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"REEL-DOWN"

How Jim Anderson's team of scientists achieved a history-making advance in high-altitude research

A painter's painter: Realist Fairfield Porter

Taxation table-turning: Will it work?

A solution to "The Mystery of Edwin Drood"

DISCOVERY: Letters of Archibald MacLeish

Harvard scientists, with Tiny Tim, "the monkey," and a balloon the height of a skyscraper, attempt to make history.

Reeling through the stratosphere

by Jonathan Leonard

Resplendent in the Texas dawn, a high-altitude balloon payload gets ready for possible lift-off. Designed and built at Harvard by Professor James Anderson's research group, the payload has two parts: a 130-pound package of research instruments (on the back of the station wagon, opposite) to probe the stratosphere and a 2,700-pound winch platform (above) to reel the smaller package down from the balloon. The small package's orange-and-

(continued on page 28)

PHOTOGRAPH BY JIM TROTMAN


NATIONAL CENTER FOR
ATMOSPHERIC RESEARCH
SCIENTIFIC BALLOON FACILITY

white parachute hangs below the winch platform. The launch vehicle, largest employed at the National Scientific Balloon Facility in Palestine, Texas, is nicknamed "Tiny Tim."

As of the taking of this picture, however, trouble is brewing. Anderson and his field team haven't slept in 24 hours. Persistent problems have delayed things to a point where time is critical. A deadline imposed by the balloon base and a shift in the seasonal stratospheric winds are imminent. If the balloon cannot be launched in a few hours, rising ground winds will prevent lift-off. And if that happens, base officials are likely to scrub the mission.

Like many research centers, the world's largest balloon base keeps a low profile. You can reach it by driving along rural Route 19 in East Texas—across rolling hills and lush cow pastures, between the improbably named towns of Athens and Palestine (pronounced "Palesteen"), until you come to a large sign bearing an arrow and the words "Coffield Unit, Texas Department of Corrections." Follow that arrow and you will soon come upon much smaller signs saying simply "balloon base" and a half mile further on "national scientific balloon facility." After that you will begin to see the buildings, vehicles, and launch pads of the base itself. They are a far more impressive introduction than any sign, including the small-print at the gate reading:

NATIONAL SCIENTIFIC BALLOON FACILITY
Operated by
THE NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
Sponsored by
THE NATIONAL SCIENCE FOUNDATION

WARNING:
EQUIPMENT OPERATING ON THIS FACILITY
MAY INTERFERE WITH HEART PACEMAKERS

I went to Palestine last September to report the doings of a Harvard team led by Jim Anderson, a blue-eyed, 38-year-old chemistry professor with a hankering for adventure and a genius for high-altitude research. Anderson—who recently assumed the title of Philip S. Weld professor of atmospheric chemistry—loves balloons. Large balloons. Giants eighty stories high that carry multiton payloads thirty miles into the stratosphere and that get big enough in some cases (on the order of fifty million cubic feet fully expanded) to hold a hundred Goodyear blimps with ease.

To someone like myself, who never graduated beyond the toy balloons sold at county fairs, that's impressive. But even the youthful Anderson, who routinely masterminds the payloads for these Palestine-base leviathans, finds their flight exciting. As he remarked recently, after a balloon rig as tall as Boston's John Hancock Tower lifted off the pad, "The emotional impact of a launch never diminishes."

Anderson's fascination with balloons goes way back. "When I was a child," he says, "I used to see pictures of high-altitude balloons, and I used to think, 'Wouldn't it be fun to send them up.' " But his home town of Pullman, in the wheatlands of eastern Washington, offered no ready outlet for this incidental interest; nor did the University of Washington at Seattle, which he attended as an undergraduate. Indeed, his first high-altitude experiments (done while working for a doctorate in physics at the University of Colorado) made use of sounding rockets. It was only later, after he became an assistant research professor of physics at the University of Pittsburgh and a research scientist and associate professor at the University of Michigan, that he began working with balloons. Nevertheless, by the time he came to Harvard, in 1978, Anderson had been doing high-altitude balloon research for many years, plenty long enough to be considered a veteran by the old hands at Palestine.

But of course, Anderson gets to spend relatively little time in Texas. Most of his hours are divided between teaching one or more of four Harvard courses (physical

JONATHAN LEONARD

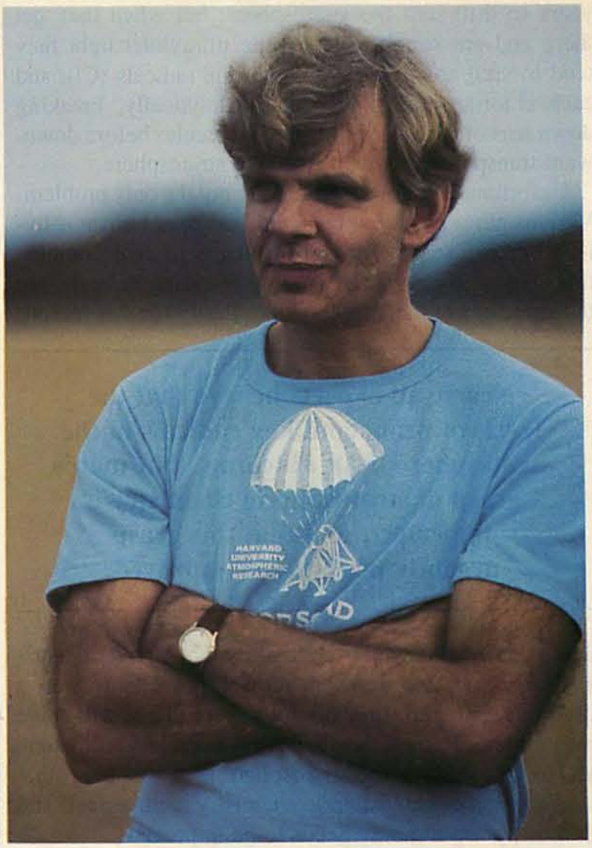
How to launch an 800-foot balloon with a 2,830-pound payload

