Up, up and away

Balloons will soon be able to carry telescopes for months at a time, matching some of the capabilities of satellites, but at a fraction of the cost. Tony Reichhardt charts the course of a new era in ballooning.

Smashing pumpkin: astronomers hope that this balloon design will be able to fly for about 100 days.

NASA

This week, near the remote central Australian town of Alice Springs, a group of NASA scientists hopes to unfurl a new kind of balloon. If all goes well, the balloon's clingfilm-thin material will billow outwards as it is pumped full of helium, stretching until it takes on a lobed, pumpkin-like shape. The craft should then drift upwards and begin its journey around the globe, one of the last test flights in a project that aims to transform the way in which astronomers use balloons.

If successful, similar craft could carry telescopes on high-altitude, 100-day missions that would match some of the scientific potential of satellites. The results of the test flight will be keenly watched by astronomers who want to lift their telescopes above the interfering influence of Earth's lower atmosphere, but who lack the funds for satellite launches. "You can do an awful lot in a 100-day balloon flight," says Giovanni Fazio of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, who has been flying experiments on balloons since the 1950s. "It's like a little satellite experiment at one-tenth of the cost."

The new balloon technology has arrived at just the right time. NASA has tried various schemes to broaden access to space experiments, but with little success. In 1998, it opened competition for University-Class Explorers (UNEX) — low-cost missions that require less than $15 million for equipment and about $20 million for launch costs. But the funding was too sparse.

By the time a team has built instruments that can withstand launch and the harsh environment of space, as well as being reliable enough to work for a year in orbit, the $15 million is spent. NASA envisioned several UNEX missions a year, but the launch two weeks ago of the Cosmic Hot Interstellar Plasma Spectrometer, which will study the hot, diffuse gas that exists between stars, was the first — and could well be the last — UNEX launch.

Compare this with scientific ballooning, where astronomers have for decades lofted instruments into the upper reaches of the atmosphere, close to the boundary with space, for a few days at a time. Most observations taken by this equipment are at wavelengths such as those of X-rays, which are blocked by the atmosphere and so are invisible to ground-based telescopes. Interested parties need only a few hundred thousand dollars, plus another million or so to pay for the crew and other costs associated with the launch. If something goes wrong, it's easy and cheap enough to try again. And, unlike satellites, you get your equipment back at the end.

Positive altitude

Despite the short flight times, NASA's balloon programme has scored some successes. In 1998, the Balloon Observations of Millimetric Extragalactic Radiation and Geophysics experiment — known as BOOMERANG — returned what were then the highest-ever-resolution images of the cosmic microwave background (CMB), the radiation left over from the Big Bang. And all of the devices that flew on the Cosmic Background Explorer (COBE), the pioneering satellite that revealed ripples in the CMB in the early 1990s, had been tested on balloons. COBE was just "three glorified balloon experiments", jokes Stephan Meyer of the University of Chicago, who has worked on both balloon and space-based CMB studies.

Scientific ballooning is now poised to enter the big time. Flying above 99% of the atmosphere, balloons already approach the capability of satellites in terms of generating a clear view for astronomers. Flight times have progressed from less than a week in the 1980s to about a month, and current long-duration balloons can loft about 2,800 kilograms — more than can be carried on all but the most powerful rockets. But because helium gas expands in the heat of day and contracts at night, current balloons have to vent helium to avoid bursting during the day, and cast off ballast to maintain altitude at night. Balloon scientists can avoid this effect by flying over

Alaska or Antarctica in the constant daylight of polar summer. But for trips anywhere else, the mission ends once the ballast is used up.

If the Alice Springs test is successful, all this will change, heralding the era of ultra-long-duration ballooning. The new 120-metre-diameter balloons should fly for about 100 days for a launch cost of about $2 million. The secret is that, unlike the conventional balloons, the new balloons are sealed to keep the helium at high pressure and their volume constant. Any heat-induced expansion of the helium is absorbed by the balloon's tough skin material and by flexible tendons made from a polymer called polybenzoxazole.

The boost in flight times could be just the first piece of good news. Foreign balloons are currently not allowed to fly over Russian territory, but Vernon Jones, NASA's programme manager for balloons, based at the agency's headquarters in Washington DC, says he has "never been so hopeful" that NASA and the Russian Space Agency will soon reach agreement over letting this happen.

Ways to steer balloons are also being developed, so that in a worst-case failure, a one-tonne telescope payload will not fall out of the sky over populated areas. The odds of this happening are extremely low, says Jones, but some steering capability will be needed to reassure NASA's paymasters that the programme will not spark a disaster.

The simplest idea, proposed by Global Aerospace, a company in Altadena, California, involves using a rudder-like wing to give rough trajectory control. That project has also received interest from NASA's Office of Earth Science, which thinks that such a system would make ultra-long-duration balloons attractive to researchers interested in remote sensing studies. Jack Tueller, an astrophysicist at the Goddard Space Flight Center in Greenbelt, Maryland, and NASA's balloon project scientist, suggests that adding other devices, such as propellers, could also enhance steering capability.

The 100-day flights will open up new possibilities for balloon research, says Fiona Harrison, an astrophysicist at the California Institute of Technology in Pasadena. She is the principal investigator for the balloon-borne High Energy Focusing Telescope (HEFT), which later this year will use state-of-the-art optics and detectors to observe supernova remnants and active galactic nuclei during flights a few days long. Over such limited periods, says Harrison, instruments can only make "proof of science" observations, pointing to a few quick targets, and then returning home. But in three or four months, an experiment such as HEFT could study as many as 100 sources and begin to draw more substantial conclusions, says Harrison. And it would carry the latest sensor technology — giving it an advantage over satellites, which usually require instrument design to be fixed early in a mission's development.

