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Meeting the Challenge of Balloon-Borne Science Missions

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The National Aeronautics and Space Administration (NASA) Balloon Program is committed to meeting the challenge of the science community to enable extended duration and global scientific investigations based on the development of advanced balloon vehicles and support systems. It is also committed to inspiring future generations of scientists and engineers through active educational outreach activities and student launch programs. The Swedish Space Corporation/Esrange and NASA inaugurated a joint capability for medium-duration heavy-load scientific balloon flights from Sweden to Canada or Alaska beginning in June 2005. This capability will complement the NASA/U.S. National Science Foundation (NSF) Office of Polar Programs achievement of more than a decade of successful long-duration flights around Antarctica. Typically, Antarctic flights circumnavigate the South Pole one time, in 8 to 20 days using conventional zero differential pressure balloons. One flight has circumnavigated twice in 31 days, and another went three times around in 42 days. A new super-pressure (constant volume) balloon is currently under development for future flights of 60 to 100 days at any latitude.

1. Introduction

The NASA Scientific Balloon Program is a suborbital space flight program utilized primarily in support of space and Earth sciences research activities sponsored by NASA. Most of the operational and engineering aspects of the Program are accomplished through the activities of the National Scientific Balloon Facility (NSBF), located at Palestine, Texas. NSBF is managed and operated by the Physical Science Laboratory of New Mexico State University located in Las Cruces, New Mexico.

More than 2,000 scientific balloon flights have been conducted by NSBF personnel, with ~80 percent being launched at the permanent launch site in Palestine. The other 20 percent were conducted at remote sites and within the contiguous United States, Alaska and Hawaii. Remote launch sites include locations in Canada, Brazil, Sweden, Australia, New Zealand, Antarctica, Argentina, Sicily, and India. Although some special-purpose larger balloons [1] and heavier suspended payload weights have been launched by NSBF personnel, standard operating limits of approximately 1.11 million cubic-meter (MCM) volume balloons and suspended weights of 3600 kg are currently in effect. The routine launching of balloons with volumes greater than 0.7 MCM with suspended weights greater than 2000 kg is a unique capability in scientific ballooning provided by NASA. The suspended load capabilities of NASA's zero differential pressure, more commonly referred to as "zero-pressure", balloons are shown in Figure 1.

2. Development of Long Duration Ballooning (LDB)

In the late 1980's, NASA made a decision to extend the capabilities of zero-pressure balloons and to develop a near global Long Duration Ballooning (LDB) capability. The LDB plan included systems required to conduct flights with scientific experiments having mass of 680 kg or more on zero-pressure and special-purpose balloons for periods of up to three weeks. Operational implementation of LDB represented a new capability in scientific ballooning. Further development of flight support systems and the balloon vehicle has continued to increase the flight capability and duration of LDB missions.

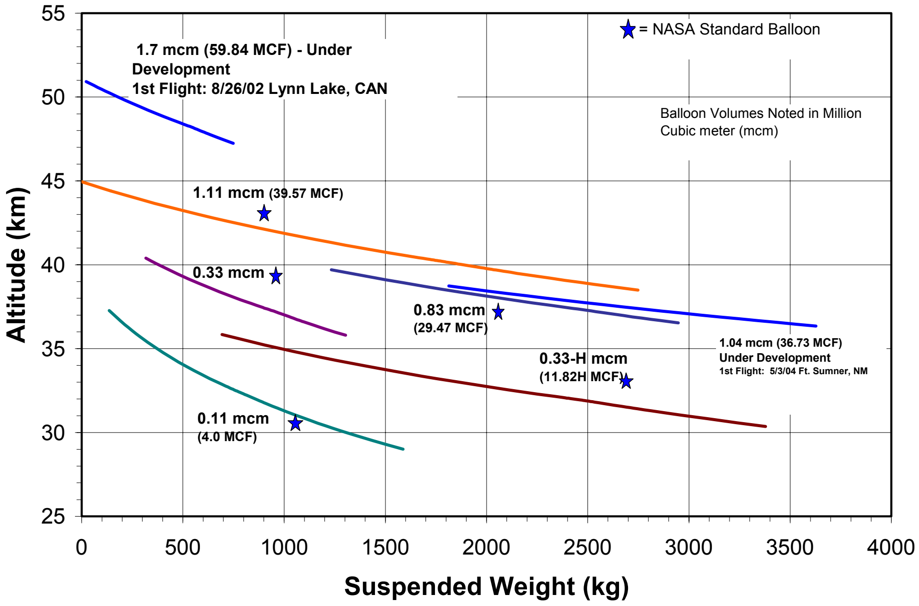

Figure 1. Suspended weight capability of the NASA's zero-pressure balloons.

Most of the LDB missions are currently conducted from Antarctica during the Austral summer. Typical missions are 8 - 20 days. In 2002, a record was set when a 0.83 MCM balloon carrying the Trans Iron Galactic Element Recorder (TIGER) payload flew for a duration exceeding 31 days [2]. In 2005 a new LDB flight record was set when a 1.11 MCM balloon carrying the Cosmic Ray Energetics and Mass (CREAM) experiment flew for over 41 days [3].

NASA's LDB missions are not limited to the southern hemisphere. Recently, NASA and the Swedish Space Corporation/Esrange inaugurated a joint capability for medium-duration heavy-load scientific balloon flights from Sweden to Canada or Alaska. In June 2005, a 1.11 MCM balloon was launched from Kiruna, Sweden carrying the 2700 kg Balloon-borne Large-Aperture Sub-millimeter Telescope (BLAST) payload [4]. The westerly flight, which lasted for 4.2 days, was terminated over Northern Canada, approximately 315 km northwest of Cambridge Bay on Victoria Island. The average float altitude was 39 km.