A first-time visitor to the National Scientific Balloon Facility at Palestine, Texas, can be forgiven for temporarily bypassing the base's metal buildings sprouting microwave antennas and packed with computers, tape recorders, charting devices, data-projection screens, communications gear, base personnel responsible for operating the balloons, balloon experiments in various stages of assembly, and ten or so research teams from half a dozen countries working long hours to get experimental packages ready for lift-off. Those buildings house the real works of the operation. But they are not nearly so eye-catching as the giant of the supporting cast parked nearby—a launch vehicle over thirty feet tall and seventy feet long with eight-foot tires, large red jaws, and foot-high letters spelling out the name "Tiny Tim." This massive launcher's job is to keep an upward-bound balloon's scientific cargo from dragging on the ground at lift-off, a feat it performs by maneuvering under the balloon on a paved circular pad 300 yards across.

The job is tricky, partly because the balloon does not start upright. Instead it starts flat, lying on a protective canvas "road," wrapped in pink or red plastic, and look-chemistry, photochemistry, planetary atmospheres, and chemical kinetics) and heading a thirty-person research group attached to the Harvard Center for Earth and Planetary Physics. This latter group, which provides a foundation for the balloon work, concerns itself principally with the bizarre chemistry of the stratosphere (the part of the atmosphere extending from roughly seven to thirty miles) and ways in which that chemistry could affect life on the ground.

The group's main reason for concern about the stratosphere is ozone, a divorce-prone union of three oxygen atoms that singlehandedly absorbs most of the sun's low-energy ultraviolet radiation. Ozone is continuously formed in the stratosphere through the interactions of regular oxygen molecules (O_2) with ultraviolet radiation. And it is continuously broken down, most notably through the catalytic intervention of certain "radicals" (reactive atoms or small molecules whose outer shells contain an unpaired electron) such as the lone chlorine atom (Cl), nitric oxide (NO), the hydroxyl radical (OH), and other denizens of the upper atmosphere. The net amount of ozone present in the stratosphere at any given time is rather small, sufficient only to create a layer of gas an eighth of an inch thick at the earth's surface. But that ozone is essential; for its reduction would permit larger amounts of low-energy ultraviolet radiation to reach the ground; and there is good evidence that progressive increases in such radiation at ground level could damage plants, reduce crop yields, promote melanoma and less dangerous skin cancers, cause cataracts, and at some extreme point, induce cataract-related blindness in nearly all land animals. As Anderson explains, "If the amount of stratospheric ozone were to fall by as little as ten percent, the implications would be extremely serious for plants and animals; and if it fell by half, the effects would prove devastating for virtually all life on earth."

Neither Anderson nor any other expert expects the prevailing stratospheric ozone level to fall by anything like half in this century. But there is good reason to believe that various man-made gases (most notably the fluorocarbons used as aerosol propellants, working fluids in refrigerators and air conditioners, fillers for synthetic foams, and cleaners of electronic parts) can do real harm. These fluorocarbons, inert at ground level, take many



JIM TROTMAN

Anderson watching balloon launch preparations on the pad at Palestine.

ing like an immense ribbon on the ground. At its far end (600 to 800 feet away from Tim), what will become its top is surrounded by attendants, a small launch vehicle called the "spool truck," and one or two tank trucks bearing long, orange cylinders of compressed helium. From there extends the rest of the balloon, a parachute, its shroud-lines running over the rear and top of Tiny Tim, a pin held in Tim's jaws, and the suspended payload.

As launch time approaches, the balloon's upper end is placed through what looks like a giant sewing spool on the small launch vehicle. That spool (actually a vise used to restrain the balloon upon inflation) is clamped down; black hoses terminating in large, cylindrical aluminum nozzles designed to reduce the velocity of incoming helium are joined to the balloon's two plastic conduits for admitting helium; valves on the helium trucks are opened; and inflation starts.

Even though the balloon typically receives some $5,000 worth of helium, that is not enough to inflate more than its confined upper end—maybe a fifth of its whole length. But air pressure diminishes with height; the gas will expand and completely fill the balloon at higher altitudes; and so only partial inflation is desired.

Following inflation, a few minutes after the plastic conduits have been tied off, the confining spool suddenly snaps back and the balloon's inflated end rears upward, quickly raising the rest of the balloon and the parachute assembly off the ground. This is the moment when Tiny Tim starts to move. The brief maneuvering is critical, because the combination of ground winds and Tim's motion must cause the balloon to rise directly behind and over the big launcher's back. Then, just as the balloon passes the vertical and can support its intended load, Tim's jaws must spring apart and release the pin. If Tim releases too early, before the balloon can support its load, then the load may fall to earth; and if Tim waits too long, until the balloon is well past the vertical, then the load may swing like a pendulum and strike the ground. But if the release is well timed, as it generally is, the payload will float free and will begin rising toward the stratosphere at some 900 feet per minute. This carefully orchestrated drama, repeated at the Palestine base something like 75 times a year, is the one recurrent event upon which all other activities depend.

years to drift into the stratosphere; but when they get there and are struck by energetic ultraviolet light they tend to split apart, releasing chlorine radicals (Cl); and each chlorine radical then acts catalytically, breaking down tens of thousands of ozone molecules before downward transport removes it from the stratosphere.

