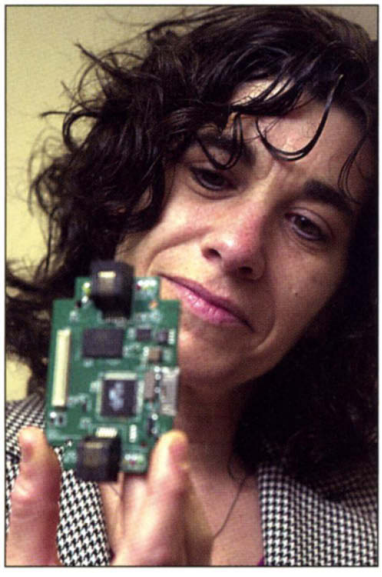
RESEARCH CENTERS

Science With an Agenda: NSF Expands Centers Program

A 15-year-old program of collaborative academic-based research centers at NSF is thriving after a controversial start. What makes it tick?

This summer, six U.S.-based university consortia will cross the finish line as the sole survivors of a grueling competition that began with 143 entrants. Barring last-minute hitches, the six will sign contracts with the National Science Foundation (NSF) to establish science and technology centers (STCs) in fields ranging from space weather modeling and biophotonics to water purification and Earth-surface dynamics (see next page).



Sensitive. Deborah Estrin hopes to use vast networks of tiny sensors to monitor changing environments.

The winners have run a 2-year gantlet of proposal development, reviews, endless rewrites, site visits, and intense interactions with NSF officials. Their reward: up to $20 million over the next 5 years, with the likelihood of another 5 years' support if they make it through an exhausting midterm review.

"What's not to like?" says psychiatrist Thomas Insel, director of the Center for Behavioral Neuroscience at Emory University in Atlanta, one of five winners of a similar STC competition in 2000. "It's a lot of funding, for a long time. It's really a fantastic opportunity."

But, although receiving an STC sounds like the fulfillment of every scientist's dream, it's actually the start of a longer, and even more difficult, race. Conducting world-class research is only part of the centers' mission. They are also expected to improve education in local schools; strengthen undergraduate and graduate training; improve minority representation in the sciences; and link up with other academic institutions, industry, and the community. It's a tall order, and one for which many academic scientists have scant training.

There's also nowhere to hide: NSF officials engage in a hands-on style of supervision that some would call micromanagement. "There are no rules," says Nathaniel Pitts, head of the Office of Integrative Activities, which oversees the STC program. "But we expect a big return for our investment."

Welcome to NSF's flagship program to support long-term interdisciplinary and cooperative research centers, begun amid controversy in 1987 by then–NSF director Erich Bloch. Many scientists worried that the proposed centers would drain funds from NSF's traditional support for individual investigators or, even worse, that they would promote applied research at the expense of basic science. But Bloch persisted, bolstered by a bevy of review panels that endorsed the concept.

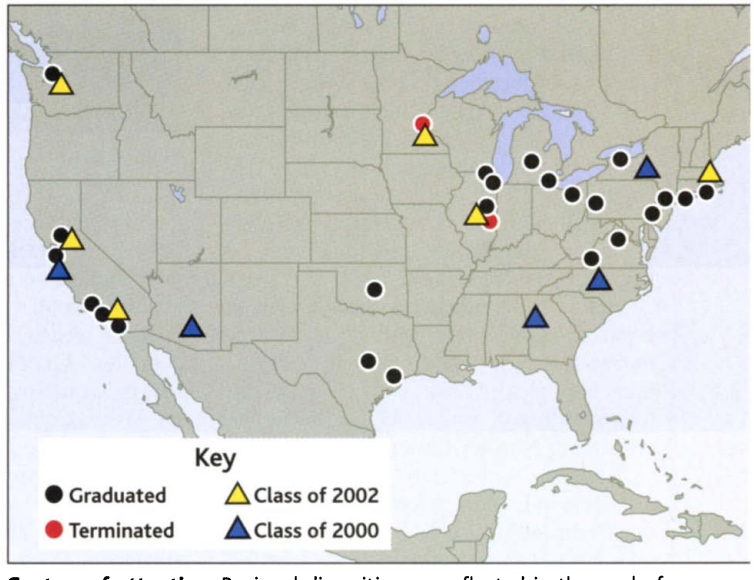
In the end, the critics' fears proved groundless. With an annual budget of $45 million, the program this year will consume a mere 1.1% of NSF's overall research budget. Industrial participation is voluntary, and many centers focus on the most basic of scientific pursuits.

