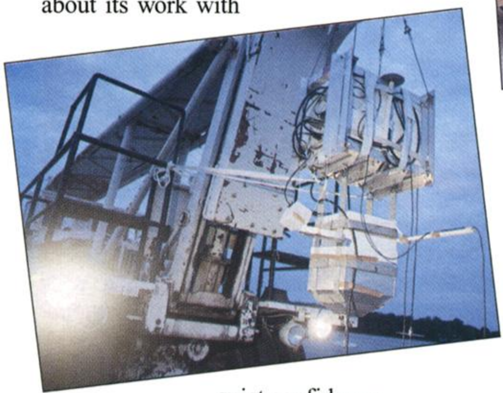
INSTITUTIONAL PROFILE

Scientific Ballooning's Buoyant Mood

Morale is high at the National Scientific Balloon Facility, as the crew looks forward to a new era of ultralong-duration balloon flights

PALESTINE, TEXAS—It is almost 7 a.m. For the past 3 hours, a crew of 20 engineers and scientists has been working in the dark, preparing a balloon and its payload for this morning's launch from the National Scientific Balloon Facility (NSBF), the Cape Canaveral of the nation's balloon-borne research program. As the sky starts to glow pink and orange, several metal-sided buildings emerge from the gloom. They look like airplane hangars turned on end, nestled among 1100 hectares of the rolling, pine-covered hills of east central Texas. The five-story-tall control tower, bustle of activity, and faint scent of working machines are all reminiscent of a small-town airport, with one difference: The runway is round.

The crew has less than an hour to get this balloon in the air. If the sun rises too high in the sky, the payload—a "lobster trap" containing an experiment to calibrate solar power cells—will have to go up another day. After a final check, the team loads the payload and a washing-machine–sized wooden crate containing the balloon onto a truck and then leads a caravan on the 1-kilometer trek from the hangar to the launch pad, a 300-meter-wide disk of asphalt in the center of a grassy clearing. Despite the activity, the scene is surprisingly silent. After almost 2000 balloon launches in the last 30 years, the NSBF team goes about its work with quiet confidence.



Scientists value that expertise. "They are truly unsung heroes," says Andrew Lange, a cosmologist at the California Institute of Technology in Pasadena who was the principal investigator for BOOMERANG, a balloon-borne experiment that in December 1998 made the most detailed map ever of the cosmic microwave background (CMB) and in the process discovered dramatic proof that the universe is flat (*Science*, 28 April, p. 595). Paul Richards, the principal investigator of MAXIMA, a balloon experiment that strikingly confirmed the BOOMERANG results just 6 months later, agrees. "They have done wonders," says the University of California, Berkeley, cosmologist. The wonders arrive at cut-rate prices. Compared with their high-flying, publicity-grabbing cousins, satellites, balloons are amazingly frugal with time and money. For a small fraction of the cost of a satellite mission, a balloon can loft a payload into the stratosphere for days at a time. And an entire mission can be conceived, designed, flown, and analyzed in a matter of months. A comparable satellite mission could take a decade or more to complete.

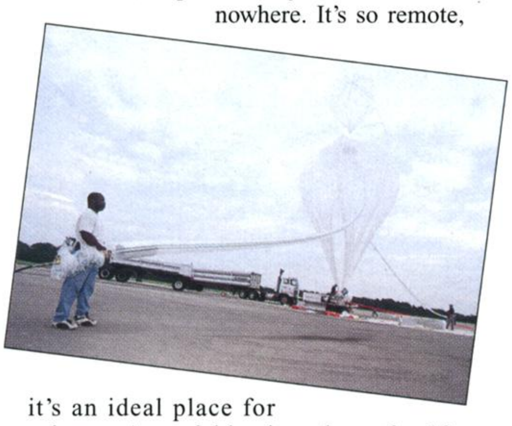
Up, up, and away. As the sun begins to rise, the launch crew completes a tightly choreographed sequence of procedures to send a small balloon carrying a solar cell experiment on a 6-hour flight.

Those advantages made ballooning so popular that by the late 1970s the NSBF was flying upward of 80 missions a year from sites around the globe. For the past decade, however, ballooning has been in a steady decline: The NSBF launched only 20 missions last year. "Most of the easy, cheap science has been done," explains NSBF Operations Manager Danny Ball. At the same time, Congress has slashed NASA's budget for new balloon payloads.