Unfortunately, fluorocarbons are not the only problem. Various gases produced by a wide range of human activities—from use of artificial fertilizers to coal combustion—could conceivably wind up releasing radicals into the stratosphere that affect ozone. Partly for this reason,

Nearly all experts believe that the levels of ozone and key radicals in the stratosphere bear watching, that man's grasp of stratospheric chemistry is imperfect, and that this grasp urgently needs to be improved.

while nearly all experts feel that the U.S. government's 1978 ban on fluorocarbon aerosol propellants was a desirable first step, they do not expect that it will solve the problem. Rather, they believe that the levels of ozone and key radicals in the stratosphere bear watching, that man's grasp of stratospheric chemistry is imperfect, and that this grasp urgently needs to be improved.

To help improve it, researchers at Anderson's headquarters study radical-radical interactions at a high-tech laboratory on the second floor. The results, together with a large body of additional information, are used by others (notably Professors Michael B. McElroy and Steven C. Wofsy at the Harvard Center for Earth and Planetary Physics) to create large global computer models of what stratospheric chemistry is like.

Unfortunately, that is not enough. For it is no easier to predict the exact gas mixture someplace in the stratosphere than it is to predict the exact chemical composition of seawater someplace in the mid Atlantic. There are simply too many variables. By itself, no amount of computer simulation can do the job. And since the crucial but highly reactive radicals involved are only present in minute quantities and cannot be preserved, the stratosphere cannot be brought to the laboratory. Instead the laboratory must be taken to the stratosphere.

Until recently, the Anderson group's fieldwork consisted of just that—tying instrument packages to Palestine balloons, flying the balloons to about 140,000 feet, dropping the instrument packages through the ozone-rich reaches of the stratosphere by parachute, and taking readings as the instruments fell to earth. That work yielded important information. It told something about prevailing levels of chlorine and other radicals; and it proved that Anderson's sophisticated plasma guns and optical sensors could measure the concentrations of key radicals present in amounts as low as one part per trillion parts of air—equivalent to measuring a drop of iodine in an Olympic pool.

Nevertheless, the technique has its limitations—as became evident on Bastille Day, July 14, 1977, when an Anderson package looking for the chlorine monoxide radical (ClO) reported roughly eight times the ClO concentration detected by eleven previous balloon flights, while ozone concentrations that should have been affected by that radical apparently remained unchanged. Perhaps, as some claim, the fault lay with the instruments. Or else, as Anderson suggests, unusual local conditions may have existed in the stratosphere. The problem was, the truth could not be learned, for there was no way the test could be repeated. The instruments had to be recalibrated after impact; conditions in the stratosphere change fast; and so, at least for the time being, the actual cause of that strange reading would remain a mystery.

"It was about ten days after that," says Anderson, recalling his frustration, "that I thought of using a device that could hang from the balloon and reel a package up and down through the stratosphere repeatedly." Such a device would do more than permit repeated testing. It would allow researchers to take numerous readings at well-defined altitudes; to go back and study unusual situations; and to explore the stratosphere—which is too high for planes, and too low for satellites—as it had never before been explored.

That concept required a line that could reel a payload down the necessary eight miles or so without snapping. Few, if any, materials could do the job. A steel cable that long would break of its own weight. But in the early 1970s Du Pont came out with Kevlar, a synthetic fiber with ten times the tensile strength of steel; and so, after satisfying himself about Kevlar's abilities, Anderson decided to go ahead. Work began in January 1980, and by last August his group had built a prototype. Dubbed "reel-down" by the experts and "the world's biggest yo-yo" by New York Times science writer Walter Sullivan, it showed promise of making a major breakthrough in the techniques of high-altitude research.

The prototype had two parts: a 2,700-pound winch platform that would hang under the balloon and a 130-pound payload dubbed "the monkey" that would be lowered through the stratosphere. Both parts were hand-built and tested at 40 Oxford Street with the loving care customarily lavished on Rolls Royces. They were then disassembled, packed gently into a Hertz rental truck, and driven south, reaching Palestine on August 23. Two members of Anderson's seven-member field crew drove the truck; the other five, including Anderson, flew into Dallas and drove the hundred miles southeast to Palestine.

The pair who drove the truck, Stod Rowe and Bill E. McLaren, reflected the reel-down project's two locales. Stod, a friendly, outgoing type making his first trip to Palestine, belonged to the Harvard Class of 1981. Among the College's first engineering-and-visual-arts concentrators, he did engineering drawings for Anderson as an undergraduate and signed on full time with the group after graduation. Last winter he turned out many of the more difficult and innovative mechanical design drawings for reel-down under the direction of Nathan Hazen, the project's head engineer.

The truck's other driver, Bill McLaren, was an amiable Texan with considerable launch experience. A senior electrical technician, he had the vital job of seeing that a complex maze of "housekeeping" circuits on the winch platform operated as they should.

He also had an unswerving devotion to his native state. Spending roughly half his time in Cambridge and half in

Palestine, Bill had the choice of locating his family in either place. Apparently there never was much question. "Texas is home," he told me one sunny afternoon. "That's where we belong, and that's where we plan to stay."

The choice in fact may not have been so easy; for outwardly, at least, Palestine has little to recommend it besides its Texan culture and its people's open hospitality. A major railhead from 1872 to around the end of the century, the town once boasted a center with considerable charm. But since then that center has fallen on hard times. Like a wagon train besieged by Indians, it has been encircled at a distance by highways armed with plastic-modern malls, motels, and restaurants. So businesses in the center have slowly been snuffed out; and despite its well-maintained Greek revival courthouse, much of downtown Palestine has the blighted look of a place whose day has long since passed.

