Astride the Wind

Meteorologists follow Franklin's high-flying legacy

By RICHARD MONASTERSKY

Ben Balsley's training as an atmospheric scientist didn't prepare him for wading through shark-infested waters, nor did it train him to fly world-record kites. But two years ago, he found himself doing both as part of an unusual experiment on Christmas Island, in the middle of the Pacific Ocean.

Balsley and his cohorts had traveled to this distant atoll in an attempt to reunite two former partners who separated over half a century ago: kites and meteorology.

Although kites have dropped out of favor as research tools, Balsley proposes that new designs made from space-age materials could rise to unprecedented heights and remain there for weeks on end — soaring platforms that could prove an invaluable means of studying global warming, ozone destruction and a host of other atmospheric concerns. "This is probably the most exciting thing I've ever been involved with," says Balsley, who specializes in wind speed studies at the Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder.

Almost 240 years earlier, another Ben sent his kite up into a thunderstorm in a flashy experiment that still burns bright in the memory of schoolchildren. While not the first to use kites in the service of meteorology, Benjamin Franklin captured widespread public attention with his shocking exploits. After the invention of the box design in 1893, the U.S. Weather Bureau adopted kites as a meteorological tool, flying them from a network of stations for the next 30 years. But with improvements in scientific balloons and the growing importance of airplanes, the popularity of research kites plummeted in the years following World War I. In 1933, the Weather Bureau finally closed its last station dedicated to this task. In recent decades, kites have served in a mere handful of atmospheric experiments.

Balsley's thoughts first turned to kites a few years ago, during a casual conversation with a colleague who studies the Earth's electric field. Lamenting the limitations of current techniques, this researcher wondered how he might monitor the field in a spot high above Earth over a period of several days. Balsley had little experience with electric fields, but he suggested that a kite might solve the problem.

In 1990, Balsley received a small grant from the National Science Foundation to test the idea. A search around the country put him in touch with G. William Tyrrell Jr., of Doylestown, Pa., who specializes in designing kites for unusual projects. Tyrrell holds several world records for large kites and kites that lift the most weight. In the past, he has produced designs for filmmaker Woody Allen, the Rolling Stones and even a Japanese fishing fleet that wanted underwater kite-like lures to catch tuna without killing dolphins.

Tyrrell recognized the need for a third person: someone with aerodynamic expertise who could help develop a kite capable of riding the thin air at high altitudes. While visiting his seamstress, Tyrrell ran into her husband, Joseph Williams, a former Air Force pilot working as an aeronautical engineer for Modelsym, Inc., in Doylestown. Williams specialized in designing the wings of low-speed planes, which bear more than a passing resemblance to kites. The leap to kite design proved a short one.

For the initial experiment, Balsley asked Tyrrell and Williams to fashion a form that could lift a package of scientific instruments 3 kilometers above the ground in light winds. This altitude is far beyond the range of the average kite.

Balsley chose Christmas Island in the Republic of Kiribati because it lies in the equatorial belt where rains are rare and the wind is steady. Aside from providing a flat, nearly treeless expanse, the 40-kilometer-long atoll offered one other important advantage: It hosted only one airplane each week, on Wednesday. The rest of the week, the skies remained free of traffic.

Before traveling to Christmas Island, Tyrrell and Williams had to find the right design. Williams created a computer program to analyze the various characteristics of kite flight, including cable weight, cable strength, drag and airfoil shape. The program indicated that only one particular design — a parafoil — could do the job.

Made entirely out of fabric, without any hard frame, parafoils are a series of parallel tubes connected like logs on a raft. In the wind, the tubes inflate and take on a curved shape similar to the camber of an airplane wing. This shape makes air flowing above the kite move faster than the air below the kite, providing the lift that carries the parafoil into the sky.

Instead of building one large kite that might rip if the winds grew abnormally strong, Tyrrell decided to construct four that could fly in different combinations to suit the weather conditions. To carry the requisite scientific payload, the kites would have to be quite light, tipping the scales at no more than 2.25 kilograms each.

