The Super Pressure Balloon (SPB)

Extended duration stratospheric flights of large science instruments at mid latitudes is a goal of the National Aeronautics and Space Administration’s (NASA) Balloon Program Office. Balloon flights near the poles fly in almost constant sunlight. Balloon flying at mid-latitude will experience day-night cycles which limit the flight duration of conventional balloons. Super Pressure Balloons offer the promise of extended duration mid-latitude flights. The goal of these flights is to lift a ton of science to greater than 33.5 km (~110,000 ft).

The Super Pressure Balloon (SPB) is a balloon that always maintains a positive internal pressure in relationship to the environment it is floating in. The NASA Super Pressure Balloon is a sealed structure that is filled with a measured and specific amount of helium lifting gas. The balloon rises after launch, and the helium expands as the ambient atmospheric pressure goes down. The balloon is designed to fly at a specific pressure altitude with a known mass of payload hanging from the balloon.

When the balloon reaches the desired float altitude, the extra helium is not vented off, but fills out the shape and pressurizes the balloon. The amount of helium in the balloon is determined by how much is needed to lift the entire flight system plus some extra to provide an upward force. This extra helium is enough to pressurize the balloon when it reaches the float altitude and also to over pressurize the balloon to the design limits. The Super Pressure Balloon is designed to fly with a positive internal pressure at all times. As the sun heats up the balloon during the day, the internal pressure (differential pressure) increases, and at night when the balloon cools down, the differential pressure significantly decreases, but still above ambient, hence maintaining super pressure condition at all times. The differential pressure range is up to 180 Pa (0.0261 psi). This is a very small internal pressure, but it is enough to keep this balloon flying through the night!

As a result of maintaining near constant volume, SPB will offer greater stability at float altitude with minimal altitude excursion during the day/night cycles when compared to that experienced on conventional or so-called Zero-Pressure (ZP) balloons. This added stability and extended durations at mid-latitudes will enable new science missions that currently are not feasible with ZP balloons.

The Super Pressure Balloon will offer platform stability at float altitude. It will also enable cost effective long duration missions at mid latitudes.

Super Pressure Balloon at float
Design Characteristics of the Super Pressure Balloon

The overall shape of the NASA Super Pressure Balloon is an oblate spheroid (like a sphere, only squashed on the top and bottom). The height is about 60% of the diameter. The Balloon is made up of many separate panels called gores that run from top to bottom on the balloon. The gore edges are heat sealed together along with a tape that contains a very strong and light weight tendon or rope that runs from top to bottom on the balloon. Each of these gores is shaped such that, while under pressure, it has a slightly curved lobed shape, resulting in a “pumpkin” shape for the fully-inflated balloon structure.

An upward looking view of the Super Pressure Balloon at float is shown below. Prior to launch, this sealed structure is filled with a measured and specific amount of helium lifting gas. The balloon rises after launch, and the helium expands as the ambient atmospheric pressure decreases. The balloon is designed to fly at a specific pressure altitude with a known mass (payload + flight system) hanging from the balloon. When the balloon reaches the desired float altitude, the extra helium is not vented off, but fills out the shape and pressurizes the balloon. The amount of helium first put into the balloon is determined by how much is needed to lift the entire mass plus some extra helium to provide an upward force. This extra helium is enough to pressurize the balloon when it reaches the float altitude and enough to overpressurize the balloon to design limits. The Super Pressure Balloon is designed to fly with a positive internal pressure at all times. When the sun heats the balloon during the day it has a higher internal pressure (also called differential pressure since this represents the pressure difference above the atmospheric pressure it is flying in). At night, when the balloon cools down, the differential pressure is much lower, but still above ambient. The differential pressure range of the Super Pressure Balloon is up to 180 Pa (0.0261 psi). This is a very small internal pressure, but it is enough to keep this balloon flying through the night! At float, the super pressure balloon always maintains a positive internal pressure in relationship to the environment it is floating in.

The Super Pressure Balloon is designed to maintain positive pressure at all times, hence constant volume and altitude stability

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Flight 616NT Trajectory

SPB launch - flight 631 NT (Kiruna, Sweden)

Fully deployed super pressure balloon at float (Flight 616NT)

Close view of lobing at float

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**Historical Development and Status**

The development of the Super Pressure Balloon has been evolving through extensive research and development efforts in conjunction with a series of test flights. These test flights have explored various design and deployment aspects, as well as, flight duration. It has also aided in improving the balloon fabrication approaches through new and innovative production processes. Furthermore, advancements in the launch operations techniques have also been achieved.

