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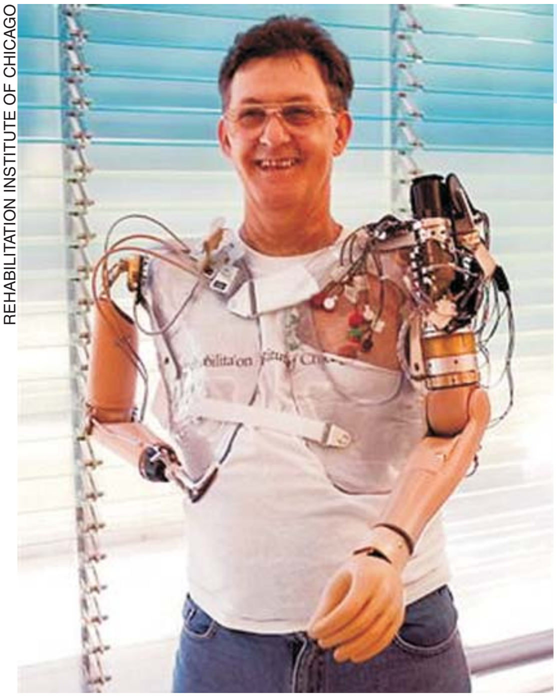

Electrodes on one side of double-amputee Jesse Sullivan's chest pick up thought-generated signals from his nerves to control a state-of-the-art prosthetic arm. His other arm is an old-fashioned pincer.

OTTO BOCK HEALTH CARE

A well-worn prosthetic arm. Some users prefer an old basic design, like this one, rather than a more modern device.

sion of this story). He can take out the garbage, shave, and put on his socks, but he does not have the dexterity to tie his shoes, pick a flower, or throw a ball. His prosthesis is also cumbersome and expensive—$100 000 not including surgery—and requires frequent maintenance.

In the short term, to gain better user control over prosthetic arms, APL is looking into combining RIC's technique with sophisticated pattern-recognition algorithms to "guess" the user's intent from the limited nerve signals and preshape the hand to grasp objects, for example. For the long term, cortical neural interfaces, in which neural impulses to and from the brain are intercepted for direct communication with the prosthesis, and peripheral neural interfaces appear to be better bets. "It's a challenging part of the project, but cortical plasticity could be the key. We need to train the limb and the user to both respond to mistakes and learn from them," says APL's James Beaty. "Once installed, the system has to work in real time."

APL is also creating virtual-reality simulations for patients to learn how to control their artificial limbs. "We need to get to the point that when someone is pushing against a virtual table, it feels like a table to the user," says APL's James Burck, a systems engineer.

Another approach is to use injectable myoelectric sensors (IMES). Partners in the APL team at NUPRL and at Sigenics Inc of Lincolnshire, Illinois, are developing centimeter-long devices that can be implanted in residual muscles to record and amplify small nerve signals directly from activated muscles. Researchers at the University of Utah and elsewhere are developing miniature recording systems to access the body's inherent neural signals for control of the prosthetic limb. These efforts will make the small neural signals naturally transmitted to the human hand and the limb more readable, Harshbarger says.

Power problems

"Once you have your next-generation artificial limb, you still have one major problem," says Harshbarger, "how to power it." Whereas traditional prosthetic arms are maneuvered with body motion, DARPA's first prototype will be battery-powered, like the state-of-the-art limbs today, and future versions may rely on fuel cells or small cartridges of hydrogen peroxide—which could be jettisoned and replaced almost as easily as a flashlight battery. "We're also looking to see whether body movement could power the small sensor components and whether highly efficient hydraulic pumps could be used [to move the limb]," says Harshbarger. Current prosthetic arms can lift a maximum weight of about 9 kilograms. DARPA hopes to raise that to 27.3 kg, which requires stronger, more efficient motors and more power. The arm and hand for Proto 2, weighing 3.2 kg itself, can manipulate 22 kg. "This is unprecedented for robotic arms," says Van Doren.

DARPA plans to make design decisions about the phase-one prosthesis in November 2007. In the end, says Harshbarger, "DARPA may decide that [the APL team] should build an arm with 15 to 18 degrees of motion and less strength that could potentially cost less per system than our initial prototypes might. These are the kinds of system tradeoffs that will be addressed as we prepare the system integration plan for transition to phase two." In the meantime, no one is forgetting how beneficial even a minor improvement will be for the injured troops. Says Harshbarger, "I've never been on such an extremely rewarding project in which so many research groups have set aside their competitiveness with each other to work towards the common good."

Paul Guinnessy

NASA saves SOFIA by slashing planet-finding funds

A US–German telescope will fly high to observe the infrared sky.

A winged telescope got a reprieve this summer when its funding was restored by NASA. The Stratospheric Observatory for Infrared Astronomy (SOFIA), a 2.5-meter telescope aboard a modified Boeing 747 jet, is now expected to take its maiden test flight this winter and to begin collecting data at the end of the decade.

