (250 lb) payload to an altitude of 1500 km.

NASA sounding rocket vehicles are composed of commercially available rocket motors (Black Brant and Nihka) and military surplus motors (Terrier, Taurus, Talos, etc.). New vehicles are currently under development. These include the Mesquito (M26-Dart) and the Terrier-Improved Malemute.

2.1 Sounding Rocket Science

NASA's Science Mission Directorate (SMD) sounding rocket science and technology investigations are peer reviewed and competitively selected via NASA Research Announcements (NRA). The flight rates for the various science disciplines for FY2006 through FY2009 are listed in Table 1. The FY09 entries represent missions that have flown as of May 2009, and those planned for the second half of the fiscal year.

Table 1 – Flight Rates
(FY09 is flown & planned)

Discipline	FY 06	FY 07	FY 08	FY 09
UV/Optical Astrophysics	0	1	1	3
High Energy Astrophysics	0	1	1	1
Solar System Exploration	0	0	0	0
Heliosphysics (solar & geospace)	2	14	6	10
Technology/Test	4	1	3	5
Student	2	0	1	2
Reimbursable / Non-Core	14	1	1	9
Year Total	**22**	**18**	**13**	**30**

2.2 Campaigns and Missions

The NASA Sounding Rockets Program continues to conduct missions from points around the globe. While the “campaign mode” has not been exercised in recent years, operations have continued at Andoya Rocket Range. The Svalbard launch option has been reestablished and an option for limited flights from the Kwajalein Atoll are being offered in the current Research Opportunities in Space and Earth Science (ROSES). Highlights of field operations over the last two years are as follows:

2.2.1 White Sands Missile Range

White Sands Missile Range (WSMR) still serves as the program’s primary site for solar and astrophysics missions. Five NASA missions were flown from WSMR in FY 2007, and four were flown in FY 2008. Of these 9 flights, one was an attitude control system test, and eight were science missions. Seven WSMR flights are currently on schedule for FY 2009, with two already flown.

2.2.2 Poker Flat Research Range

While the SRPO has transitioned back to annual operations at Poker, there were no missions scheduled for 2008 due to the timing with the proposal cycle. The 2009 campaign, conducted in January, February, and March of 2009, involved one educational flight and seven science flights. Missions included four Terrier-Improved Orions that were launched in two separate pairs. The payloads included both Trimethylalumimum (TMA) and instruments. A second mission involved a single stage Black Brant and a Terrier-Black Brant launched within 90 seconds of one another. The goal of this mission was to have the two payloads flying though the same magnetic field lines at the same time during the scientific data period. The third mission involved a very complex payload that deployed two Particle Free Fliers (PFF), and two e-field subpayloads. Each e-field subpayload included 12 meter tip-to-tip wire boom systems developed by Cornell University. All of the missions were flown successfully with good scientific data obtained. Figure 1 shows aurora over the launch pad. The next Poker campaign is scheduled for January 2010.

Figure 1 – Poker Aurora

2.3.3 Wallops Flight Facility

A total of seven missions were launched from Wallops Flight Facility in the 2007 and 2008 time frame. These flights supported one science mission, two vehicle development tests, one educational project and three technology demonstration projects. Ten flights are currently scheduled to be launched from Wallops in FY09. Several of these flights will involve flight tests of new vehicle stacks (see Section 2.4).

2.2.4 Andoya Rocket Range

Three rockets were successfully launched from Andoya Rocket Range in the December 2007 and January 2008 time frame. Two Black Brant XII rockets, shown in Figure 2, were launched within 2 minutes of one another.

Figure 2 – Two BBXII vehicles rising to the launch position at Andoya Rocket Range

The goal, which was achieved, was to have the high flier and low flier payloads intersecting the same magnetic field lines near apogee. The third mission, which involved another Black Brant XII vehicle, was also successful in achieving its scientific objectives. The next Andoya flight is currently scheduled for January 2011.

2.3 High Altitude Launch Vehicles

The high altitude Black Brant vehicles (BBXI and BBXII) were returned to operational status following a high altitude ignition demonstration mission conducted in September of 2006. All four subsequent high altitude missions have successfully used the Black Brant MK1 motors, as have numerous Terrier-Black Brant missions.