But a comeback is in the works. This year's Decadal Review of astronomy has for the first time recommended that NASA increase support for this oft-neglected stepchild of the space program. And in June, the NSBF completed a milestone test flight of its Ultra-Long Duration Balloon (ULDB), a sealed balloon capable of carrying several tons to 37,000 meters for 100 days. If the final ULDB test flight—scheduled for launch in January 2001 from Alice Springs, Australia—is successful, the NSBF expects to start sending up scientific payloads on ULDBs by the end of 2001. "The day has finally arrived when balloons can be competitive with satellites," says astrophysicist Jonathon Grindlay of Harvard University. "[The ULDB] will do big-impact science at incredibly low cost."

Pilgrimage to Palestine

Palestine, about halfway between Houston and Dallas, is quite literally in the middle of nowhere. It's so remote, it's an ideal place for prisons. A roadside sign along the 10-minute drive from Palestine to the NSBF launch site warns drivers not to pick up hitchhikers: They could be escaped convicts from any of the four prison units that lie within 20 kilometers of the control tower.



There is good reason for the NSBF's remoteness. A top-of-the-line balloon holds 40 million cubic feet (MCF), or slightly more than a million cubic meters, of helium. "That is about the same volume as the Houston Astrodome," says Ball. Taller than the Eiffel Tower but as thin-skinned as a plastic bag, these mammoth balloons can lift almost 4 metric tons, about the same weight as three small cars—or one big Texas Cadillac, steer horns and all. In the event of an "unplanned descent"—the NSBF code phrase for a balloon crash—NSBF managers must ensure that no one on the ground is hurt. "So we look for areas with low population density," Ball says.

In 1963, when the National Science Foundation moved its 2-year-old balloon program from Boulder, Colorado, you could hardly find a place on Earth as deserted as Palestine. (The program moved to NASA in 1982 and is now administered by the Physi-

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cal Sciences Lab of New Mexico State University in Las Cruces.) But the population growth around Palestine and the desire for longer flights throughout the year has prompted the NSBF to go global. In addition to the Palestine site, the NSBF now regularly launches balloons from Fort Sumner, New Mexico; Lynn Lake, Manitoba, Canada; McMurdo Station, Antarctica; Fairbanks, Alaska; and Alice Springs, Australia. They have also made special launches from Brazil, Sweden, and the Northwest Territories of Canada.

Wherever the wind blows

When Ball arrives at the NSBF launch site at 4:30 a.m., he is already in a hurry. The first stop is the weather room, a spare linoleum and cinderblock affair lined with computers displaying weather maps. Balloonists take no chances with the weather. In the stratosphere, winds are a good thing; without them, balloons would never get anywhere. But when the balloon is on the ground, wind is the enemy. Launches are postponed if wind speeds top 5 knots (2.6 meters per second) at the surface or 12 knots at 150 meters, or if a thunderstorm crosses the flight path. The morning weather report indicates surface winds of only 2 knots. The launch is a go.

It's crew chief Victor Davison's job to get the balloon into the air. In the predawn dimness, Davison conducts an orchestra of a dozen engineers, two trucks, and one 45-meter-long balloon. Instead of a baton, he holds a tethered pie-ball, a balloon about the size of a child's toy bouncing at the end of a 30-meter string. The air feels dead calm, but to Davison it is alive and kicking. The light breeze pulls the pie-ball to and fro, and Davison moves around until he is satisfied that he knows the exact direction of the wind. Then he gives the order to roll out the empty balloon, which resembles a very long, 60-centimeter-wide red garbage bag.

Today's launch is unusual because the payload rides on top of the balloon to keep its electronic eye on the sun; only the communications package will hang below. This configuration requires a small extra balloon to levitate the experiment before the main balloon is inflated underneath.

Everything looks ready, so Davison hops into the launch truck—a converted tractor-trailer to which the bottom of the main balloon is clamped—and gives the signal to start pumping. There is a sharp hiss of escaping high-pressure helium, and almost instantaneously the small balloon, a nearly transparent milky-white bubble, emerges from the tangle of hoses and bags strewn on the ground. Once the small balloon is full and the experiment is hovering a meter or two off the ground, an ear-splitting whine rends the heavy morning air as technicians start to inflate the main balloon. Ten minutes later, the clamp holding the top end of the balloon on the ground snaps open and the fully inflated balloon leaps into the air over the launch truck. Davison guides the truck directly under the balloon and lets the payload fly. The balloon rises into the sky, dangling its payload like the tendrils of a jellyfish.

