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Evolution of scientific ballooning and its impact on astrophysics research

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Abstract

As we celebrate the centennial year of the discovery of cosmic rays on a manned balloon, it seems appropriate to reflect on the evolution of ballooning and its scientific impact. Balloons have been used for scientific research since they were invented in France more than 200 years ago. Ballooning was revolutionized in 1950 with the introduction of the so-called natural shape balloon with integral load tapes. This basic design has been used with more or less continuously improved materials for scientific balloon flights for more than a half century, including long-duration balloon (LDB) flights around Antarctica for the past two decades. The U.S. National Aeronautics and Space Administration (NASA) is currently developing the next generation super-pressure balloon that would enable extended duration missions above 99.5% of the Earth's atmosphere at any latitude. The Astro2010 Decadal Survey report supports super-pressure balloon development and the giant step forward it offers with ultra-long-duration balloon (ULDB) flights at constant altitudes for about 100 days.
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Keywords: Ballooning; Antarctica; NASA balloons; Super-pressure balloons; LDB; ULDB

1. Introduction

Numerous conferences and workshops have been held to commemorate the centennial anniversary of the 1912 discovery of cosmic rays on a manned balloon by Victor Hess while conducting an experiment to understand radiation changes with altitude. He received a Nobel prize for that discovery in 1936. The Montgolfier brothers are credited with inventing and experimenting with balloons in France more than 200 years ago. Figs. 1–3 illustrate the evolution in balloon designs over this span of almost two centuries, starting with the Montgolfier invention (Fig. 1). In the early days, balloons were usually coated fabric filled with hydrogen gas (Jones, 2002). Scientists used them to carry instruments aloft to make in situ measurements of, among other things, atmospheric pressure and temperature. Some of those intrepid scientists suffocated or died of exposure in the bitterly cold upper atmosphere.

Large rubberized balloons capable of reaching altitudes of about 20 km in the atmosphere were introduced in the early 1930s (Fig. 2). Aeronauts in sealed, airtight capsules were able to survive to 60,000 feet ($\sim$18 km). An altitude record of 72,395 feet set in 1935 stood for 12 years, indicating a limit for rubberized balloons.

In 1950 Otto C. Winzen patented the modern day, natural shape balloon (Fig. 3). Those polyethylene balloons with integral load tapes could carry heavy payloads to around 100,000 feet ($\sim$30 km). They played a significant role in paving the way for the U.S. manned space flight program, and they have revolutionized ballooning. Polyethylene balloon film can be extruded into long sheets that can be cut into desired gore patterns. The gores can be heat sealed with load-bearing tapes integrated into the seals, which enables arbitrarily large balloons that can attain very high altitudes. The float altitude depends, of course, on the size of the balloon and the suspended weight. In any case,

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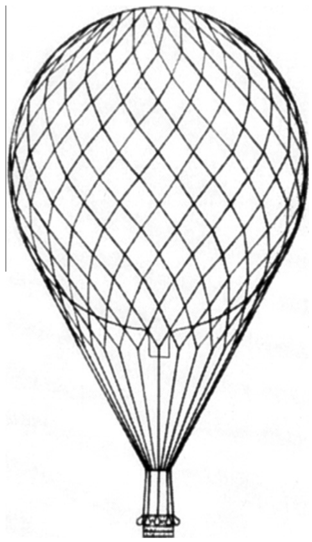

Fig. 1. Illustration of net suspension for varnished silk bag balloon (ca. 1784).

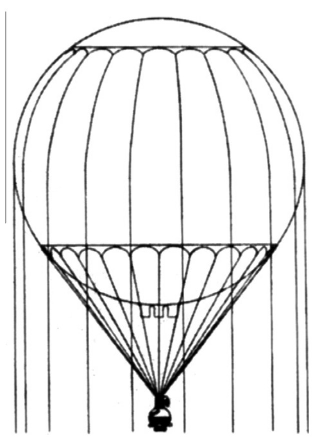

Fig. 2. Illustration of catenary suspension for rubberized fabric balloon (ca.1930).