The six new centers will bring to 36 the number funded since the first group was chosen in 1989 (see map). Their predecessors have helped spawn a population explosion of academic research centers in the United States and around the world: NSF alone will spend $360 million this year on 18 different types of centers, in fields ranging from early childhood education to earthquake engineering. Agency officials say that more than a dozen countries have sought NSF's advice in creating similar programs.

The STCs are in a class by themselves, however. Whereas most academic research centers focus on a single discipline or field, be it mathematics or nanoscience, STCs are open to researchers working in any area that NSF typically supports. Each center reflects a unique combination of participants and goals, and every one is a work in progress. Insel says he wanted to create what he calls a "collaboratory," but "with 10 to 20 [principal investigators] at the table, we didn't have a clue how to do it. It took us 2 years, and lots of people dropping out and coming in, before we really figured it out."

Computer scientist Deborah Estrin, director-designate for the new Center for Embedded Networked Systems (CENS) at the University of California, Los Angeles, spent more than a year signing up collaborators at five universities for the center, which aims to develop algorithms for wireless and distributed sensing systems. For example, researchers will develop technology to monitor tree canopies, wildlife corridors, and other systems in the James Reserve in Southern California, as well as instrumenting structures on shaker tables that simulate damage from an earthquake. Their goal is to learn the best way to collect, analyze, and disseminate vast amounts of data. "The Internet was built on that same idea" of linking independent nodes, says Estrin. "It's a powerful model when it works."

Indeed, figuring out what works has been a challenge for all the centers—and for their NSF overlords. In fact, NSF pulled the plug on one center in each of the first two

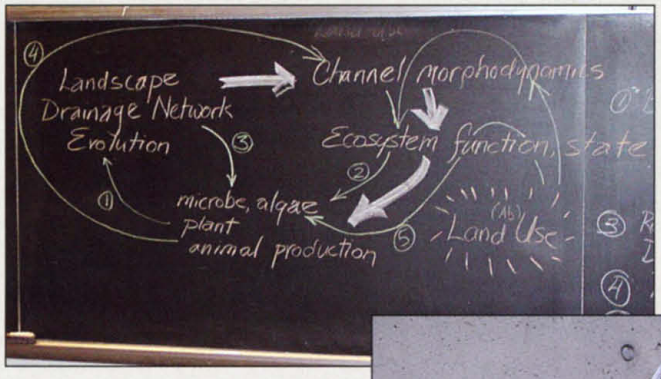


Centers of attention. Regional disparities are reflected in the pool of 36 centers that NSF has funded.

CREDITS: (TOP TO BOTTOM) REED HUTCHINSON/UCLA PHOTOGRAPHIC SERVICES; SOURCE: NSF

Power of the Purse: Down-to-the-Wire Talks Shape a New NSF Center

MINNEAPOLIS, MINNESOTA—Civil engineer Gary Parker was nearing the end of a grueling 16-hour day this spring preparing his senior management team for a visit from National Science Foundation (NSF) officials. The stakes were high. Parker and his colleagues had spent much of the past 2 years shepherding, through a complex process, a proposal for one of NSF's coveted Science and Technology Center awards. They already knew that their plan for a National Center for Earth-Surface Dynamics (NCED) at the University of Minnesota had made the final cut. Now, if they could reach agreement with NSF on a final strategic plan, a 5-year, $18.8 million grant would be theirs.



But first, they had to deal with a casual remark by NSF program manager Doug James early in the 3-day workshop about how to describe their intended research. His comment had forced the center's three teams to abandon their takeout pizza slices and scurry back to laptops and blackboards for a long night of revisions aimed at pleasing their funders. Environmental conditions only added to the tension: The lecture hall at the St. Anthony Falls Laboratory (SAFL), a dank, bare-bones facility built in the 1930s on an island alongside the only major waterfall on the Mississippi River, was stifling from an April heat wave, and the hard wooden chairs were uncomfortable.

Each of the new centers-to-be carried out a similar drill this spring as NSF tried to make sure that its money would be well spent. And the Minnesota partnership had no shortage of ideas about how to use the anticipated award. The goal, the teams had already decided, was to create "a complete set of tools for interpreting the past and predicting the future evolution of the Earth's surface." It was a once-in-a-career opportunity to create a new field—surface process science—that could provide new insights into everything from how to mitigate an impending subsidence of New Orleans and the surrounding Mississippi River delta to explaining erosion on the surface on Mars.

But NSF officials seemed to want more. "We don't care what you call the science," Parker said an NSF official had told him. "We want to know what this center will do for people."