Like virtually all motels in Palestine, the two-story Palestine Inn where the Anderson team stayed is located on one of the big roads on the town's outskirts. I arrived there on the evening of September 1 to find several team members sitting by the swimming pool, where they usually gathered after work, cheered at having just run the partly reassembled winch platform through its paces. "Now we know it works," said Anderson; "what we have to do is learn to drive it."

The "driving" process, as he described it, called for reeling the 130-pound payload down and up just once, because this would be its first trial. But even the present battery-powered prototype could repeat the action various times; future solar-powered models using the strong sunlight of the upper stratosphere should be able to repeat it indefinitely; and so the prospects for repeating the basic reel-down action seemed unlimited.

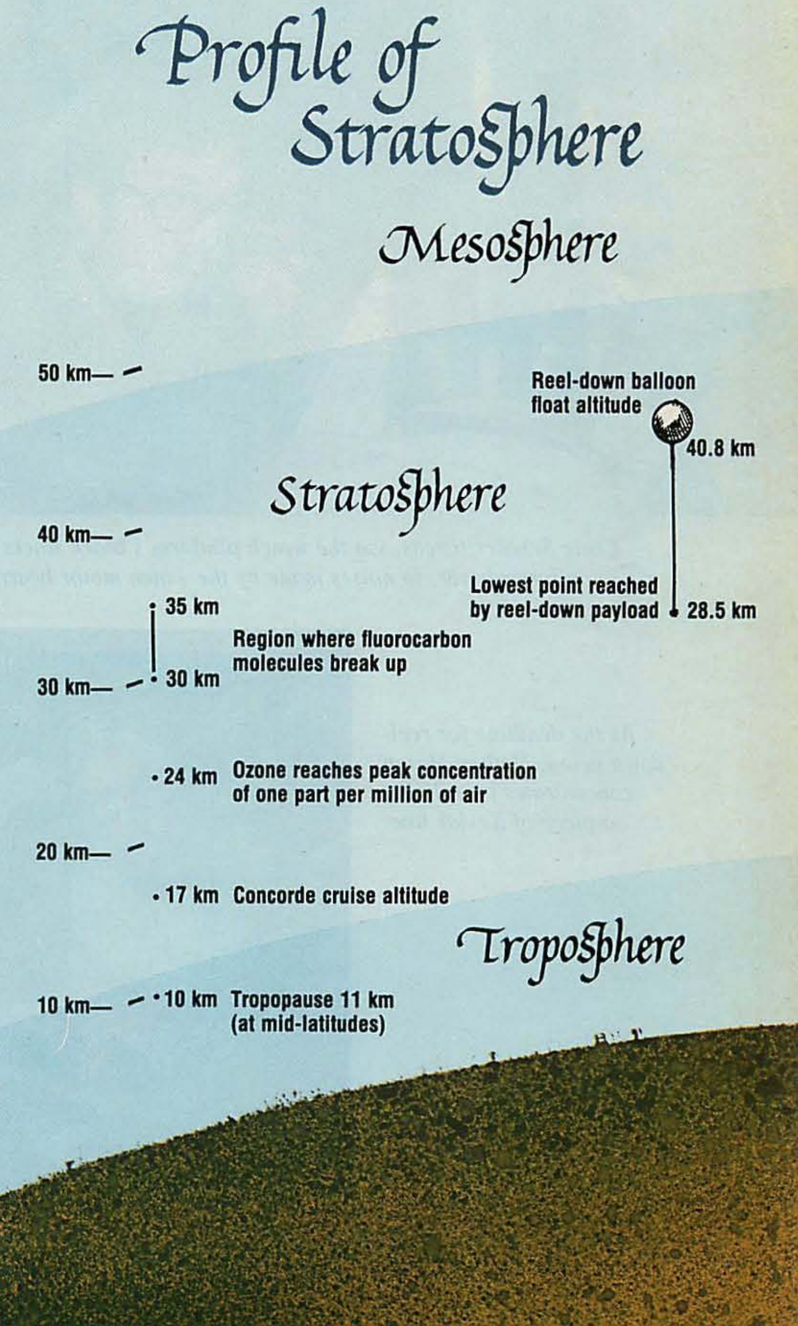
"In that case, how long could the balloon fly?" I wondered. "Almost forever," he said. "Ordinary high-altitude balloons cannot stay aloft indefinitely, and are lowered by remote commands that cause them to vent their gas. But if you prepared one for a long flight, the main constraint would be distance. You would have trouble flying it around the world in the Northern Hemisphere, because the Russians wouldn't like it. But you could circumnavigate the Southern Hemisphere if you launched from Australia or Brazil, and both countries have facilities that can launch stratospheric probes."

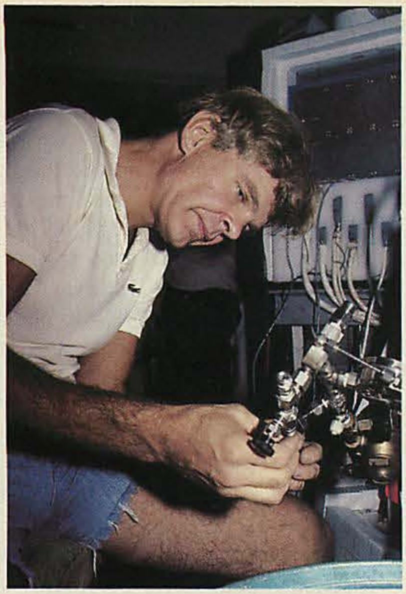
Here, obviously, was the adventurous imagination that had conceived the whole reel-down idea. But to get this far, the project had needed more than just imagination. It had required a convincing advocate with a compelling command of high-altitude research and a proven ability to get results. That made Anderson one of a few people—perhaps the only person—capable of giving birth to the idea, building a strong technical argument, getting the grant money, supervising the design and engineering, and coming to Palestine ready for a launch. The big question now was, if the package could be reassembled and tested on schedule, and if all the intricate technical gear on board performed as ordered, would the reel-down concept actually work? Nobody, including Anderson, knew enough about the stratosphere to answer that.

