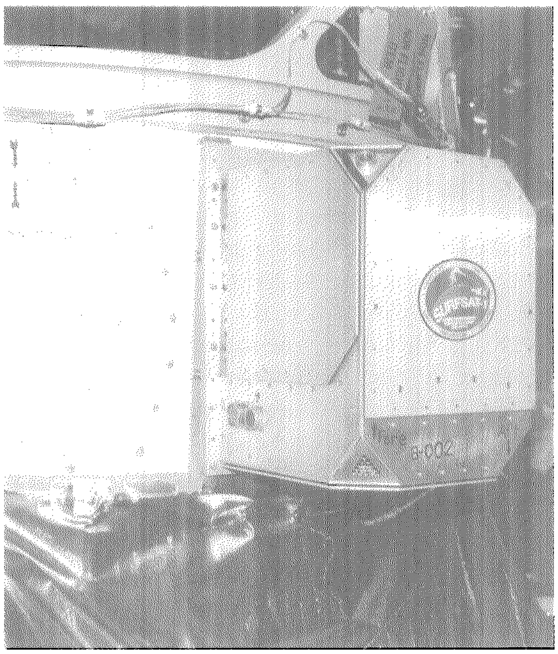
SURFboard

Radical Stick, Dude!



Above: The SURFSAT boxes were mated to the rocket on pad SLC-2W at Vandenberg Air Force Base about a week before launch. The job isn't quite done yet in this photo—the metal panels protecting the solar cells have yet to be removed.

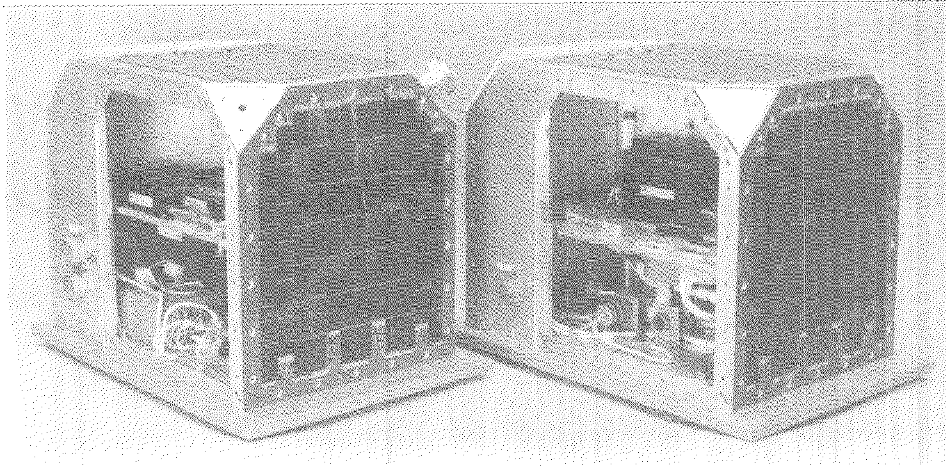
Some folks surf at Zuma, some surf the Internet, and now there's a SURFer dude in space. His buzz-cut, sunglassed visage adorns the Delta II rocket that lofted the Canadian RADARSAT into polar orbit from Vandenberg Air Force Base last November 4. Bolted to the Delta's second stage are two aluminum boxes, each the size of the proverbial bread box, that were designed and built by nearly a decade's worth of SURF (Summer Undergraduate Research Fellowship) students and others. The boxes, collectively known as SURFSAT-1, are being used by engineers at Caltech's Jet Propulsion Laboratory (JPL), to test new technology for use in the Deep Space Network, the worldwide system of antennas that is our communications link with JPL's armada of far-flung spacecraft such as Voyager and Galileo.

Commands are sent to these spacecraft, and data returned, over a chunk of the radio spectrum called the X band. But in 1979, JPL was allotted another region called the Ka band, which can, in theory, carry up to 14.4 times more data. (The names were assigned by the bands' original military users, and serve primarily to confuse people.) However, the Ka band demands that ground stations using it point their antennas much more accurately, and it's also more sensitive to atmospheric effects during bad weather.

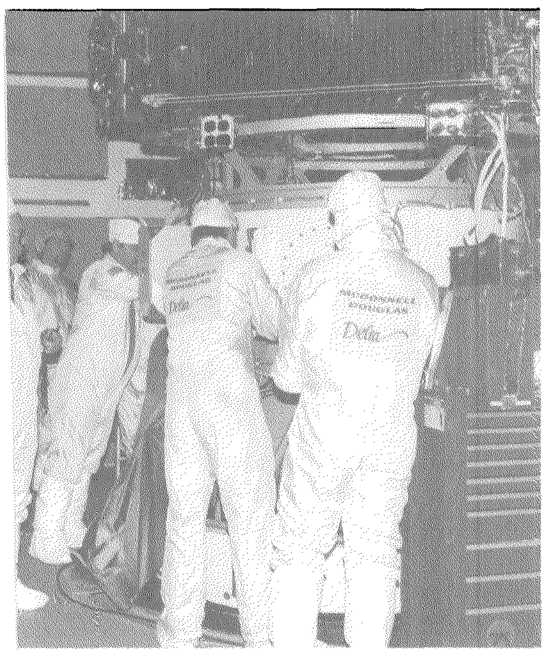
So before outfitting all future deep-space probes with Ka-band radios, the engineers wanted to see how their tracking equipment would really perform. What they needed for this was an orbiting Ka-band source that emitted a very weak signal. "What we needed," recalls Project Manager Joel Smith, "was a small, cheap satellite. And, of course, we were laughing, because there were no such things, and in comes Ed Posner [then a visiting professor of electrical engineering at Caltech, and JPL's chief technologist for telecommunications and data acquisition], who said, 'Hey guys, I've got a bunch of students coming this summer. Do you have any good jobs for them?' And we said, 'You bet!'" Six SURF students were hired that year—1987—to begin designing the spacecraft. Posner eventually cosponsored 43 SURFSAT students before his untimely death in 1993. In all, more than 60 students from 14 colleges in the US and UK were involved.

