NEON: Planning for a New Frontier in Biology

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In the past century we learned an enormous amount about individual species and about ecological processes at the scale of watersheds and landscapes, but there is much we do not understand. In this century we must further our understanding of ecological processes and learn how local processes can be scaled up to biomes or continents if we are to accurately predict changes in the composition, structure, and dynamics of the nation's ecosystems and understand how those changes are likely to affect us. To develop that understanding, a new type of scientific infrastructure is needed—an infrastructure that enables the simultaneous collection of compatible data on fundamental ecological and evolutionary processes over broad geographical and temporal scales.

—IBRCS Working Group white paper, "*Rationale, Blueprint, and Expectations for the National Ecological Observatory Network.*"
(The executive summary of the IBRCS white paper begins on p. 526 of this issue of *BioScience.)*

If field biologists were to be granted one major piece of research equipment—the biology equivalent, say, of a super-telescope or particle accelerator—what would that one tool be? The cost could be high, tens of millions of dollars, even. But it would have to advance the entire field. What would it look like? What would it do? In short, what is the one thing that just about all field biology could use?

As open as the question might seem, for decades the only answer might have been a shrug or a flip comment—How about an army of robot graduate students? Or a Rube Goldberg contraption that writes grants at one end, brews coffee at the other? But now, the Directorate of Biological Sciences (BIO) at the National Science Foundation (NSF) hopes it has found a serious answer in the National Ecological Observatory Network (NEON), a 17-site, $356 million to $378 million "network of networks" that would take the ecological pulse of the continent. The first $12 million for the infrastructure is currently under consideration in the president's fiscal year 2004 budget.

Big science

The BIO Directorate has long wished it could match the huge sums of money going to such fields as physics and astronomy, says Jeffrey Goldman, project manager of Infrastructure for Biology at Regional to Continental Scales (IBRCS, pronounced "ih-brix"), an AIBS undertaking funded by NSF. But funding for those fields comes from a portion of the NSF budget allocated for Major Research Equipment and Facilities Construction (formerly and still colloquially referred to as Major Research Equipment, or MRE), which has not been considered part of the BIO Directorate's province. The reason, Goldman says, is simple: Biologists could not reach consensus on the one major tool that would advance their field. Indeed, there seemed to be no *one* thing.

By 1997, however, the NSF BIO Directorate was abuzz about something colleagues in the Engineering Directorate had accomplished. The engineers had snagged NSF approval for their first MRE proposal by creating a novel model: Rather than a single instrument, the Network for Earthquake Engineering Simulation (NEES) would use a distributed network of sites aimed at a single goal.

"This was the first time that the MRE account had been used for something other than a singular facility or an investment at more than one location," says Bruce Hayden, who in August 1997 was just beginning a two-year stint as director of the environmental biology division. The internal success of NEES, he says, inspired assistant director Mary Clutter to canvass the BIO Directorate for "big ideas." His first week on the job, Hayden had one, inspired to some extent by his work with Long Term Ecological Research (LTER) stations. He took the concept of "a national network of ecological/environmental observatories linked with state-of-the-art information technology" and floated it informally in the hallways with researchers at the annual meeting of the Ecological

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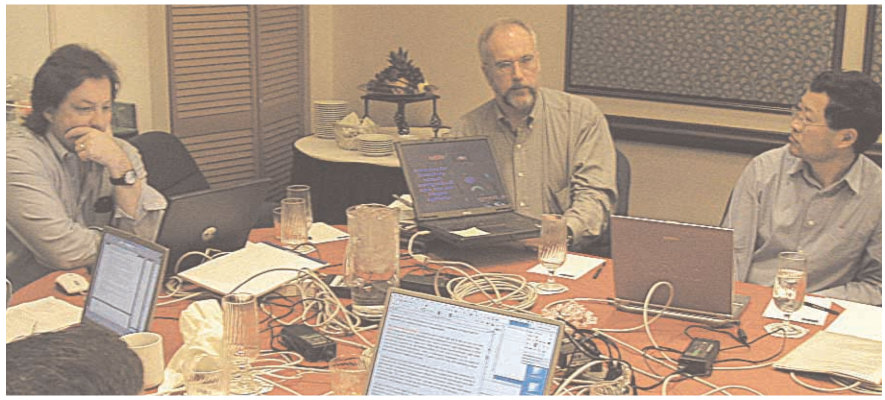
Society of America. After a warm reception there, Hayden took the idea back to NSF, where he and Clutter began to shape the network that is now NEON. The evolution, he concedes, was "not really grassroots. But then, when opportunities are presented, you have to take the challenge and move forward."