What everybody on the team did know were the main uncertainties. These were discussed that night over dinner at Silvaggio's, an odd Italian restaurant housed in what looked like a low-roofed ski lodge, which had once been the private home of a local magistrate. Silvaggio's decorative ceiling fans didn't work, but since everything in Palestine is air-conditioned against the Texas heat, they didn't have to. Instead, Silvaggio's concentrated on good food and personal service; its odd history and architecture relieved the loop's chain-store anonymity; and so it provided a congenial place for conversation.

One big uncertainty was what might happen to the Kevlar line. Would the stratospheric winds make the line oscillate, causing the monkey to swing like a pendulum or begin bouncing up and down? And would such oscillation gradually build up forces that could exceed the line's 650-pound tensile strength and tear the rig apart?

That latter possibility, of concern to the Anderson group, had the balloon-base people very worried. The base was responsible for seeing that no instrument package ever broke loose, hurtled downward, and caused





Anderson working on a gas line beside the nearly assembled winch platform.

Craig Schiller listens, via the winch platform's black stacks and a screwdriver, to noises made by the winch motor bearings.

As the deadline for reel-down nears, Nathan Hazen concentrates on splicing a piece of Kevlar line.

damage on the ground. So even though the winch platform and the monkey would each carry separate parachutes, the base personnel were monitoring things closely, holding an unprecedented series of review meetings on the project's status, and insisting that the entire reel-down experiment be conducted 140 miles away from Palestine, over virtually uninhabited portions of west Texas, after the balloon was carried there by prevailing stratospheric winds.

This last condition created more uncertainty, because the stratospheric winds are seasonal. From April to September they blow westward; from October to March they blow eastward; and in between (beginning as early as mid September and mid March) they go through a brief time of blowing any whichway that is known as "turnaround." To get permission for a launch, Anderson would have to be ready before September 16, while the winds were still blowing strongly to the west. And since adverse ground winds, thunderstorms, and a host of other weather troubles could scrub the mission on any given day, it was essential to be launch-ready as many days as possible before the anticipated September 16 cutoff.

The problem with getting ready, as I discovered when Anderson briefed me at the assembly building the next morning, was the complex nature of the reel-down apparatus. Even something as simple in concept as the winch (in essence, a big fishing reel run by two electric motors) required hordes of accessories. For example, when the winch motors were used as brakes to slow the monkey's fall they would generate unwanted electricity. To dispose of that, Ed Thompson, the team's electrical engineer, ran electric lines from the motors over to a pair of large, square panels that projected winglike from the platform's sides. These lines were then hooked up to naked high-resistance wires running through the panels; the high-resistance wires (like those in a toaster) turned the electrical energy into heat energy; and the panels, reaching temperatures as high as 300 degrees Celsius, radiated the heat energy away.

It turns out that heat can build up dangerously in the stratosphere, because the air is too thin to effectively remove it by convection. So other unwanted heat produced by friction in the motor bearings was removed by surrounding the bearings with a water bath, and venting the heated water as steam through two conspicuous black stacks. Lesser heat in the motor casings was removed by a special water-circulation system. And general heat build-ups were minimized by painting the platform white, using a common pigment (titanium dioxide) that radiates heat while reflecting most of the sun's light.

These were only a few of the elegant arrangements that Anderson described, and only a small fraction of those needed to make the platform work; but they helped to explain why a mere winch platform should require the careful ministrations of top-flight engineers, and should look at least as strange as many of the craft that fly through space.

Such complexities also helped to explain why the project was a few days behind schedule. For each intricate component had to be assembled. Electronic monitors and controls had to be hooked up. Tests had to be run to determine that both the gear and the electronic remote controls were working properly. Each time a major reassembly step was taken, or each time something failed, more tests were needed to ensure that related components were all right. And since a natural tendency of people in a hurry is to hope things will take less time than is actually required, the reassembly and testing schedule had been slipping ever since the team arrived.

The monkey was complex in other ways. It consisted of three cylinders in a row, the middle one housing radio and electronic gear and the other two containing the actual experimental apparatus.

When I first saw it, the monkey was being ministered to by Janie Phillips, a Wellesley graduate (class of '78) with serious blue eyes and a warm smile, who had joined the group some years before as a technician. Since then she had taught herself electronics and had gradually become an indispensable member of the Anderson crews that came to Palestine. On this mission she had been given full charge of the small payload, a responsibility she executed in dead earnest.

As she pointed out, each of the monkey's outer cylinders was really an elongated hollow "doughnut" designed to permit passage of stratospheric air through its central opening, and each contained a plasma gun trained to fire a beam of light across that opening. The carefully calibrated wavelength of that light would be just right for absorption by oxygen radicals (lone oxygen atoms); and so lone oxygen atoms passing through the beam would absorb some photons of that light and would be stimulated to emit new photons. However, those newly emitted photons would not necessarily follow the direction of the beam. Instead they would go off in all directions, like subway riders getting off a train. So some would register on optical sensors mounted at right angles to the beam, and in this way the sensors could measure the concentration of lone oxygen atoms in the passing air.