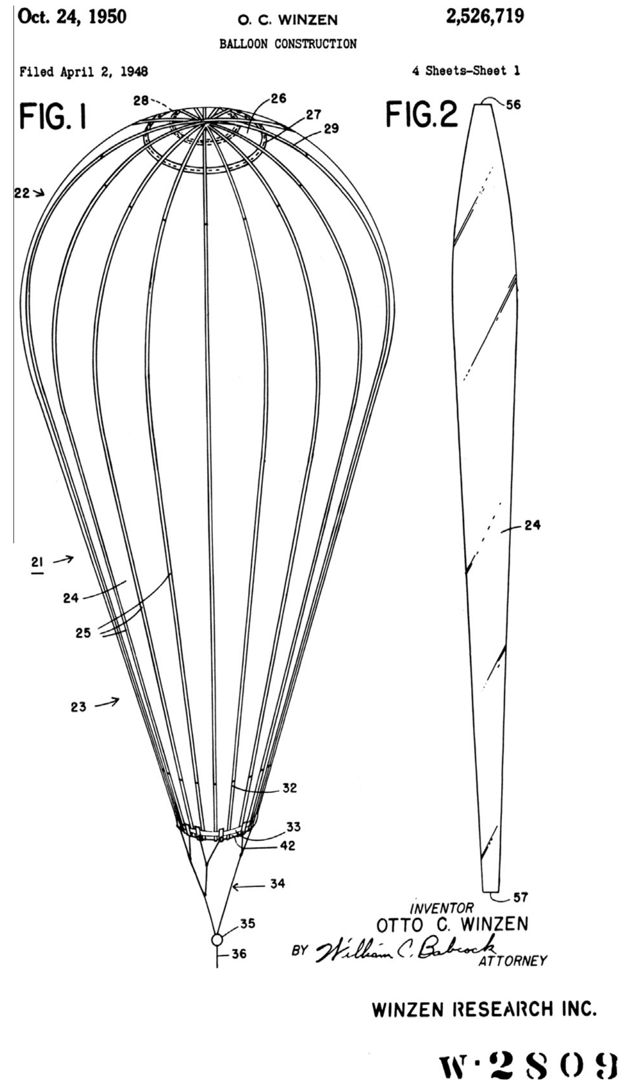

Fig. 3. Copy of Otto C. Winzen's 1950 patent for modern-day, natural-shape balloon.

ballooning has provided a unique capability for frequent access to near-space for a variety of science instruments ranging in mass from a few kilograms to approximately 2000 kg. Furthermore, ballooning has produced a steady stream of new instrumentation and science results for several decades that have raised new questions, which led to numerous additional balloon flights and some new space missions of relatively small satellites. It is generally true that a satellite launch for any discipline reduces its interest in balloon flights, because of the enormous difference in their exposure times.

The vented zero-pressure balloons used today are in equilibrium with the atmosphere. They have changed only incrementally from balloons introduced in the 1950s (Jones, 2005). Since that time, large polyethylene balloons have been employed for a variety of scientific pursuits and technological developments. Approximately 85% of NASA's balloon flights over the past decade have supported investigations of astronomy and astrophysics disciplines needing massive payloads for observations of cosmic rays, X-rays, gamma rays, cosmic microwave background, infrared/sub-mm astronomy, and high-energy neutrinos. About 15% supported non-astronomy and astrophysics disciplines, including Earth science, solar physics, heliospheric physics, and geospace sciences.

2. Antarctic long duration ballooning

Modern scientific balloons are very large polyethylene structures capable of carrying up to 3,600 kg (8,000 lbs.) payloads (suspended weight) into the near space environment above about 99.5% of the Earth's atmosphere. Fig. 4 illustrates the gigantic size of one of these polyethylene balloons, which have carried science, applications, and technology payloads for periods of 1–2 days since the 1950s. Launches have occurred from various locations around the world. Antarctica is the premier launch site,