The incremental approach in the development of the SPB is depicted in the selected recent balloon flights listed below:

- **Test Flight 586NT** – Fort Sumner, NM (June 2008): The goal of this flight was to test balloon deployment. The balloon volume was approximately 56,800 m$^3$ (2,006,000 ft$^3$), 200 gores. The suspended payload was approximately 295 kg (650 lbs.). Total flight time was 4 hours and 7 minutes. The final float altitude was ~31.3 km (~102,800 ft.). The altitude stability was exceptional, on the order of ~90 m (~300 ft.), and the maximum differential pressure measured during this flight was over 360 Pa, a level that represents 1.8 times the design level. The flight goal of full deployment at float was achieved and the flight was terminated by command.

- **Test Flight 591NT** – Williams Field, Antarctica (December 2008): The goal of this flight was to test balloon deployment and flight duration. The balloon volume was approximately 200,000 m$^3$ (7,000,000 ft$^3$), 200 gores. The suspended payload was approximately 680 kg (1500 lbs.). Total flight time was 54 days, 1 hour, and 29 minutes. The final float altitude was ~33.5 km (~110,000 ft.). Full deployment and altitude stability was achieved throughout the mission duration and no gas loss was detected. The flight was terminated by command to adhere to the established flight safety rules to not leave the Antarctic continent.

- **Test Flight 616NT** – Williams Field, Antarctica (January 2011): The goal of this flight was to test balloon deployment and flight duration. The balloon volume was approximately 422,400 m$^3$ (14,900,000 ft$^3$), 230 gores. The suspended payload was approximately 1800 kg (4000 lbs.). Total flight time was 22 days. The final float altitude was ~33.5 km (~110,000 ft.). Full deployment and altitude stability was achieved throughout the mission duration and no gas loss was detected. The flight was terminated by command to retrieve high dollar flight hardware.

- **Test Flight 631NT** – Kiruna, Sweden (August 2012): The goal of this flight was to test the deployment of the new scaled up balloon volume of 532,000 m$^3$ (18,800,000 ft$^3$), with 280 gores. The suspended payload was approximately 2270 kg (5000 lbs.). The final float altitude was ~33.5 km (~110,000 ft.). Full deployment and altitude stability was achieved throughout the mission duration and no gas loss was detected. The flight was terminated by command after short flight due to high winds at float altitude.

The next steps in the development will test the deployment, balloon performance, as well as the long duration of the 532,000 m$^3$ (18,800,000 ft$^3$), with 280 gores balloon. When development ends, NASA will have a 736,238 m$^3$ (26,000,000 ft$^3$) balloon that can carry 1200 kg to 37 km or 1800 kg to 36 km with flight durations of several weeks at mid-latitudes.

*The performance and stability of the Super Pressure Balloon design have been validated through a series of successful test flights*
The Super Pressure Balloon will Enable New Science

The Super Pressure Balloon will play an important role in providing inexpensive access to the near-space environment for science and technology investigations. Mission durations could last from several weeks to a few months at mid-latitudes. In contrast to Zero-pressure type balloons, SP balloons will provide stable platforms with much less altitude excursion at float, as depicted in the flight performance comparison below. This, in turn, will open up opportunities for both greater science return and for new innovative payloads with advanced technologies. Therefore, balloon-borne telescopes, operating in the regions of the spectrum — namely X-rays and γ-rays — that can’t be studied as effectively at the poles because of the strong background of charged cosmic rays funneled in by Earth’s magnetic field, will be enabled to venture into new science and discovery missions onboard a super pressure balloon.

SPB will also provide a platform for making some of the critical measurements that cannot be accommodated from space, or for which there are no planned satellites, with exposures comparable to short-duration spacecraft. SPB will also enable Earth Science investigations for Venture Class at a modest cost and for the development of instruments and subsystems for future use on Earth observing spacecraft.

For more information on the NASA Super Pressure Balloon, Please Contact the Balloon Program Office at (757) 824-1480; or visit http://sites.wff.nasa.gov/code820/; or scan the QR code to the right.

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