Detailed analysis of flight data collected on multiple flights since the return to flight mission has revealed an interesting vehicle dynamic associated with fin stabilized, solid propellant vehicles operating at the fringe of the atmosphere. The NASA Sounding Rocket Program will continue to collect data on high performance flights to better characterize the phenomena.

2.4 Technology Developments

The Sounding Rocket Program Office continues to infuse new technologies into the program to enable new scientific and engineering investigations. Examples of these efforts include:

2.4.1 Mesospheric Sounder (MLRS-Dart)

The Mesospheric Sounder (also known as the Mesquito) is based on the U.S. Military Multi-Launch Rocket System (MLRS) rocket motor. The design goal is to carry a 10 cm (4 inch) diameter instrumented non-propulsive dart with a 3.2 kg (7 lbs) experiment to an altitude of 100 km. This low-cost system will allow instrumented payloads to be injected into a geophysical event with minimal perturbation and will enable temporal investigations over several days or weeks.

Figure 3 – Mesquito Liftoff

The first two developmental flights were conducted in March 2008. The first launch is shown in Figure 3. Both un-instrumented vehicles experienced apparent fin loss just after Dart separation approximately 2 sec. into the flight. The failures were most likely due to instabilities induced during the supersonic separation event. The resulting angle of attack created aerodynamic loads that exceeded the design limits. The most difficult element of the mechanical design was the mechanical attachment of the fins. The design had to rely on the attachment points for the original hinged fin system. A new fin mounting design has subsequently been developed and four test flights are scheduled for summer 2009. The first two flights will have the dart pinned to the booster motor to verify the complete system stack will survive the aerodynamic loads. The second pair of flights will allow for dart separation and is intended to demonstrate the clean separation of the dart and booster motor. All four flights will be instrumented with new miniaturized electronics (see section 2.4.3)

2.4.2 Terrier – Improved Malemute

The NASA Sounding Rocket Program is currently developing a new surplus vehicle composed of the Terrier

Mk70 booster and what has been dubbed the Improved Malemute. As part of the development effort, a static firing will take place at Wallops Flight Facility in July 2009. The vehicle stack will leverage existing hardware including much of the hardware that was used on the standard Malemute rocket stage. The first test flight will take place at Wallops Flight Facility sometime in late summer 2009.

2.4.3 Miniaturized Avionics

The Mesquito system (see Section 2.4.1) requires compact and robust flight electronics to meet the acceleration levels and packaging constraints of the 10 cm diameter Dart. The RF transmitter, encoder, power control module and lithium-ion batteries are designed to withstand the anticipated 135 G's at lift off.

2.4.4 Wallops Acceleration and Attitude Sensor Package (WAASP)

The Wallops Acceleration and Attitude Sensor Package (WAASP) was developed to provide low-cost, reasonably accurate payload attitude using a magnetometer and solar sensors. This system requires some relatively painstaking post flight data analysis and is limited by the accuracy of the magnetometer. While the published accuracy is on the order of 3-5 degrees, its low cost is attractive for many applications not requiring high precision.

2.4.5 Real Time Attitude Solution (RTAS)

This compact sensor suite consists of a Gumstix flight computer, solar sensors, digital magnetometer, horizon crossing sensor, and a miniature rate gyro. This system utilizes a sensor suite similar to that of the WAASP so the accuracy is similar (3-5 degrees). The advantage is in the Gumstix flight computer, which is capable of calculating the attitude solution in real time. The RTAS will likely replace the WAASP once adequate flight heritage has been achieved. To date, the RTAS has flown twice.

2.4.6 High Data Rate Data Collection

The NASA Sounding Rocket Program has begun work to enable data rates up to 150 Mbps (and possibly higher). This will be accomplished by utilization of X-band data transmission for real time downlink or onboard digital recording for situations where X-band can not be used. The telemetry link system will utilize an X-band wrap around antenna, a Low Cost TDRSS Transceiver (LCT2), GPS time tagging, and a yet to be developed data encoder. The first test flight of a developmental system is currently planned for February 2010.