Ever since NSF director Rita Colwell advanced the structure four years ago as part of an ambitious biocomplexity initiative, NEON has set imaginations going. Says Scott Collins, who was NEON program director with the Division of Environmental Biology: "Once we had the concept...we asked the community to design it for us."

The effort did not come naturally. "It's a new thing for our research community," Collins says. "We've pretty much limited people out there to writing a grant project for a certain amount of money, and suddenly we're saying, 'We want you guys to think about a $350 million product.' It took a while for people to get their minds around it and see the advantages. This is really a huge shift to big science."

Like the funding mechanism behind it, NEON will represent a new approach to biology, one that—with its emphasis on big-picture collaborations and questions—many expect to challenge the existing culture of the field sciences. "A lot of ecology is based in natural history research, which involves almost the mindset of one or two scientists going out into the field with a pencil and a book recording observations," says Goldman. "And I think we've matured as a science, which realizes that a lot of the questions are so huge that they require teams of scientists representing many different disciplines to address them. And we also need ready accessibility of data from all of those different disciplines, [for the data] to be synthesized and used to more comprehensively answer complex questions."

He likens NEON to a research vessel, "where you have a cruise put together and all of the scientists then go on a ship in order to answer a question; they all need to share their data on an almost immediate basis. I think the same will hold true in NEON [observatories]."



On the first of two days spent putting together the final version of a NEON white paper, Bill Michener (middle) shares an image with group members. Also pictured are AIBS executive director Richard O'Grady (left) and University of Oklahoma ecology professor Yiqi Luo (right). Photograph: Sonya Senkowsky.

IBRCS project manager Jeffrey Goldman listens as working group members discuss the final draft of a white paper on NEON. Photograph: Sonya Senkowsky.

"Many people in field biology and field sciences are not used to working in this kind of framework," notes IBRCS working group member Eric Nagy, president of the Organization of Biological Field Stations. "We're still in a culture of small, independent, lone-wolf PIs running their own labs,...often associated with one or a few field sites that are directly under their control." But, he says, among these lone wolves is a new generation that will embrace NEON. "What I think will happen," he says, "is we will build it and they will come. A whole new generation of research programs will be incubated by the NEON."

Shedding light on NEON

As the biological community has trodden the unfamiliar territory of NEON, enthusiasm has sometimes been tempered by skepticism, confusion, and questions: How will the sprawling network meaningfully integrate interdisciplinary data? Are field biologists capable of the major culture changes the new network will require? Who will be included, and who will be left out? And can we be absolutely sure that this giant project won't cut into funding for [insert your favorite project here]?

With many questions in the air and a need to further define the need for

At the Denver NEON town hall meeting on 14 February 2003, Deborah Goldberg, of the University of Michigan, takes the microphone to address the IBRCS working group. Looking on is president of the Crop Science Society of America, Stephen Baenziger, of the University of Nebraska–Lincoln. Photograph: Sonya Senkowsky.

biological infrastructure projects such as NEON, NSF awarded a $1.3 million grant to AIBS in September 2002 to create IBRCS. AIBS executive director Richard O'Grady is principal investigator.

IBRCS's charge goes beyond NEON. The group's purpose, explains O'Grady, is to initiate and maintain a dialogue in the scientific community and public about a range of infrastructure needs in the biological sciences, with NEON merely its first project. AIBS, an umbrella organization whose member groups encompass a membership of more than 240,000 biologists, is uniquely positioned to begin such a dialogue, says O'Grady.