Tyrrell selected a thin ripstop nylon for the kite fabric and a 6-kilometer-long tether made out of kevlar, an extremely strong, lightweight material used for bullet-proof vests. Each kite had a surface area of 12.5 square meters, or roughly the size of two compact cars parked side by side.

When they reached Christmas Island — so named because of its discovery on Dec. 24, 1777, by Capt. James Cook — Tyrrell, Williams, Balsley and Balsley's son, Chris, headed to an abandoned runway at the atoll's southeast end. The airstrip provided a long, flat surface ideal for preparing the launch. But under the blazing equatorial sun, the pavement

During a test flight on Hawaii, the parafoil displays its curved top, which generates lift as air rushes over it. The leading edge of the kite is open so that wind will inflate the individual chambers. Inset: On Christmas Island, Williams, Balsley and Tyrrell watch the parafoil in action. Between them lies the anchoring system and the large spool of Kevlar line.

C. Balsley

heated the air to 43°C (110°F), generating strong thermal updrafts that confounded efforts to fly the parafoils.

A kite caught in a thermal updraft can move forward until it sits overhead with its line perpendicular to the ground — an extremely unstable position. "The kite will then go past 90° and start wandering, and usually it comes screaming into the ground nose first," explains Tyrrell. He and his colleagues finally conquered the thermals by hanging a windsock on the tail end of the kite to shift weight backward, enabling the kite to rise safely above the updrafts.

The winds above Christmas Island blew stronger than expected, and the team needed only two of the parafoils to lift the scientific instruments. They put up the first of the red and blue kites, then attached a second one to the kevlar tether about 2 kilometers below the first.

Balsley, who had worked on the island previously, promised his co-workers it wouldn't rain. But soon after the test flight began, an errant storm suddenly appeared. The rain soaked the lower parafoil, adding enough weight to send it diving into the ocean, where it ripped on a coral reef. When the two Balsleys and Williams waded through the surf to retrieve the kite, they ran into a 2-meter-long shark prowling the area. Both people and shark survived the encounter, and the team went back to replace the torn kite.

With two kites flying, the line held seven identical instrument packages spaced 300 meters apart. Each package measured air pressure, temperature, humidity and the electric field, sending the information down via radio to a laptop computer on the ground. By the time the team had let out all the available tether, the kites had reached an altitude of 3.5 kilometers, the highest ever achieved by a parafoil, says Tyrrell. The group had also succeeded in keeping the kites flying for four straight days.

"We would come out in the morning and that kevlar line went up into a clear blue sky. It just disappeared. And when you pulled on it, it was alive," says Balsley, describing the thrill of keeping the kites aloft for so long.

For the future, Balsley and his cohorts have set their sights even higher. Extrapolating from their test flights and from computer analyses, Williams calculates that a larger parafoil design could carry scientific payloads to an altitude of 19 kilometers in locations with the right wind. That accomplishment would double the highest official altitude record for kites, set in 1919 by a string of eight box kites that reached 9,740 meters.

Depending on where it flies, the parafoil design could reach up into the stratosphere, home of the endangered ozone layer. This high-flying kite would measure about 10 times the size of the ones used on Christmas Island. For scale, imagine three tractor-trailers parked side by side.

To construct the large parafoil, the group plans to use a fabric made of kevlar-strengthened mylar, which has greater strength and absorbs less moisture than nylon. Mylar also stands up better to damaging ultraviolet radiation. The kites will need that protection because they could remain aloft for weeks, if not longer. "If we can get them up into the lower stratosphere, there's no reason they should not stay up for months," Balsley says.

While that feat would certainly shatter some record, Balsley has other aims. He sees high-altitude kites as potentially filling a major gap in atmospheric studies. Scientists have limited means for probing regions more than 15 kilometers high. Currently, only one type of research plane — the ER-2 — can readily perform missions above that altitude, and NASA has only three of these planes available for atmospheric research. The ER-2 has proved invaluable to researchers in the past, but it is extremely expensive to operate — dangerous too. If the plane's single engine quit in a remote area, such as over the ocean near Antarctica, its pilot would probably die. Also, NASA restricts ER-2 flights to less than 8 hours to keep the pilot from growing dangerously fatigued.