An on-board data recording unit will be used on recovered missions that can not utilize the X-band spectrum. The most promising approach is to utilize the Goddard Space Flight Center's SpaceCube that is currently under development. A test flight is currently planned for June 2010.

2.5 Education and Work Force Training

The NASA Sounding Rocket Program supported two educational missions in the 2008 and 2009 time frame. The first flight of the RockOn Workshop payload was flown from Wallops Flight Facility in June 2008. The payload carried approximately 20 experiments assembled by the workshop participants. The post-flight celebrations are shown in Figure 4.

Figure 4 – RockOn workshop participants disassemble the payload after flight

The RockOn Workshop was conducted over a one week period where participants built, tested, and integrated experiment kits and then participated in launch activities. Experiment kits included a flight computer, a Geiger counter, and an accelerometer suite. RockOn II is scheduled for June 2009, with a repeat of the kit concept as well as more sophisticated student built RocketSats.

A single stage Orion carrying an engineering experiment for the University of Alaska was also launched from Poker Flat Research Range in January 2009.

2.6 Program Implementation

The NASA Sounding Rockets Program is managed by a small office of ten civil service employees and implemented by approximately 165 contractor personnel working under the NASA Sounding Rocket Operations Contract (NSROC). The NSROC contractor team is lead by Northrop Grumman with team members including Orbital Science Corporation, Reliant Systems Services Corp, and Arcata Associates. The NSROC I contract has been extended by one year to allow for the completion of the NSROC II procurement activities.

2.7 Future

The NASA Sounding Rocket Program is currently undergoing a rejuvenation with a budget that will support an annual flight manifest of 24 flights plus reimbursable activities. NASA recognizes the program as an excellent tool for unique science investigations, new instrument development, technology maturation, and work force development. New projects and proposals include solar experiments, space physics experiments, Mars atmospheric entry system development, smart-lander technology development, and a host of other exciting concepts. Many of these projects offer new and unique challenges for the NASA Sounding Rocket Program Office and its NSROC contractor.

3. NASA BALLOON PROGRAM

NASA's Scientific Balloon Program supports science and technology development for projects that require near-space environment. Table 2 shows missions supported in fiscal years 2005 through 2008 and for missions planned in 2009 (fiscal year is October 1 through September 30.) Test flights are conducted to support development of new ballooning capabilities. Special Projects includes missions in support of educational grants as well as space article testing and technology development for other NASA Centers.

Table 2 – Flight Rates

Discipline	FY 05	FY 06	FY 07	FY 08	FY 09
IR/Sub-mm Astrophysics	2	1	1	0	2
Particle Astrophysics	3	4	1	3	3
Gamma Ray X-Ray Astrophysics	3	1	3	0	2
Solar & Heliospheric	0	1	4	1	3
Upper Atmos. Research	2	2	3	0	2
UV Optical	-	-	-	-	1
Special Projects	4	1	1	1	2
Test Flight	1	3	5	9	4
Year Total	15	13	18	14	19

NASA balloons provide a wide range of payload and altitude support capabilities. The majority of missions are high-altitude heavy-lift balloons using the 0.8 million cubic meter (MCM) and 1.11 MCM design balloons. NASA standard-design balloons are listed in Table 3.

Table 3 – NASA Balloons

Balloon Size (million cubic meters)	Maximum Suspended Weight (kgs)	Float Altitude (kilometers)
1.66	748	48
1.11	2722	38.7
1.02	3629	36.3
0.8	2948	36
0.33	3379	29.7
0.33	1304	35
0.11	1587	29

3.1 Program Implementation

The NASA Balloon Program is comprised of the program office located at NASA Wallops Flight Facility and the Columbia Scientific Balloon Facility located at Palestine, Texas. The program office is comprised of 8 civil servants and 3 contract support personnel. Balloon operations are accomplished through the Columbia Scientific Balloon Facility (CSBF). New Mexico State University's Physical Science Laboratory operates the CSBF. CSBF employs 75 personnel. Additional personnel from Wallops and PSL provide project support as needed.

3.2 Flight Program

NASA continues to provide support for conventional and Long Duration Balloon (LDB) missions each year. Typical durations for conventional flights are 4 to 36 hours duration. Longer duration "Conventional" flights of 24 to 36 hours are achieved from Fort Sumner, New Mexico during stratospheric wind turnaround each spring and fall. Long Duration Balloon (LDB) flights lasting several days duration are launched each year from Antarctica. LDB and conventional missions are launched from other remote locations as needed in support of science requirements.