Between December 2002 and February 2003, IBRCS held three NEON town hall meetings, in Arlington (Virginia), Los Angeles, and Denver (concurrent with the annual meeting of the American Association for the Advancement of Science), inviting scientists to share their input, ideas, and criticisms. One of the most crucial roles IBRCS is taking on, says O'Grady, is to better define and explain the envisioned network, often with the help of comments and suggestions that came out of these meetings. In late February 2003, IBRCS, which is coordinated by a 20-member working group elected and appointed from across the scientific community, met in a Virginia hotel to finalize the white paper on NEON they had been developing for the last five months. Over two days, at a conference table topped with laptops and tangled with network wiring, the group reworked the wording, refining and expanding on aspects of NEON ranging from management structure to a formalization of the role of educational collaborations.

Town hall meeting attendance was less than organizers expected, though "a simple head count is misleading," says O'Grady. "Many of those who testified were attending and speaking as the appointed representatives of their society or organization and their thousands of members." O'Grady says that "large chunks" of the input from the meetings and submitted written comments made it into the group's white paper, a report on the scientific merits of the network. "We ended up getting 15 to 20 really focused comments," he says, adding that AIBS is very pleased with how useful the town meeting comments ended up being to the working group.

In Denver, Patricia Morse, acting professor of zoology at the University of Washington, addresses the IBRCS working group. Her proposals for implementing NEON's education mission were incorporated in the IBRCS white paper released 25 March 2003. Photograph: Sonya Senkowsky.

"NEON had developed a Superman complex," he says. "Now we have redefined what NEON is for the '04 requests." It is, O'Grady says, a piece of research equipment extending thousands of miles across the North American continent—and beyond. "Everything else flows from that core."

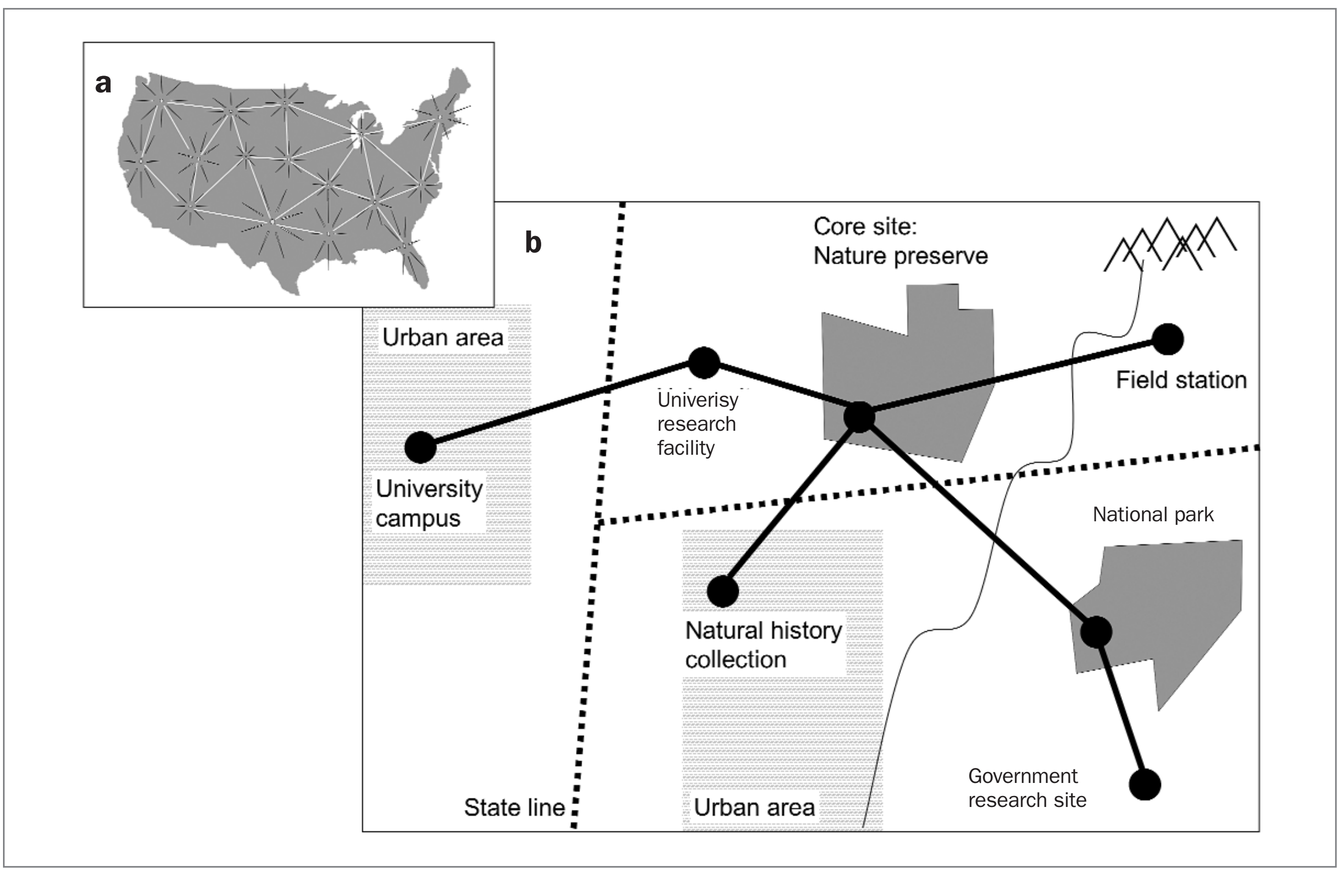
As described in the IBRCS white paper and NSF budget documents, NEON would be a "continental-scale research network" of 17 smaller networks (16 in ecoregions throughout the United States and 1 in Antarctica), each led by a core site equipped with "highly specialized research infrastructure, including field-based sensor arrays, flux towers, stable isotope analyzers, microarray analyzers, and automated DNA sequencers." No one can accuse NEON's creators of thinking small; its goals are to conduct "integrated ecological research at local, regional, and continental scales on all aspects of biological change, from molecules to biomes," and on temporal scales stretching into geological time. Universities would share responsibility for the sites, which would establish partnerships with other data-gathering programs, such as those at LTER sites. "Above all," adds O'Grady, "NEON would be a 'common science facility'—think 'National Laboratory'—available for use by all scientists for their research investigations."