The next day, James and his NSF colleagues reinforced that message. In addition to a portfolio of world-class research that would benefit society, they said, the center needed a plan to improve science and math in the public schools and the community, broaden participation by underrepresented groups, and strengthen training for undergraduate and graduate students weighing careers in science. No detail was too small to attract NSF's attention, from whether a summer program should serve children in foster homes to the allocation of graduate students.

The elements of the proposed center had remained surprisingly fluid throughout the review process. NCED began as a joint effort of Minnesota scientists—in particular, Parker and his co-directors, sedimentary geologist Christopher Paola and SAFL's director, Efi Foufoula-Georgiou—and colleagues from the University of California, Berkeley; Princeton University; and the Science Museum of Minneapolis, which offered land adjacent to its new $100 million facility in downtown St. Paul for outdoor exhibits on the changing Earth.

David Mohrig, a sedimentary geologist at the Massachusetts Institute of Technology, was added to the mix after his work on submarine channels seemed a good fit with planned studies of terrestrial changes. And a suggestion from NSF to link up with a minority institution led the team to Fond du Lac Tribal and Community College, 2 hours north of the Twin Cities in Cloquet. Fond du Lac had just received a $2.5 million NSF grant to strengthen its programs, and the college already runs several environmental monitoring projects.

NSF officials also thought that the center would benefit from studies of how humans change the landscape, and the foundation added money to the center's proposed budget for that purpose. The first step is likely to be a workshop, at which social scientists will be asked to draw up a research agenda. "Even though we didn't include a social science component in the original proposal, we have gotten quite excited about the possibilities," says Paola.

The door swings both ways, however. Midway through the workshop, the group agreed to part company with one proposed collaborator, U.S. Geological Survey hydrologist Dick Iverson of the Cascades Volcano Observatory in Vancouver, Washington. The decision would also mean doing without the observatory's 87-meter-long flume, with a 31-degree slope, that is used to study landslides and other sudden shifts in the landscape. "[Iverson is] very protective of his debris-flow facility," Parker told the group, "and he's clearly uncomfortable with the idea of attaching his name to a paper that might contain concepts and ideas with which he strongly disagrees."

Making a silk purse ... The University of Minnesota's Gary Parker heads a multidisciplinary team taking an integrated look at Earth-surface dynamics.

Iverson, who did not attend the workshop, said later that his decision to bow out was based mostly on concern that "I couldn't serve two masters. ... The center is focused on the big picture, while we have a mission to develop new tools for hazard prevention."

One unexpected conference guest didn't appear until just after the full NSF delegation was seated. That's when Berkeley field ecologist Mary Power handed Parker a gift-wrapped box. Inside was a toy pig. The audience broke into applause as the pig, hanging on a cord attached to a light fixture, floated about the room on its battery-powered wings. "The pig can fly," Parker proclaimed. The unspoken message to NSF was clear: And so can NCED.

–J.D.M.

CREDITS: (TOP TO BOTTOM) NCED; GRAHAM RAMSAY

The Geometry Center, 1991–1998. RIP.

Was the cause professional jealousy, loss of key personnel, shifting priorities, the lack of community support, or a breakdown in communication with National Science Foundation (NSF) managers? Observers disagree on what killed the first Science and Technology Center (STC) at the University of Minnesota, created in 1991. But its demise provides a cautionary tale. Only one other center in the program's history has been terminated early, and that death was due to technical problems in trying to apply magnetic resonance technology to basic biology.

From the start, the Geometry Center faced long odds. Even its mission was controversial. "Its attempt to introduce computer graphics and visualization into pure mathematics and geometry was novel, and the community wasn't very welcoming," says Princeton University's David Dobkin, who chaired the center's governing board. "It wanted to change the field, but people weren't ready for that."

The center's enviable budget of $2 million a year was another red flag to a community in which investigators typically receive $25,000 grants and work alone or with a single student. "We were immediately a target for people who said we didn't deserve all that money," recalls its former director, Richard McGehee. Shifting leadership was also an issue: McGehee took over after 2 years from Albert Marden, the center's founding director, although McGehee and others say the center's intellectual father was William Thurston, a Fields Medal winner who had little involvement in the center once it was established.

NSF's first site visit team identified numerous problems—in particular, too narrow a scientific focus. That led to an abrupt shift toward developing educational products for students and teachers, as well as exploring possible applications for the fledgling World Wide Web. "We had one of the first 100 Web sites," recalls McGehee, "but there wasn't any way to put math on the Web."