NASA scientific balloon launch sites include Fort Sumner, New Mexico; Palestine, Texas; McMurdo, Antarctica; Alice Springs, N.T., Australia and Esrange, Kiruna, Sweden. Antarctica LDB missions are launched annually from Williams Field near McMurdo Station with flight durations lasting several days or weeks depending upon requirements.

LDB missions are launched from Esrange every other year. Esrange LDB missions fly 5-7 days to the west and are recovered in northern Canada. NASA's goal is to launch LDB missions annually from Esrange as requirements dictate and resources become available. While Esrange LDB flights have been shorter duration than those launched in Antarctica, global overflight clearances would provide northern hemisphere LDB opportunities for 21 or more days flight duration; thus, greatly enhancing the return on science.

3.3 Operational Enhancements

NASA and the U.S. National Science Foundation (NSF) are currently working toward provision of additional aircraft recovery assets for support of Antarctic LDB missions. Possible options include a second Basler DC-3 or Twin Otter (Figure 5) with the goal of providing dedicated support for NASA balloon flight terminations, payload recoveries and balloon recoveries during the same season. In recent years, one Basler DC-3 and a few Twin Otters have been shared each year between various NSF projects and the NASA LDB program.

Figure 5 – Twin Otter on Antarctic LDB recovery.

NASA is planning for a conventional southern hemisphere campaign in 2010 to be conducted from Alice Springs, Australia. Working with the University of New South Wales and CSIRO, NASA has funded the construction of a new payload preparation building that will be co-located with the existing balloon launch facilities at the Alice Springs airport. This new building will accommodate up to 4 -5 payloads.

During the 2008/2009 Austral summer season, NASA and NSF completed the third Antarctic LDB campaign supporting three flights. Existing Antarctica facilities were designed to support two payloads but judicious scheduling and planning by CSBF have allowed for preparation of three payloads at a time. Nonetheless, NASA remains committed to its plans to construct a third Antarctic LDB payload building as resources become available.

NASA completed a successful test flight of a 0.201 MCM super-pressure balloon that carried 680 kilograms to 33 kilometers for over 54 days flight duration. By the end of 2009, NASA will complete two long duration test flights on 0.396 MCM super-pressure balloons that will carry 1996 kilograms to 33 kilometers. NASA is now offering these vehicles for consideration as part of NASA's announcements of opportunity. Combined with the lightweight CSBF Micro Instrument Package (MIP), which utilizes satellite telemetry and command relay, NASA now has the capability of supporting global missions for extended durations for science instruments less than 226 kilograms mass. By the end of 2009, NASA will demonstrate the capability to support extended duration missions for science instruments less than 454 kilograms mass. However, NASA's goal remains to qualify a 0.6 MCM super-pressure balloon that will carry 2721 kilograms to 33.5 kilometers by the year 2012.

3.4 Technology Development

The NASA balloon program maintains an ongoing broad range of balloon technology and flight support systems development activities in order to meet new customer requirements or improve upon existing capabilities.

3.4.1 NASA Standard Balloons

NASA, CSBF and Aerostar International maintain an ongoing program of excellence in balloon manufacturing and quality assurance. An excellent flight success rate on standard NASA balloons is the result of aggressive and conscientious quality control throughout the film extrusion and balloon manufacturing process.

3.4.2 Ultra Long Duration Balloon Vehicle

The NASA test flight of a 0.201 MCM super-pressure balloon from Williams Field Antarctica on December 28, 2008 was the most successful flight of the entire super-pressure balloon development project [1]. This 200-gore balloon was 82.6 meters in diameter and 51.7 meters tall