Vernon Jones: keen to send balloons over Russia.

B. INGALLS/NASA

Lofty ideas

If the flightworthiness of NASA's new balloon is verified by the Alice Springs launch, the first to benefit will be the University of Maryland's Cosmic Ray Energetics and Mass (CREAM) experiment, scheduled to launch from the National Science Foundation's McMurdo Station in Antarctica this December. CREAM will study fast-moving subatomic particles, called cosmic rays, with energies of 10^{12}–10^{14} electron volts.

Fazio has longer-term plans. He wants to build the Stratospheric Observatory for Astronomical Research (SOAR), an infrared telescope with a three-metre-diameter mirror — bigger than that on the Hubble Space Telescope. Observing in far-infrared and submillimetre wavelengths for 100 days at a time, and able to be launched again and again, SOAR would conduct sensitive, deep-sky surveys of early galaxies and the clouds of dust in which star formation takes place.

But will such ambitious plans actually be realized? Critics of NASA's attitude to balloons, including Fazio, say that the agency treats the balloon programme like an unwanted stepchild. Recent competitions for NASA's Explorer missions, of which UNEX is the cheapest type, offered long-duration balloons as a platform for the first time. But Fazio and Harrison complain that the dice were loaded. In rating the proposals, NASA considered overall science capability, not 'science per dollar', which put balloons at a disadvantage. Few balloon payloads were proposed, and none was selected.

The competition with satellites may even out once ultra-long flights are demonstrated. If NASA selected a balloon payload for Explorer funding, says Meyer, "it would be an enormously important shot in the arm". Another way to level the playing field would be a balloon-only programme, says Harrison. Either solution, say advocates of balloon studies, would indicate that NASA sees ballooning as a viable high-technology option.

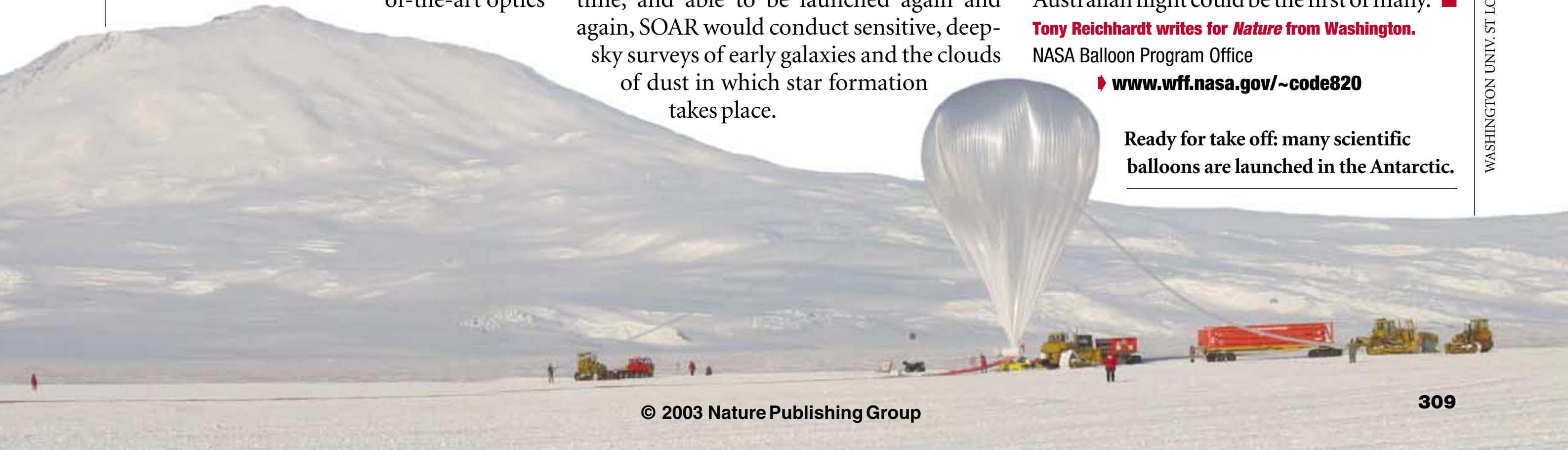
But embracing new technologies could cause problems. Cheapness is ballooning's strongest selling point, although ultra-long-duration missions will cost more than existing ones. Even so, at between $1 million and $2 million, these balloons will cost about a tenth of equivalent satellite launches. But the level of technology will have to change, says Meyer. Instruments must be more reliable if they are to operate for 100 days, and researchers will want more advanced devices to take advantage of the longer flights, including telescopes that are even larger than those currently launched by rockets.

Total costs for SOAR, therefore, could reach $30 million — still cheap by satellite standards, but a far cry from existing balloon experiments. In recognition of this, the decadal review of astronomy by the National Academy of Sciences, published in May 2000, recommended that an extra $35 million per year be made available for balloon studies.

The scientists developing the concept of ultra-long-duration ballooning are undaunted by potential budgetary pitfalls. "I never expected that building a whole new balloon programme would be easy," says Tueller, who is confident that the payoff will be worth the trouble. If he is right, this month's Australian flight could be the first of many. ■

Tony Reichhardt writes for *Nature* from Washington.

NASA Balloon Program Office
➧ **www.wff.nasa.gov/~code820**



Ready for take off: many scientific balloons are launched in the Antarctic.

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