The original plan was to fly an X-band and a Ka-band transmitter that would continuously broadcast weak (microwatt) signals that the ground stations would try to lock on to and track. The performance of the two carriers could then be compared.

Meanwhile, the Deep Space Network was gearing up for a pair of international orbiting very-long-baseline interferometry missions. The idea here is to have a spaceborne radio telescope—either Russia's RadioAstron or Japan's VSOP satellites—observe a distant quasar, or whatever, at the same time that a ground-based antenna does. The signals are combined in a computer, and the result is a "virtual" radio dish whose effective diameter is the distance between the ground station and the satellite. In order to combine the signals properly, however, you need to know their arrival times at both receivers to within a billionth of a second, which means that a time signal has to be sent continuously from the ground station to the spacecraft. This had never been done routinely before, so SURFSAT was also volunteered as a test receiver for the time signals. Its transmitters were traded in for transponders to permit two-way communication—otherwise the ground crew would have no way of knowing if



Above: The box at left is the primary payload, housing the X-band and Ka-band transponder. The other box contains the Ku-band unit. The X band spans the frequencies between 7,000 and 8,500 million cycles per second, the Ka band runs from 31,800 to 32,300 million, and the Ku band is at 14,100–15,300 million.



Above: Antsos is second from the left in the crowd, through which one of the SURFSAT boxes can be seen at shoulder height. The entire second stage is about six feet in diameter and 18 feet tall.

the time signals were getting through. (The Russian satellite uses the X band, and a new, Ku-band transponder was added to accommodate the Japanese.)

At that point in late 1993, SURFSAT acquired a task manager, Steve Johnson, and became a real Flight Project. It was his job to shepherd SURFSAT through the fabrication, test, and review process and turn the design into real hardware. Then he had to get the hardware flight-qualified and mated to the rocket. This meant leading a joint effort with folks at McDonnell-Douglas Aerospace, which manufactures and launches the Delta, and Darren Bedell and Marissa Achee of Orbital Launch Services at NASA's Goddard Spaceflight Center, who made sure that nothing SURFSAT could do would harm RADARSAT in any way, and figured out how to attach SURFSAT to the rocket.

SURFSAT's design is an essay in simplicity. Each of the two boxes is a self-contained payload—one houses the X- and Ka-band transponder and the other the Ku-band transponder. Each box is shingled with solar cells—the only on-board power source—which are kept illuminated by the spacecraft's sun-synchronous orbit. There are no thrusters, no attitude-control gyros; the transponders' fixed-view, wide-angle antennas are trained on Earth by gravity-gradient stabilization, which essentially means that the spent booster section that carries them is nose-heavy, so the front-facing antennas point down. And riding a dead rocket means that the SURFSAT team gets its position information for free. "The Air Force has to track us as space debris," Smith explains. "And they've agreed to tell us where we are once a day, so we can never get lost."

There isn't even an onboard computer. "We worked *hard* to keep it that simple. The students would want to make it more complicated. 'What if we put a boom out here? What if we added a battery? What if we had a timer?'" But sticking to basics and using commercially available, mil-spec parts kept the project's cost to under three million dollars—the least JPL has spent on a satellite since Explorer One was launched for two million in 1957. (Adjusting for inflation, SURFSAT even beats that.)

As the project matured into actual flight hardware over the last two years, it outgrew the SURF students—ten weeks a summer per student just wasn't sufficient. The project turned to COOP students—who work six months a year full-time at JPL and are full-time college students the other six months—and to JPL staff. One of the latter was Dimitri Antsos (BS '90, MS '91, PhD '93 [under Posner]), who had started on SURFSAT in 1988 as a sophomore, and had been working on it on and off ever since. JPL hired him outright the moment he got his PhD, and building the transponders became his first official responsibility. He; Greg Carr, who built the power systems; Jim Springett of Neocomm, who designed the other electronics; and JPL's Johnny Duong, who built them, put in a lot of overtime. So did scores of people at McDonnell-Douglas, at Vandenberg, and elsewhere, because, of course, things never go as smoothly as you'd expect. "SURFSAT really brought out the best in everybody," Smith says. "It was a marvelous program. Every time we got in trouble, people just came out of the woodwork to help the student spacecraft."

Now that SURFSAT is flying, everything is working just fine. The mission-operations crew expects to get all the data they need on the relative merits of the X and the Ka bands within a year, which coincides with Radio-Astron's and VSOP's planned launch dates. The crew originally planned to turn SURFSAT off when they were done with it, but now other people who have antennas to test want to borrow it. So JPL may leave it running as a kind of public resource for whoever wants to use it. Ed Posner would be proud. □—*DS*