The Anderson group had measured stratospheric concentrations of one-atom oxygen radicals that way before; and indeed, such oxygen radicals are about the easiest stratospheric radicals to detect. But the past measurements had been made while Anderson's parachute-borne apparatus was descending through the stratosphere's thin air at more than 200 miles an hour, and there was no guarantee it would work the same at slower speeds.

To find out how it would work at a range of slower speeds, the group had placed small fans atop the holes running through the centers of both cylinders. They could use those fans to control the airflow through the cylinders; and so, by making the air pass through at different speeds (from ten to sixty miles per hour) while reel-down was in progress, they would learn about the combined effects of altitude and relatively slow air speeds on their detectors. In this way they could gather information deemed essential for future reel-down flights.

Later that day I paid a call on Robert Kubara, the balloon-base operations chief. He was a key man at Palestine. If there was any question about whether a launch should go ahead, he would make a recommendation to the base commander, and that recommendation generally stuck. Likewise, he generally decided when and if a given flight should be aborted.

Apparently in his fifties, with steel-gray hair and several decades of experience, Kubara could have told me any of a thousand balloon stories. Instead he stressed a single theme: that Jim Anderson was only one of many

PHOTOGRAPHS BY JIM TROTMAN

Janie Phillips assembling "the monkey." Her ear protectors block out noise from the winch platform's motors. The colorful maze of radio and electronic gear in the monkey's central section will transmit and receive radio messages, permit remote control of test equipment in the two outer sections, and relay test results to the ground.

Harvard people who had done balloon work at Palestine, and that Giovanni Fazio of the Harvard Center for Astrophysics was actively engaged in balloon research right now.

This point was valid; but with all the current reel-down excitement, I wondered why he brought it up. Perhaps he felt credit should be spread around, particularly since the base personnel who flew the balloons got very little. If so he had good reason; for quite aside from the credit due other researchers, Kubara's men did essential work. As Craig Schiller, an Anderson crew member who helped engineer the winch platform put it, "The base has so many guidelines governing balloon launches that if you went completely by the book, it wouldn't work. Kubara and his people, with sound judgment and years of balloon experience, aren't afraid to act. If it weren't for them, a lot of balloons would never have gotten off the ground."

Over the next few days, however, I began to wonder whether Kubara's men or anybody else could help the project. Delays cropped up continually; the schedule kept slipping; and by Friday, September 3, a kind of quiet desperation had set in. The team prepared to celebrate Labor Day weekend by working through it. Twelve-hour days became the norm. Nate Hazen, Anderson's second in command, estimated that they "might" be ready by September 11 if they were really lucky. And although some hoped he was just being pessimistic, his opinion was far too respected to ignore.

The low point came the evening of Labor Day, September 6, when everybody realized they faced a long, uphill struggle despite the lost weekend. That was the night Janie threw an aluminum can top in the motel pool, Craig took off his shoes and dove in after it, somebody threw the shoes in after him, he responded as could be expected, and several people wound up in the drink. Given the circumstances, it seemed the healthiest possible way to let off steam.

The next week saw slow progress. The schedule continued slipping, and Nate's prediction proved correct. Nevertheless, by Friday, September 10, they were ready enough to get a "go" from the base for a possible launch on Tuesday, September 14.

After that things really tightened down. As Anderson said, "There's no more time for driving lessons—the aim now is to avoid getting arrested." Accordingly, the team drew up a timetable for all prelaunch preparations, arranged for final weighing of the payloads, and ran a test of the winch motor's powerful silver-zinc batteries. Monitors were then appointed to oversee recharging of the batteries, and team members could generally be found in the assembly room around the clock.

Philip Weld (Harvard Class of '36) and his wife, Anne,

The reel-down launch. The spool truck with the balloon's upper end looped over its spool (above) and partially inflated (right). Bottom, from left to right, the entire balloon-payload assembly; the balloon rising behind Tiny Tim; the balloon's attachment cables approaching the vertical. Opposite, the entire rig, which at 800 feet stands taller than Boston's John Hancock Tower, at its moment of release.

arrived Monday afternoon to see the launch and provide moral support. An expert yachtsman, former newspaper owner, and Harvard patron, Weld shared Jim Anderson's adventurous spirit and conviction that reel-down was important. So he and his wife had left their home in Gloucester, Massachusetts, and come to Palestine, anticipating that the launch would go as planned.

That was not to be, for on Monday Tropical Storm Chris struck the Texas-Lousiana coast with sixty-mile-an-hour winds. Miraculously, however, the blow was not fatal to the project. By Tuesday afternoon the storm

Ed Thompson, the electrical engineer, was more emphatic: "We've poked it, probed it, kicked it, kissed it, and done everything we can. I have every confidence in it. We're ready."

was showing signs of clearing out, suitable weather was predicted for Wednesday morning (September 15), and the stratospheric winds were still blowing to the west. So in hopes that the meteorologists were right, that low-level winds would be under the maximum launch speed of ten knots, and that they could launch before 9 a.m. when the morning winds typically picked up, the team went back to their last-minute preparations.

As of 3:30 a.m. Wednesday, they were still at it. "I've had more sleep than anybody else," said Stod. "I had three hours and everyone else had fifteen minutes. We got a change of clothes and stopped at the Pitt Grill to eat, and that's all we did. We're moving out though."

By then the big launch vehicle nicknamed "Tiny Tim" had arrived and was waiting outside the assembly building. Through the building's windows, four people could be seen simultaneously clambering over the winch platform.

Jim Anderson emerged at 3:50 and indicated they were done. "We had those thousand little things at the last minute, but we're definitely set to go." Ed Thompson, the electrical engineer, was more emphatic: "We've poked it, probed it, kicked it, kissed it, and done everything we can. I have every confidence in it. We're ready."