Balloons play a major role in atmospheric science, but they, too, have limitations. Normal research balloons rise quickly, limiting the time that instruments can collect measurements in any one layer of the atmosphere. Other balloons are designed to fly at a relatively constant height, but these travel with the wind, not necessarily in the direction scientists want them to head.

Unmanned robot planes will soon provide a way of carrying instruments even higher than the ER-2, and for a fraction of the cost (SN: 3/2/91, p.136). NASA last year funded the construction of three small robot planes, which are expected to roll off the assembly line next year. But even with their relatively inexpensive price tag, the bill for such planes will run into the millions, and current designs cannot stay aloft for weeks on end.

In contrast, instruments carried by kites could collect long-term measurements in upper regions of the atmosphere. Balsley envisions instruments with special adaptations for extended flights. Some devices could carry solar cells, tapping the sun's energy to power their sensors and radio transmitters. Others might include a wind generator. Still others could use tiny motors to ride up and down the kite tether, collecting data at different levels in the atmosphere.

Ron Taylor, program director for physical meteorology at the National Science Foundation, agrees that high-altitude kites could prove quite useful. For example, he says, they could answer some long-standing questions about clouds, which scientists regard as a major impediment to their efforts to predict how much the climate will warm in the future.

High cirrus clouds apparently help warm the Earth, and climate experts want to know whether a greenhouse warming will suppress or enhance cirrus development. But atmospheric researchers know relatively little about the ice crystals that form these thin, wispy clouds. "That's the big mystery about cirrus clouds. We just don't have enough information to say whether there are little crystals, big ones or all kinds. We don't have many aircraft available for meteorological research that can get to those altitudes readily," says Taylor.

While kites can potentially fill a meteorological niche, they have their own limitations. The high-altitude designs require a steady, moderate breeze and cannot fly in places where the wind is too light or too variable, as it often is in the mid-latitudes of the globe, says Balsley. He expects the high-flying kites would find their greatest use in the equatorial

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fetal body weight among the ultrasound-exposed animals, regardless of the ultrasound dose received. They present their findings in the December 1991 TERATOLOGY.

"It's an interesting study," comments Carole A. Kimmel, a teratologist at the Environmental Protection Agency in Washington, D.C. The new data add to previous evidence suggesting there is no link between birth defects and ultrasound exposure. Kimmel's own work, which involved anesthetized mice, also showed no risk of birth defects after ultrasound exposure.

Such work eases one fear. There remains the worry of many scientists that sound waves might have the potential to cause subtle brain damage in the fetus. That concern dates to a 1984 study indicating a possible link between prenatal ultrasound exposure and dyslexia, a type of learning disability in which children have difficulty reading.

Obstetricians generally order a sonogram between the 16th and 22nd week of pregnancy, a very important period in fetal brain development. During this time, fetal nerve cells travel to their final destinations in the brain. If a sonogram somehow disrupts that journey, could learning problems result?

A study led by Kjell Salvesen of the University of Trondheim, Norway, appears to provide a reassuring answer to that question.

Salvesen's team recruited 2,011 pregnant women attending obstetric clinics in central Norway between 1979 and 1981. Physicians gave half the group sonograms during the 16th to 22nd week of pregnancy. The remaining half, for the most part, did not receive an ultrasound test during pregnancy. (A few women in the control group got a sonogram if they experienced problems during pregnancy, such as bleeding.)

Eight to nine years later, the Norwegian scientists sent questionnaires to the women in the study, asking about their children's health. With parental consent, the researchers then contacted the teachers of all the children, asking them to assess each child's achievement in reading, spelling and arithmetic, and to give an overall score on school performance. The teachers did not know the children's ultrasound status.

In the Jan. 11 LANCET, Salvesen and his co-workers report that they found no differences in school performance between the two groups. If anything, the ultrasound-exposed kids did slightly better in school than the control group.

Because a teacher's assessment of a child's performance can be biased, the team also selected 603 of the kids for a special test designed to diagnose dyslexia. Trained examiners tested the children for intelligence, reading comprehension, reading speed and spelling. Kids whose reading ability fell far below their predicted skills, based on intelligence, were diagnosed as dyslexic.