3. Development of Ultra Long Duration Ballooning (ULDB)

In the late 1990's, NASA decided to extend balloon systems again in order to realize Ultra Long Duration Ballooning (ULDB) at any latitude. Currently under development, ULDB will extend the operational concept of LDB capabilities to flights of 100 days or more. The key ULDB system element is a pumpkin shaped super-pressure balloon capable of extended duration flights without consumables at any latitude. Technology advancements include the development of a variety of composite materials for the ULDB envelope, the utilization of the highest strength-to-weight synthetic fibers available to date, commercially labeled as "Zylon®", and the practical application of a "lobed" structure. With suspended loads of up to 2800 kg, the ULDB balloons are intended to fly at nearly constant float altitude densities without the need for ballast. Numerous scaled model balloons have been fabricated and tested in the development program. Figure 2 shows the 200 gore 14.3-meter diameter model of the 0.17 MCM ULDB.

Figure 2. ULDB Scaled Model Balloon.

4. Pushing the Envelope

Other technologies in support of additional enhancements to existing capabilities are also being pursued. Most notable is the development of a propeller driven trajectory modification system that would allow recovery over dry land and aid in alleviating the safety and geopolitical constraints for ULDB missions. Plans are also underway to develop technologies that would allow planetary ballooning on Mars and Venus. Novel materials, new balloon designs, and innovative air inflation techniques are just a few of these emerging technologies. Validation of both Montgolfiere and super-pressure type balloons are underway to demonstrate aerial deployment and inflation from a stowed configuration. Deployment Experiments for Ballooning on Mars (DEBOM) was established to study the inflation rate and stability effects of different balloon types. Over 125 different experiments were conducted from a tethered aerostat, as shown in Figure 3. Montgolfiere balloons and para-balloons were studied with (Figure 4) and without (Figure 5) burble fences.

Most recently, new balloon support systems, including the Command Data Module (CDM) for ULDB Missions, have also been developed and test flown [5]. The CDM was first used on the CREAM/LDB Mission launched from McMurdo station, Antarctica [3]. This advanced ballooncraft support system is needed to provide redundant, reliable power and high-data-rate communication systems for long-duration flights. The system contains a number of enhanced communication systems. Most notable are the development and implementation of a low-cost Tracking and Data Relay Satellite System (TDRSS) High Gain Antenna (HGA) with 100 Kb/s real-time telemetry and an Iridium based communication system that allows continuous coverage at reduced operational cost.

The Balloon Program Office has also developed a new balloon to reliably provide a 3600 kg lift capability. Several design improvements were implemented to ensure success. The first test flight was conducted from Ft. Sumner, NM on May 3, 2004.

5. Building the Next Generation of Balloon Scientists and Engineers

In 2002, the BPO funded the creation and operation of the Suborbital Center of Excellence at New Mexico State University [6]. The primary purpose is to help create balloon engineers, scientists, and technologists. In this process, students at the secondary school, undergraduate, and graduate levels will be working with faculty, NASA, and industry mentors gaining hands-on experience with suborbital problems as part of their education. In addition, NASA supports education through the Educational Flight Projects Office (EFPO). This effort provides undergraduate through master degree students the opportunity to plan, construct, participate in flight operations, and analyze data from experiments flown on suborbital platforms. such as rockets and stratospheric balloons provided by NASA. The programs are meant to be equally relevant to students in academic fields as diverse as science and engineering, education, business administration, industrial management, and/or public relations.

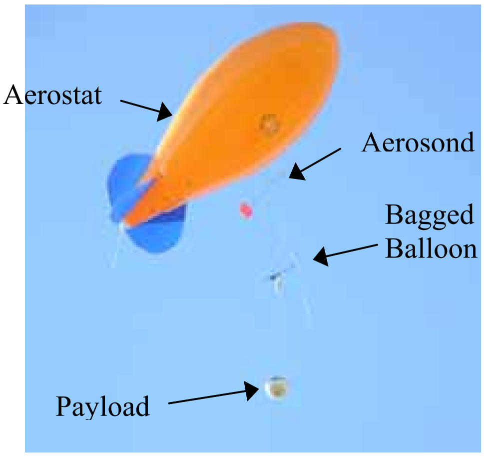

Figure 3 . DEBOM

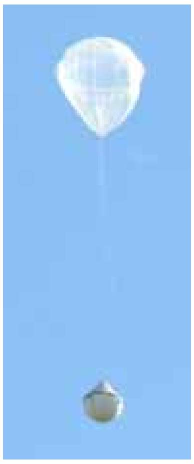

Figure 4. Montgolfiere with Burble Fence.

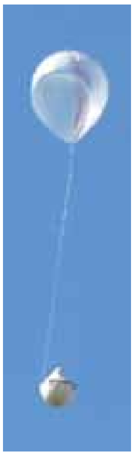

Figure 5. Montgolfie Balloon

6. Conclusions

The NASA Balloon Program has over 40 years experience in Scientific Ballooning and over 14 years experience operating LDB Missions from Antarctica [7]. It offers low-cost, near-space access to a wide range of scientific disciplines. Payloads ranging from a few hundred to a few thousand kilograms are carried to float altitudes of up to 48 km. Recent developments and enhancements have enabled heavy payloads, extended durations, higher data transmission rate, more power, and global coverage in the polar regions. Technological developments for planetary ballooning are currently focused on new materials, aerial inflation, structural designs, and other support systems for planned Mars and Venus missions. The NASA Balloon Program is also actively preparing the next generation of scientists and engineers through a number of student related activities.

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