For the next half-hour, there is nothing to do but wait. Most of the crew heads for the control tower, a dusty, cluttered outpost standing five floors above the hangars where a dozen early-rising scientists have just begun the day's work of preparing for their own flights later this week. The control room is ringed with windows, but almost everyone's eyes are glued to a battery of computers that monitor the balloon's climb to 37,000 meters. Everyone except Bruce Anspaugh, that is. The Jet Propulsion Lab physicist who is the principal investigator on today's mission stays outside to watch his slowly ascending experiment. Even after almost 3 decades of yearly launches, he never gets tired of balloon flights.

Cheaper and faster

It is no coincidence that Anspaugh, like many of his colleagues, started ballooning as a graduate student. From its inception, the NSBF was intended to be "a training bed for scientists," says Philip Lubin, an astrophysicist at the University of California, Santa Barbara, who observed the CMB from balloons before getting involved with the Cosmic Background Explorer satellite program. Because graduate students are notoriously short of cash and impatient to finish their theses, balloons have to be inexpensive and the experiments able to fly on short notice.

They succeed admirably on both counts. The small 3-MCF balloon that Anspaugh is flying today cost a mere $30,000, and a giant 40-MCF balloon will set you back only $120,000. That's very small potatoes compared with a satellite's multimillion-dollar price tag. Add to that the fact that satellite experiments take decades to develop, and ballooning becomes an even better bargain. "An instrument built last month in the laboratory can be flying on a balloon this month," Lubin says. In fact, because of the rapid turnaround and ability to reach near-space conditions, prototypes of virtually all satellite experiments are first tested on balloons. "You would have to be foolish to fly a new detector on a satellite without first testing it under the conditions of a balloon experiment," says Jerry Fishman, an astrophysicist at Goddard Space Flight Center in Greenbelt, Maryland, who led the Science Working Group of the Compton Gamma-Ray Observatory.

Balloons do have their drawbacks, though. Once a satellite reaches orbit, it can stay there almost indefinitely. Few balloon flights, on the other hand, last more than 3 weeks. In the NSBF's so-called zero-pressure balloons, an opening in the bottom releases gas to keep the inside of the balloon at the same pressure as the surrounding atmosphere. When the air around the balloon cools at night, the slightly deflated balloon sinks, or droops, deeper into the atmosphere. To regain the lost altitude, scientists lighten the payload by dropping ballast; when the ballast is gone, the mission is over.

Droop doesn't matter much to a scientist like Anspaugh, who can gather all the data he needs in an hour. But for astrophysicists who want to collect rare cosmic rays, make images of faint newborn infrared galaxies at the edge of the universe, or catch the gleam

Tense moments. As the balloon ascends *(top)*, Danny Ball *(above, center)* and colleagues monitor its progress on computer screens.

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of an extrasolar planet, short missions won't do the trick. The lost hours spent at lower than optimal altitudes "really hit your science," says Harvard's Grindlay. But there is a way to stop the droop: seal the balloon. And that is exactly what NASA and the NSBF are doing with their superpressure ULDB balloon program.

The pumpkin-shaped ULDB balloons are about the same size as a large zero-pressure balloon. Because all the buoyant gases are sealed inside, the superpressure balloons being developed by Goddard at the Wallops Flight Facility in Wallops Island, Virginia, are impervious to the diurnal temperature changes that cause the droop that eventually grounds zero-pressure balloons. A ULDB should be able to stay at a constant altitude for at least 100 days. To maintain constant contact with a ULDB on its globetrotting journey, the NSBF will link these balloons to the constellation of three satellites that forms the Tracking and Data Relay Satellite System. The high-speed data link permits scientists to gather data from and send commands directly to the balloon over the Internet. "Now the scientists can just sit at home and watch the data flow in," says ULDB project manager Steve Smith of Wallops.