A few minutes later the big door on the assembly shed rose; the winch platform moved forward; a fork-lift raised the platform within reach of Tiny Tim; the attachment cables were hooked up; the platform was suspended from Tim's jaws; and Tim departed for the launch pad looking like a benevolent praying mantis.

It was only at five o'clock, after Tim had reached the pad and the monkey had been hung from the winch platform, that trouble surfaced in the communications apparatus. That trouble, located in the base controllers' gear, had nothing to do with Anderson's equipment. Nevertheless, it required replacement of key components; the repairs had to be performed quickly on the pad; and time was running out.

By seven o'clock, when those repairs were done, the wind had started to act strangely. Nothing unusual was happening at 400 feet, where the wind was blowing gently in the direction forecast; but the ground-level wind was unexpectedly blowing in the wrong direction. This meant that even if the canvas "road" on which the balloon was now laid out could somehow be moved 180 degrees, to the other side of the huge launch pad, the balloon would still run into a significant wind shear as it rose. And since the balloon's polyethylene skin was only 0.5 mils thick (about a third the thickness of plastic gardening mulch), such wind shear could tear the bag apart. Therefore, the only real option was to wait and hope the ground wind changed.

Finally, around eight o'clock, the wind began to shift; but by then there was already talk of scrubbing. How long the shift might last was hard to tell. The strange cross wind could signal incipient thunderstorm activity near Dallas, something that had created scary situations in the past. By the time the crew got helium into the balloon, the morning winds might be rising. And by the time they got ready for reel-down, it might be dark.

On the other hand, if they didn't launch soon, the winds would definitely pick up and the morning would be gone. That could end reel-down's chances, because future ground-weather patterns looked uncertain and turnaround was due.

These considerations produced a hasty conference on the pad between Albert Shipley (the base commander), Kubara, and two base meteorologists. Kubara then discussed the situation with the head of his launch crew. Anderson, watching all this from a distance, gave a thumbs-up sign and said, "We're going." He was right. The decision, by a whisker, was to launch.

After that, orders were issued quickly. Valves on the waiting helium trucks were opened. Helium, making the keening noise of a grass reed held between a child's thumbs, entered the balloon; and the 26-million-cubic-foot bag began to fill. The balloon was committed to the flight.

In about twenty minutes the desired amount of gas had been pumped in, and the lines through which the gas entered were tied off. By then maybe a fifth of the balloon was in the air, towering above a secondary launch vehicle called the "spool truck." That vehicle's "spool" (actually a rotating vise) was restraining the launch-ready balloon and preventing gas from entering the uninflated portion of the bag lying between the spool truck and Tiny Tim.

Suddenly, at 8:53 a.m., the restraining spool snapped back and the inflated top of the balloon began to rise. Mushrooming out, the top rose quickly, pulling first the rest of the balloon, then the winch platform's parachute, and then the parachute's long shroud-lines toward the vertical. It was a rough launch, for Tim held onto the two payloads well past the ideal release point when the balloon was almost directly overhead, and the ensuing maneuvering slammed the monkey against Tim's front end. Ultimately, however, Tim's jaws flew apart, the payloads moved out majestically with no apparent damage, and the upward climb began. "From now on," said Stod, "the job's ours."

By noon the balloon had reached its float altitude of 134,000 feet. A jury-rigged television camera had survived the trip through cold parts of the lower atmosphere, to the surprise of all, and was relaying a bird's-eye view of the monkey as seen from the base of the winch platform. Several cathode ray tubes were filled with numbers relayed from both payloads; and the monkey was making preliminary measurements of oxygen radicals.

"I'm worried," said Anderson, "everything's going too well."

Outside, the balloon could still be seen. Clearly visible to the naked eye, it looked in its fully inflated form like a translucent pearl about to be engulfed by a thundercloud. But of course, the thundercloud was less than a quarter as high as the balloon, and so the cloud's passage merely blocked the view.

By then the data shown inside on the flight controllers' information screen looked very odd. The balloon, at the top of the stratosphere, should have been moving west-

Philip Weld: A seafaring man with an eye on the sky

How does a Harvard alumnus, former newspaper owner, and yachtsman come to make an important contribution to atmospheric research? Philip S. Weld '36 believes it grew out of a seafaring mishap in the North Atlantic. In 1976, en route to England, Weld's trimaran *Gulf Streamer* capsized. Five days later he was rescued, and while searching for his boat happened to fly over Nantucket Shoals. Familiarity with those shoals, in turn, caused Weld (a resident of Gloucester, Massachusetts) to become actively concerned about the subsequent *Argo Merchant* oil spill in that area. For this reason he conferred with Harvard faculty members working on pollution issues, and that is how he and James Anderson first met.

Anderson, like Weld, was an experienced and enthusiastic sailor. So, as Weld relates, "In the spring of 1979 I had a berth sailing back after the Bermuda race, and he flew down and sailed to Gloucester with me. We had a marvelous passage, during which I had a chance to get to know him. We really have become good friends since then."

Weld and his wife, Anne, became convinced that atmospheric research being done by Anderson and others was critically important. Longtime Harvard supporters, they decided to endow a chair in that field through the Harvard Campaign. As a result James Anderson, formerly Robert P. Burden professor of atmospheric chemistry, was named the first Philip S. Weld professor of atmospheric chemistry last fall.