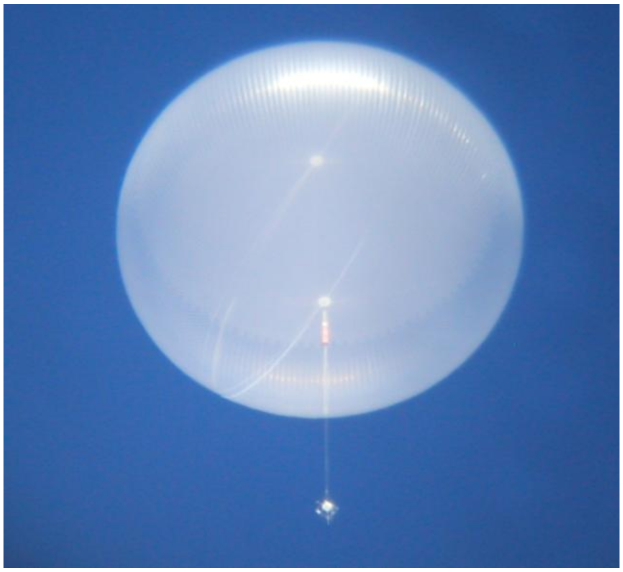

Figure 6 – 0.201 MCM Super-Pressure Balloon At Float Altitude.

when fully inflated and pressurized. It was designed for a maximum differential pressure of 125 Pa (Figure 6) [2].

The flight preparations and launch process was similar to the previous super-pressure balloon test flights. Pre-flight predictions were very good matches for the actual performance of the flight. The flight fully deployed just before reaching the target float altitude at essentially no differential pressure. It remained at the designed float altitude for the duration of the flight and demonstrated stable pressure for the entire flight. The balloon flew 54 Days, 1 hour and 29 minutes, which was a new record for this type and size balloon. The flight performance was exceptional. Daily altitude variations for the duration of the flight were bounded within 100 to 150 m over a 24-hour period. This was an order of magnitude better than the successful zero-pressure flights during the same Antarctic season. There was no detectable gas loss in the structure over the entire flight. Atmospheric changes over time were noticeable in the flight data since the balloon flew at near constant pressure altitude.

Near the end of the flight, all of the available ballast was incrementally dropped to pressurize the system to the maximum extent possible. Indications are that the balloon could have flown indefinitely with no performance degradation seen for the entire flight. NASA will scale up the design for future test flights toward meeting the project goal for development of a balloon vehicle capable of carrying 2,721 kilograms to 33.5 kilometers for 60-100 day duration missions.

3.4.3 Ultra Long Duration Balloon Support Systems

The fourth mission utilizing the ULDB Command Data Module (CDM) was flown in support of the CREAM mission launched from Antarctica in December 2008. CREAM and CSBF modified their respective systems to allow use of the LDB Support Instrument Package (SIP) in support of Ultra Long Duration Balloon (ULDB) type missions. These modifications provide the same higher data rates and power systems capabilities necessary for ULDB type missions, thus leveraging existing assets to achieve reduced costs. Used in conjunction with the newly developed super-pressure balloons, the CDM and SIP-U are designed to support ULDB missions up to 60 or more day durations by incorporating data and command telemetry systems utilizing TDRSS and Iridium as well as the capability to provide power to both the NASA support systems and the science instrument. Higher return data rates are achieved using an autonomous pointing high gain antenna to achieve 100 kilobits per second continuous return via TDRSS. With the successful demonstration of these new assets, routine NASA ULDB missions are now possible for lighter weight payloads.

3.4.4 Gondola Automatic Parachute Release

CSBF’s Gondola Automatic Parachute Release (GAPR) successfully completed qualification testing [3] and is now routinely used to provide assurance of parachute separation on ground impact, thereby mitigating risk of payload damage due to dragging. Designed for use in Antarctica and the most remote impact-recovery sites, the GAPR is activated prior to flight termination in order to automatically separate the parachute from the gondola upon impact with the ground. The GAPR eliminates system vulnerabilities to parachute opening shock loads that may damage electronic flight components that subsequently could prevent manually sent parachute separation commands from getting through.

3.4.5. Parachute Opening Shock Attenuation

CSBF completed qualification of a new shock attenuation system that virtually eliminates parachute-opening shock loads. Work is underway to expand CSBF’s inventory of these devices for multiple combinations of parachute and payload configurations. Incorporating rip-stitch technology, chute opening shock reductions have been realized (fig. 7) [3], thus greatly mitigating risk of damage to payloads and offering the possibility for relaxation of future structural requirements subsequent to additional testing and analyses. Prior to incorporating these devices, parachute-opening shock loads approaching 100 g were common.