Again, the team found no significant differences between the ultrasound-exposed youngsters and the controls. Test results classified 21 of the 309 ultrasound children (7 percent) and 26 of the 294 controls (9 percent) as dyslexic.

While that study seems to dissolve the dyslexia link, Salvesen is not ready to extend blanket approval to ultrasound during pregnancy.

"I will not say that ultrasound is [completely] safe, because there could be other [problems] that we didn't examine in these children," Salvesen told SCIENCE NEWS.

In addition, he notes that the ultrasound machines used in his study are now becoming obsolete, with many hospitals relying on higher-energy devices that produce sharper images. "The technology is rapidly developing, and these safety studies will always come 10 years after the devices have been taken into general use," he says.

No one can say with certainty that the higher-energy ultrasonic devices cannot harm a fetus, says Vorhees. Heat isn't the only way in which ultrasound might theoretically damage tissues, he adds. Sound waves may cause microscopic bubbles in body fluids to oscillate and sometimes collapse, Vorhees says. Scientists don't know whether such problems can injure the fetus.

The scientific uncertainty over ultrasound led the Food and Drug Administration to advise against sonograms during pregnancy unless there is a problem such as bleeding, a family history of birth defects, or some other medical reason for the procedure, including advanced maternal age. FDA specifically warns against using ultrasound "frivolously" — simply to watch the baby float in the womb or to learn the baby's sex.

FDA's recommendation follows the lead of a National Institutes of Health panel convened in 1984, which concluded that pregnant women should obtain an ultrasound test only when medically necessary (SN: 2/18/84, p.102).

This runs counter to the trend among obstetricians, who are ordering more and more sonograms. Most believe that ultrasound can provide valuable information, even in low-risk, problem-free pregnancies, and they say they are satisfied that the studies conducted so far have established the technology's safety.

"I don't have any concerns whatsoever," says Anthony R. Scialli, an obstetrician and reproductive toxicologist at Georgetown University in Washington, D.C. "I think most obstetricians share my opinion."

Scialli believes routine use of ultrasound during pregnancy would benefit many women, especially those with undiagnosed problems. If cost were no barrier, he says, he would recommend a sonogram during the first six to eight weeks of pregnancy and again at 18 weeks. Each ultrasound procedure costs $250 to $350. Insurers pay for the test in high-risk pregnancies or if a problem develops but generally don't pay for routine procedures used as preventive measures, Scialli says.

An ultrasound test during the first trimester can accurately date a pregnancy, he adds. Although most women can trace their pregnancy back to a missed menstrual period, sometimes bleeding will occur after the egg is fertilized. If the obstetrician relies on the menstrual history, the due date may be wrong, Scialli notes.

An early sonogram can also identify ectopic pregnancy, a dangerous condition that occurs when the fertilized egg begins to develop outside the uterus. Many women with an ectopic pregnancy don't realize they have this condition until complications develop. Because the tissue outside the uterus cannot sustain an embryo, the pregnancy cannot proceed normally. With an early diagnosis via ultrasound, doctors can remove the embryo immediately, lessening the mother's risk of severe bleeding and other problems, Scialli says.

"We've all seen instances where ultrasound has been invaluable," he adds. □

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belt or closer to the poles, at least in the beginning.

Getting away from the populated midlatitudes would also keep the kites out of the major air traffic corridors, thereby circumventing another major restriction. Researchers cannot simply float a kite high in the atmosphere anywhere they wish: In the United States, Federal Aviation Administration regulations prohibit flying kites that weigh more than 5 pounds above modest altitudes.

Balsley says these restrictions need not ground the kites entirely in populated regions. Meteorologists may be able to apply for special permits, something Balsley did when his group test flew the parafoils on Hawaii's big island. "This doesn't seem to be an insurmountable problem," says Balsley.

For now, funding presents the biggest hurdle. The Christmas Island crew is awaiting NSF's reaction to their $1.4 million proposal for building and testing several of the larger, high-altitude kites over a four-year period. Taylor says the answer should come within the next few months.

In an era of increasingly complex and problem-prone aviation technology, perhaps funding officials will find some appeal in reviving one of meteorology's simpler tools. □