NEON sites, or "observatories," would be set up to perform continuous sampling of a range of ecological measures and to enable collaboration, data exchange, and data analysis for its expected 30-year life span. "Equipment would be swapped in and out in a modular fashion, akin to outfitting a research vessel or a space telescope," says O'Grady. What research questions NEON observatories will tackle will be up to the community of scientists who use them. But working group member Eric Nagy cites climate change as an obvious example: "There are many, many little studies that say they're applicable to global climate change," he says, "and they are. But they have a lot of tiny little pieces that we put together and try to make fit and hope they make a big picture, like a mosaic. With the NEON instrument, we could take a single picture. We wouldn't be piecing together little tiny pieces any more."

Real-time, cross-disciplinary networking capability is another aspect that makes NEON attractive, offers working group member Bill Michener, associate director of the LTER Network Office at the University of New Mexico. He gives the example of the work done at LTER sites to track down the progress of an infectious agent responsible in 1993 for the outbreak of a mystery disease in the American Southwest. The culprit turned out to be hantavirus, which is carried by rodents such as the deer mouse and causes the rare and sometimes deadly hantavirus pulmonary syndrome. Tracking down the virus and explaining its origins called for quick collaboration between mammalogists, epidemiologists, and specialists in remote sensing and GIS. "They were able to do that at the LTERs, but not without difficulty," says Michener. "In a NEON, one could easily imagine those disciplines would be represented in the core NEON infrastructure." Additionally, NEON data may be used to help predict where an infectious agent such as hantavirus might show up next.

NEON's unusual provenance and the sprawling nature of the project have led to some misunderstandings, says Goldman. Even AIBS's involvement has caused some confusion. "Researchers will write to me and say, 'What are you guys looking for [for] NEON?' as though *we* can provide the money," says Goldman. "And the money doesn't come through us at all." NEON funding and future projects proposed at NEON sites would all be handled through NSF. In addition to infrastructure funds, for FY 2004, NSF is requesting $6 million from Research and Related Activities to support operations and management of NEON facilities. But although it does not provide funding, nor can it lobby under the terms of its IBRCS grant, AIBS can, through IBRCS activities, help biologists understand and shape the future of NEON. IBRCS's further plans include a NEON coordination and implementation conference later this year and an online tool for researchers and educators, designed to map research facilities and data collection sites throughout the country.