Thus the Welds' trip to Palestine (see photograph opposite) was motivated by past experience, friendship, personal involvement, and a desire to see how the project fared. But there was more to it than that. For Philip Weld has unusual personal awareness of what it means to overcome an imposing natural challenge. Most recently, in 1980, he sailed his trimaran *Moxie* from Plymouth, England, to Newport in record time, becoming the oldest person (at 65) and the first American ever to win the London Observer Singlehanded Transatlantic Race. His book, *Moxie: The American Challenge* (Atlantic-Little, Brown, 1982), shows a refined sensitivity for the travails and triumphs of those who take on Nature; and it shows that reel-down was the kind of venture that Weld, of all people, would understand.


JIM TROTMAN

The reel-down team and friends. From the left, Craig Schiller, Stod Rowe, Tracy Kidder (journalist), Edward Thompson, the author, James Anderson, William McLaren, Grady Cole (launch-crew chief), Anne Weld, Philip Weld, Jane Phillips, and Nathan Hazen.

ward at 25 to 30 knots; but the screen showed it meandering north at 1.5 knots. At this point the controllers announced they were having trouble with their monitoring apparatus, and so the data screen should be temporarily ignored.

By two o'clock, however, the balloon was again visible outside and the screen could no longer be ignored. For the balloon was hardly moving, and it was clear that something very fundamental had gone wrong. That is, at some point during the past 24 hours the westerly stratospheric winds had died. Turnaround had arrived. And the base controllers, their well-laid strategy in ruins, had the unwelcome job of brainstorming to build new plans from scratch.

Anderson looked over his shoulder, saw the monkey rushing upward on the TV monitor, brought the winch motors to "full stop," applied the winch brakes, and halted the package with six inches of line to spare.

To the controllers' credit, a reasonable plan of action soon emerged. We were told that if the balloon got north of Interstate Route 20, running east from Dallas, reel-down could begin. Then, after the experiment was over and the balloon passed further north over Interstate Route 30, the winch platform and monkey could be parachuted down into the sparsely inhabited areas beyond.

So everybody held their breath as the balloon, about sixty miles south of its goal, edged north toward Route 20. Unfortunately, it never got there. The capricious winds shifted again, sending the balloon back toward Palestine. At that point, however, the controllers had had enough. Darkness was approaching, an important experiment and half a million dollars of technical gear were in the air, and there were many places worse for reeling down than the region between Palestine and the neighboring town of Tyler to the east. So as the balloon drifted into the area between those towns, the controllers advised Anderson's team to proceed.

By then the whole team, including the principals in charge of reel-down, had gone without any true sleep for more than thirty hours, and they showed it. Nate Hazen had puffy, dark rings below his eyes; and Anderson, who had been under enormous pressure, looked dazed. Nevertheless, the two of them devised a way around the last technical obstacles, a pin that kept the monkey in place was pulled by remote command, Anderson asked, "Are there any objections to proceeding?" and Nate said, "None at all."

Then, as the onboard television camera watched, the monkey started down. Slowly at first and then faster it descended, straight as an arrow, becoming smaller and smaller until at about 400 yards down it disappeared. Now only the numbers projected on the data screens marked its seven-meter-per-second passage as it dropped deeper into the stratosphere's uncharted layers.

The monitors showed no significant oscillations or other troubles as first three, then six, and then nine kilometers of Kevlar line paid out. Finally, as the twelve-kilometer mark approached, Anderson ordered that the monkey be slowed down, and at last it halted an incredible 12.3 kilometers below the winch. By now Janie's apparatus had completed its testing for oxygen radicals. That apparatus, as well as all the other reel-down gear, appeared to have worked at least as well as could have been expected; no significant rotation, pendulum motion, or bouncing had occurred; and all that remained was to reel the monkey back.

The ascent started slowly, at about two meters per second. But the monkey's speed gradually increased until, with only 800 meters left to travel, it was running upward at eight meters a second. Then the winch motors were slowed according to a predetermined schedule, so that with 300 meters to go the monkey was moving upward at only two meters per second. However, when Stod called out "sixteen meters," the monkey was still traveling upward at one meter per second, a bit faster than planned and plenty fast enough to do serious damage if unchecked. Alerted by the call, Anderson looked over his shoulder, saw the monkey rushing upward on the TV monitor, brought the winch motors to "full stop," applied the winch brakes, and halted the package with six inches of line to spare.

Anyone in the room just then would have shared the odd sensation of standing at the frontier of man's ability to explore the stratosphere and watching that frontier advance. For indeed it had advanced. Despite the restrictions, the delays, the technical complexities, the weather, and the vagaries of stratospheric winds, all the equipment had operated to perfection. Anderson and his group had paved the way for learning what mankind needs to know about the stratosphere; they had won their bet with Nature; they had made the reel-down concept work.

Nate, with typical understatement, said simply, "All right, what do we build next?"

"I don't know," answered Anderson. "I'm still in a state of shock."

"That was very smooth, really beautiful," said Kubara.

"This is the best we've ever had," added Janie. "It's great. I can't believe it. Something *always* goes wrong. Today, on a scale of one to ten, I'd rate our part of the mission at about a 27. We've never had one like this, not ever." And she was right.

Later that day two large, orange-and-white parachutes bearing the winch platform and monkey drifted toward the earth. Nobody who saw them descend could help but wonder what they were about. Who had sent them? Had their instruments been exploring space or something else? And were they merely part of an esoteric research exercise, or could their work prove important to people on the ground? But few saw them, because they descended through thick clouds at dusk, landing softly and uneventfully in a wooded area about ten miles from a gate with an announcement warning visitors that "equipment in use at this facility may interfere with heart pacemakers." As anyone on the reel-down team could attest, events of the past few days had proven that. □

Jonathan Leonard is a contributing editor of Harvard Magazine. For more about him, see page 3.