Given those concerns, NSF boosted its oversight, holding a second site visit in 1994 and a third in late 1995. The scrutiny left investigators wondering what was expected of them. "They were like a deer caught in the headlights," recalls applied mathematician Rosemary Chang, a member of the third site visit team, which recommended renewed funding. But the reviewers also pleaded with NSF to delay the next site visit "to give them a chance to get back on track."

Instead, Donald Lewis, who had recently arrived as head of NSF's mathematics division, impaneled three outside reviewers in June 1996 to tell him if the center was likely to pass its scheduled 6-year review in 1997. The team concluded that the center would fail and recommended that it be phased out. "We didn't feel that the money was providing the same yield" as other math centers funded outside the STC program, says Richard Herman, provost of the University of Illinois, Urbana-Champaign, and one of the reviewers.

Robert Miner, a former researcher at the center who is now with Design Science Inc. of Long Beach, California, thinks the center "was right all along" to focus on Web-based communications. His company recently struck a deal to incorporate the center's software, now called Equation Editor, into Microsoft Word. And McGehee says that the center's involvement in education and training "are exactly what the division is now emphasizing."

Lewis, now back at the University of Michigan, Ann Arbor, doesn't dispute those accomplishments. But he believes that the center never lived up to its promise. "I didn't see any progress," he says, "so I pulled the plug."

–J.D.M.

classes after deciding that each had fallen short of its goals (see sidebar above). To get a sense of what the new centers can expect as they try to live up to NSF's expectations, *Science* asked current and former center directors and their colleagues about their experiences in managing these strange beasts. Here are five attributes that emerged from these discussions:

• Be a big-league manager.
"The management plan is the key to success," says NSF's Douglas James, who oversees two centers in the geosciences. "Can they run it properly? Do they have the facilities and the people to pull off what they have promised?"

For most scientists, managing a large enterprise is a lot less appealing than working at the bench or in the field. Chemist Anne Myers Kelley, for example, says she enjoyed being part of the Center for Photoinduced Charge Transfer at the University of Rochester in New York but hated her 2-year stint as its director. "I had a miserable time trying to serve a million masters. You have to be a first-rate politician, and I'm not," says Kelley, now a professor at Kansas State University in Manhattan.

One challenge that Kelley's cohort faced was a budget crunch that forced NSF to slice in half the budgets of its 1991 class of 12 centers. "We had to decide what was most important," says Gérard Mourou, director of the Center for Ultrafast Optical Science (CUOS) at the University of Michigan, Ann Arbor, which ended its 11-year run in January but continues with funding from another NSF program within the physics division. "You have to make decisions, and they're not always popular." Ophthalmologist Ronald Kurtz, a former colleague, likes the fact that Mourou ran the center "like a corporate CEO. … There was a shared interest in the success of the enterprise rather than just the fate of individual projects."

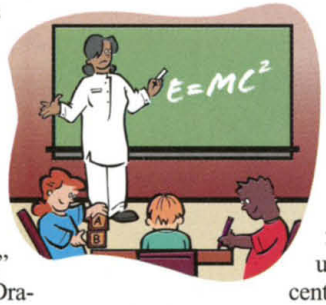
A center director is also likely to see his or her scientific productivity slump, notes biophysicist Barbara Baird, director of the 2-year-old National Center for Nanobiotechnology at Cornell University in Ithaca, New York. "My research has definitely slowed down," she says, "and that's what I need to maintain my [National Institutes of Health] grants. I'm concerned that the publications won't be there when my grants come up for renewal."

• Avoid a school daze.
Without exception, center directors consider research, not education, to be their strong suit. "We at the university are not in the business of K-12 education," says Mourou. Yet, since the early 1990s, NSF has required each center to put a high priority on improving precollege education. "We wanted to support graduate students," recalls Kelley, "but suddenly NSF was telling us to get involved in the public schools and to hire a full-time educational coordinator."

Although all the centers fell in line, some did little more than graft an education component—offering summer workshops for teachers, for example, or sending scientists into the classroom—onto existing research activities. But that's not what NSF has in mind. "We've tried to move away from feel-good educational activities and toward something much more rigorous," says Pitts. Rather than tallying the number of students

ILLUSTRATION: TIM SMITH

served or the numbers of parents who have gotten involved in an activity, NSF wants centers to show how they have helped districts boost test scores or increase the number of upper level science and math courses. "Don't talk about outreach," says Pitts's deputy, Dragana Brzakovic. "We want to see the impact you're having."