NASA has already spent $485 million on SOFIA and will have to pony up another $250 million to $300 million for the science to get off the ground, according to Rick Howard, the agency's acting astrophysics division director. Last February NASA struck SOFIA

L-3 COMMUNICATIONS

A retired passenger jet with a lightweight and sturdy telescope aboard is being readied for forays into Earth's stratosphere.

from its budget plans for fiscal year 2007 and beyond. The cut "was mainly due to budgetary constraints and the fact that [SOFIA] did have a number of problems and continued cost growth and schedule slips," Howard says.

Contributing to SOFIA's increased cost and delays were the modifications to the plane, which had been a commercial passenger jet for nearly 20 years. "It was a bigger project than anyone had anticipated," says SOFIA chief scientist Eric Becklin of UCLA. "We also got hit hard when United [Airlines] pulled out [as a SOFIA partner] because of bankruptcy." And after the *Columbia* space shuttle accident, he adds, "NASA had to refocus safety efforts. The number of people overseeing safety increased on the [SOFIA] program."

Still, the door was left ajar for SOFIA pending an independent review, which was carried out this past spring. The review found "no technical showstoppers. [SOFIA] just needed some very sound management structuring and schedule realism," says Howard.

As part of resurrecting the project, NASA has shifted oversight of test flights and the remainder of the aircraft modification from its Ames Research Center, which is still responsible for SOFIA science, to its Dryden Flight Research Center. Astronomers' opposition to killing SOFIA, plus NASA's desire to make good on its collaboration with the German Aerospace Center, which has a 20% stake in SOFIA, may also have been instrumental in the decision to save the project. Germany is providing the telescope and two of the nine initial instruments. The US is contributing the other seven instruments and modifying the aircraft.

Infrared access

By flying at altitudes up to 41 000 feet, SOFIA will get above most of the moisture in Earth's atmosphere, which blocks IR radiation. "We are like a space telescope, but we come home every night," says Becklin. SOFIA will initially observe in a band that spans UV to submillimeter wavelengths, 0.3–700 micrometers, and later instruments could go out to longer wavelengths.

The SOFIA telescope's better detectors and nearly three times bigger diameter will make it 10 to 100 times more sensitive than its predecessor, the Kuiper Airborne Observatory, which NASA flew from 1974 to 1995 before starting work on SOFIA a year later. Airborne telescopes are cheaper than satellite missions, and have the advantage that instruments can be easily changed and updated. Jürgen Stutzki, a University of Cologne astronomer who is on the design team of a high-resolution spectrometer for SOFIA, says, "We will always fly state-of-the-art instruments, whereas with a satellite you build your instrumentation five years or so before launch, so by the time it's launched it's already out of date."

Star formation will be one of SOFIA's specialties. "We have spectrometers that will measure the temperature and density of materials where stars and planets are forming," says Becklin. "Many key signatures from simple molecules, including hydrogen, are in the infrared." Adds Stutzki, "There are particularly important lines in the far-infrared regime, like the line of ionized carbon near 150 microns. It's one of the strongest cooling lines of the interstellar medium, so it's very bright wherever star formation activity happens."

SOFIA will also "do some of the best measurements" of newly discovered potential planets and other large objects in our solar system, says Becklin. By studying the drop in a background star's signal when an object passes in front of it, the object's size and the chemical composition of its atmosphere can be determined. With SOFIA, "you can fly to where a planet is going in front of a star," he adds. So, whereas a ground-based observatory might witness a few such occultations a year, scientists expect SOFIA to see a couple hundred.

For teaching purposes, adds Dana Backman, SOFIA associate director for education and outreach, "we will match teams of educators with astronomers. We will train them ahead of time, then they will fly on the plane for a flight series, and go back to enhance science and math education in their home communities." Perhaps 100 teachers and other educators will join some of SOFIA's roughly 100 flights each year. This program will take about 1.5% of SOFIA's operating budget, Backman says. NASA's 80% share in running SOFIA is expected to be $60 million to $80 million annually; an updated estimate of the operating costs is due early next year.

Mission decisions

To feed SOFIA, NASA is starving the planet-finding Space Interferometry Mission. Both projects were high priorities in the astronomy and astrophysics community's 1990 decadal survey, Howard notes, but SOFIA was higher on the list and is at a more advanced stage than SIM.

"It's a misconception to trade SOFIA for SIM," says Charles Beichman, executive director of Caltech's Michelson Science Center, which is responsible for SIM science operations. "Killing SOFIA would not have made enough money to get SIM back on the books." What troubles Beichman most is the broader neglect of planet finding. "We have a young field that is enormously exciting. Young people are turned on by it. But it's taking a back seat compared to traditional astronomy."

Stanford University's Roger Blandford, who until recently was cochair of the National Research Council's committee on astronomy and astrophysics, says he wishes the agency "would engage the scientific community more in facing up to the hard choices, which undoubtedly NASA has to make at this stage." NASA, by making top-down decisions, he adds, "invites the scientific community to find other ways of defending their missions—politicians are getting involved in the detailed choices. It's a shame it's going this way."

But political involvement could save SIM and other science missions: This fall, Congress is expected to vote on a bill by Senators Barbara Mikulski (D-MD) and Kay Bailey Hutchison (R-TX) that would give NASA an extra $1 billion over two years. **Toni Feder**