For Anspaugh, such high-tech frills are a needless luxury. Six hours after takeoff, his solar-cell experiment has parachuted safely into the west Texas desert, and the NSBF chase plane has flown him out to bring it back home. The crew seems buoyant, not just about one more successful mission, but about NSBF's future, as it prepares to open a new chapter in its history. As Grindlay says, "Ballooning is on a sharply upward trajectory." —**MARK SINCELL**

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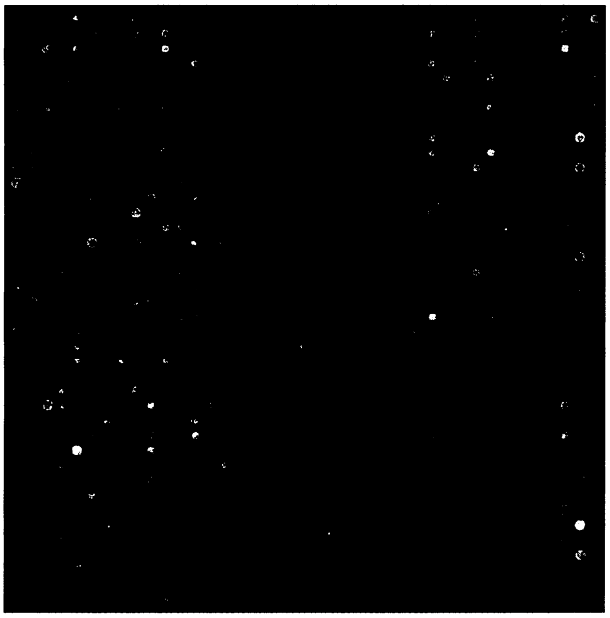
TOXICOGENOMICS

Toxicologists Brace for Genomics Revolution

Gene-array technology promises to deliver comprehensive profiles of toxic compounds, but validation will take years

ASPEN, COLORADO—Millions of animals are raised in the United States each year for routine toxicology tests, exposed to compounds in food additives, cosmetics, and industrial products, and then studied for ill effects. This is a time-honored way of identifying human health risks, but it can be an imprecise science. It's also expensive and increasingly under attack by animal-rights activists as wasteful. Now, according to researchers who gathered at a high-powered summit this month,* toxicology may be on the verge of changing the way it collects raw data—adopting a process that could reduce animal use and improve test results.

The new approach, called "toxicogenomics," grows out of the human genome project. Rather than using animal pathology to identify illnesses, it probes human or animal genetic material printed on plates, called DNA arrays. Cancer researchers have already been using such arrays for several years to compare gene expression in healthy and diseased cells (*Science*, 15 October 1999, p. 444). Toxicologists are using the same technology to profile gene expression in cells exposed to test compounds.



Gene scan. NIEHS researchers have developed a prototype array of 12,000 human DNA sequences, called ToxChip, to detect responses to known toxicants.

The advantages of these DNA tests are legion: They are fast, efficient, and reduce live-animal expenses, which can range as high as $3000 per week, per animal, when nonhuman primates are used. Some of the biggest gains may come in cancer toxicology; New tests may be able to spot the metabolic precursors of slow-developing diseases without holding up research for the months or years it takes for tumors to develop. If adapted for use in tissue cultures, these tests might even eliminate the need to sacrifice animals.

Toxicogenomics is advancing so rapidly as a specialty that the National Institute of Environmental Health Sciences (NIEHS) this spring opened a new National Center for Toxicogenomics in Research Triangle Park, North Carolina. Its express purpose is to spur the development of gene-based toxicity studies. But some leaders in the field warn against rushing too quickly to embrace DNA tests, which are still difficult to interpret. Doing so, they say, could exaggerate some risks and understate others—halting research on promising new products while overlooking life-threatening toxicities that would have shown up on traditional bioassays. "We have to be careful we don't drive beyond our headlights and run into a wall," cautions Joseph DeGeorge, a pharmacologist at the U.S. Food and Drug Administration's (FDA's) Center for Drug Evaluation and Research.

Mountains of data

The basics of toxicogenomics are straightforward, although details vary from lab to lab. The hardware uses gene arrays bearing such names as "ToxChip" or "ToxBlot" that contain thousands of genes that might be affected by toxic chemicals. These genes, arranged on plastic or glass plates about the size of microscope slides, bind to matching genetic material extracted from animals or cell cultures exposed to the substance being tested. The extracted genetic material, called messenger RNA, comes only from genes that are currently active; it is reverse transcribed and tagged with a radioisotope or a fluorescent marker to simplify detection. Researchers sometimes use a red marker for material from treated cells and a green one for untreated controls. When labeled sequences are tested on a single array, both treated and untreated types bind to a gene site, with the resulting color at each site showing the degree to which that gene has been turned on or off by the putative toxicant.

* 26th Annual Summer Meeting, The Toxicology Forum, 10 to 14 July.

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