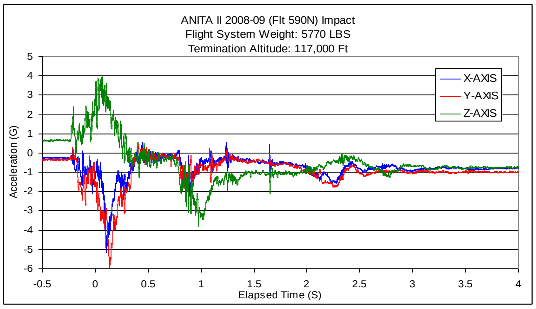

Figure 7 – NASA Flight 590N Reduced Parachute-Opening Shock.

3.4.6. Micro-Instrument Package

CSBF's Micro-Instrument Package (MIP) has completed qualification testing [3] and has been put into inventory as a lightweight and lower-power telemetry, command and flight control system. The MIP flawlessly supported continuous operation on the 54 day Antarctica super-pressure test flight conducted during the last Antarctica campaign. The MIP provides satellite as well as line-of-sight communications with the balloon.

3.4.7 Arc-second Pointing System

NASA successfully demonstrated a bench prototype arc-second pointing system. The Wallops Arc-second Pointer (WASP) prototype established the feasibility for development of systems that can support a variety of balloon requirements. This is not a one-size-fits-all design; rather, it is part of a tiered system based on a common subset of controllers and firmware that can be tailored to meet specific instrument requirements. The WASP incorporates an intermediary step of pointing control by use of the existing LDB Solar Pointing System (SPS) for rough pointing and use of sub arc-second systems integral to the instrument. NASA is planning further development and test flight of this intermediary sub-system in 2009 and 2010.

3.4.7. New Balloon Vehicle Design Initiatives

In partnership with other developers, NASA is providing support with materials, design and testing of planetary balloon concepts and terrestrial aerostats. As these technologies mature, NASA will leverage any enhancements to benefit the scientific community.

3.5 Education and Outreach

The NASA balloon program in partnership with CSBF and Louisiana State University (LSU) annually supports student payloads. The LSU High Altitude Student Payload (HASP) accommodates multiple student experiments on a single payload launched each fall from Fort Sumner, New Mexico. LSU is working to expand HASP's capabilities and opportunities to support more student science in years to come.

CSBF and the New Mexico State University Physical Science Laboratory provide excellence in undergraduate science and engineering training through the Suborbital Center of Excellence (SCE). SCE offers undergraduates with projects aligned with NASA and other sub-orbital and space related interests to include balloons, UAVs and sounding rockets. SCE annually provides highly skilled and highly motivated undergraduates who work cooperative education assignments in NASA's balloon program.

3.6 Future

NASA ballooning continues working toward meeting the goals and priorities set by the balloon science community [4]. NASA and NSF have renewed their five-year agreement to conduct Antarctica scientific ballooning, which remains in effect through March 2014. NASA remains committed to supporting more science, as requirements dictate, by offering a multi-instrument bus incorporating a common command, telemetry, power and gondola payload system. The NASA balloon program will continue to work with its international partners to conduct northern hemisphere conventional and LDB missions. Southern hemisphere LDB and ULDB capabilities remain a high priority for NASA ballooning. Extended duration flights capable of supporting smaller payloads by use of the MIP, 0.201 MCM and 0.396 MCM super-pressure balloons are now a reality. Extended duration missions capable of supporting heavier payloads with fine pointing controls are on the near horizon.

1. Cathey, H., *Internal NASA balloon program report, NASA, 2009.*
2. Smith, M. *Photograph of 0.201 MCF super-pressure balloon at float over Williams Field, Antarctica, Aerostar, Inc. 2008.*
3. Ball, D., et al., *Internal reports to NASA, CSBF, 2009.*
4. Israel, M., et al., *Revised Balloon Report: NASA Stratospheric Balloons: Pioneers of Space Exploration and Research, Report of the Scientific Ballooning Roadmap Team*, NASA, 2008.