Recognizing that some faculty members might resist spending more time working with local schools, some centers have tapped a research scientist to run their education programs. "It's a mistake to put an educator in charge," argues physicist Ramon Lopez, who will handle those chores for the soon-to-be Center for Integrated Space Weather Modeling based at Boston University. "You need someone who can go head-to-head with the scientists, someone whose body of work they respect." Lopez is a member of both camps: He did a stint running education programs for the American Physical Society while continuing to work on space-plasma physics at the Applied Physics Laboratory in Laurel, Maryland.

• Take advantage of commercial opportunities. Although NSF has never required centers to work with industry, such links are a mark of success for researchers working in commercializable fields. In addition to attracting major corporate support, successful centers foster an entrepreneurial culture that encourages researchers to cash in on their results.

It's no accident that CUOS has created four spinoff companies, says Kurtz, medical director and corporate vice president for one, IntraLase of San Diego. "The people who are going to take a technology out of the university often aren't your traditional faculty," notes Kurtz, who discovered the center while he was an ophthalmologist on call at the university hospital. Working as a center investigator, Kurtz realized that the center's ultrafast laser pulses could be applied to human tissue as well as glass. The result was IntraLase, founded in 1997 by applying the center's femtosecond technology to clinical eye care.

"The neat thing is that CUOS wasn't designed to do laser medicine," Kurtz says about his company, whose Food and Drug Administration–approved product uses a laser instead of the traditional metal blade to form a corneal flap at the beginning of corrective eye surgery. "But it happened because [Mourou] was interested in finding collaborators with good ideas." The center also became a training ground for budding scientist-entrepreneurs in ultrafast lasers, meeting NSF's wish that centers help stock emerging fields.

• Broaden the talent base. Despite NSF's explicit charge to each center to foster diversity, directing a center is by and large a white male prerogative. Although NSF officials say that gender and race play no role in selecting leaders, women have been principal investigators on only two of the 36 initial awards. Nor have any of the centers been led by an underrepresented minority (an African-American, Hispanic, or Native American) scientist. "I think the problem [that accounts for the lack of women directors] is at the point of entry," says Estrin of CENS, who says she's received "wonderful support in pursuing leadership positions. … We just don't have enough young girls who want to invest in this intellectual pursuit."

NSF expects centers to find creative ways to expand the traditional scientific talent pool. "It takes somebody to go out there and get [minority undergraduates] excited from their first year, and there wasn't anybody doing that," says Emory's Insel, describing a center program that involves the five historically black institutions in Atlanta. "Neuroscience has a really crappy record [of attracting minorities]."

Training more minority scientists is not enough, say educators; centers must also help funnel talent where it is most needed. Minnesota's new center on Earth-surface dynamics, for example, has teamed up with the Fond du Lac Tribal and Community College in Cloquet, Minnesota, in hopes of attracting more Native Americans into upper level and graduate science and engineering programs. But Fond du Lac's Andy Wold says that the college is there "to educate the local population and have them remain in the community," not to prepare them for careers at an urban center or major research university.

• Plan your next step. A successful STC can provide scientists with a huge springboard for their next project. The Southern California Earthquake Center (SCEC) received $41 million from NSF over an 11-year span that ended in January. Led by seismologist Thomas Henyey of the University of Southern California (USC) in Los Angeles, the center helped establish a 250-station global positioning system network in Southern California to monitor the buildup and release of crustal strain and coordinated analyses of the Landers, Northridge, and Hector Mine earthquakes. But NSF rejected a bid from center scientists to become part of the third round of STCs funded in 2000, deciding its proposal was too derivative.

That rejection didn't end their plans, however, or even their ties to NSF. This winter, the new entity, dubbed SCEC-2, was awarded $12.5 million over 5 years from NSF's geosciences directorate and $5.5 million from the U.S. Geological Survey, which also funded its predecessor. That's on top of $10 million handed out last year by NSF's Information Technology research program for an online collaboration of seismic researchers and $650,000 from NSF's National Science Digital Library (NSDL) project to expand a pilot version of the Web-based Electronic Encyclopedia of Earthquakes.

"SCEC reinvented itself," says seismologist Thomas Jordan, who collaborated with the original center and came back to USC in 1999 to lead the SCEC-2 effort. "The STC funding was ending, but the community felt the need for a continuing analysis of these issues." The new award, he says, will extend "a solid team that took years to build, thanks to enlightened management and a little blood on the floor."

Paying heed to all these lessons doesn't guarantee success if a center doesn't also have an exciting research agenda. "We're looking to fund the best science, with the best people," says NSF's Pitts. But, as governments around the world look to maximize the return on their scientific investment, it's a good bet that this approach to basic research will remain a center of attention. –JEFFREY MERVIS

ILLUSTRATIONS: TIM SMITH