Today, after six NSF workshops, three IBRCS town meetings, two working



National- and regional-level schematics of NEON. (a) Conceptual map of fully deployed NEON. Starbursts of various size and shape represent distributed observatories. This illustration is not intended to suggest a prescription for the geographical location of observatories in the actual network, nor are the starbursts meant to imply a radial arrangement of satellite sites around an observatory's core site. (b) Hypothetical regional observatory with a footprint that spans three states and includes urban areas. In this illustration six satellite sites are associated with the core site, but neither that figure nor the specific examples of satellites are meant to exclude other arrangements. From the IBRCS white paper, "Rationale, Blueprint, and Expectations for the National Ecological Observatory Network," 2003.

Near the end of a two-day writing marathon, IBRCS working group members share their drafts-in-progress using computers networked together in a Virginia hotel conference room as they discuss final details of a report on NEON. Pictured, from left, are Bill Michener, Yiqi Luo, Eric Nagy, and Kent Holsinger. Photograph: Sonya Senkowsky.

group sessions, a 20-page description from NSF, and a white paper from IBRCS (all reports are available online at *http://ibrcs.aibs.org*), NSF definitions and community expectations for NEON are better documented and defined than ever. "Hopefully in the white paper we will have described it well enough that people can start to really understand what it is that NEON is supposed to be," says working group member Rebecca Gast, a microbiologist at Woods Hole Oceanographic Institution.

Testing for hantavirus in wild populations of deer mice, a CDC scientist collects specimens from rodents trapped in a field study. The LTER network played a major role in making it possible to track down the source and spread of the hantavirus by sampling a large number of rodents quickly. NEON supporters say NSF's massive proposed network would make interdisciplinary collaborations on short notice even easier and more efficient. Photograph: CDC/Cheryl Tryon.

Glowing, glowing, gone?

For all its promise, NEON does not have a shining history on Capitol Hill. A NEON funding request was introduced in the FY 2001 Clinton administration budget proposal and included again in FY 2003, but both requests were dismissed "without prejudice." "The response so far," O'Grady explains, has been that: "lawmakers have nothing in principle against NEON but need more details."

Headlines from early coverage of the initiative in one science news magazine reflect the program's trajectory: They went quickly from "NEON to shed light on environmental research" to "No glow." For FY 2004, NSF requested $12 million to begin construction of the first two observatories to analyze data to detect abrupt changes or long-term trends in the environment, the same request that had been made for FY 2003. Building appropriations over six years for five observatories are currently projected to be $100 million.

Insiders say NEON has faltered in large part because the BIO Directorate and the biological community lack experience in working with this kind of large equipment appropriation, which receives more scrutiny than the typical research funding request and requires a consistent message and a steady drumbeat of advocacy from the community to keep politicians interested. At first, Collins says, he and others within the directorate treated NEON as they might any other appropriation request—as something they would have time to refine as the process wore on. "This was higher profile because it was a line item. There's tremendous congressional oversight on MRE projects," he says. The distributed network, too, was a hard sell, Collins reports: "It's hard to market that to Congress when what they're used to seeing is 'We want this toy so we can test this question, and physics cannot advance without this toy.'"

NSF may have stumbled further, he says, when it pushed NEON as a program useful for monitoring homeland security. "It was a politically bad move, because that's not what NEON was about and that's not what NSF was about. Fortunately, we backed off from that language," Collins says. "Clearly it would be useful for homeland security issues,...but that's not its main goal." In turn, the time lag to appropriation has doubtless cost NEON some credibility in a research community whose motto regarding new projects is often "I'll believe it when I see it funded."

The IBRCS white paper, which was released at a well-publicized public roundtable at the National Press Club on 25 March, and an upcoming National Research Council report should help remedy any damage caused by an early perception that the program was not well formed, Collins says. But even more important to its success will be a show of support from the biological sciences community at large. Leadership from an organization experienced in and effective at lobbying on Capitol Hill, such as the National Association of State Universities and Land Grant Colleges, would also help, Hayden says. (As of press time, NASULGC had not returned calls asking if it planned to take on this role.)

During a writing session, IBRCS working group members Eric Nagy and Rebecca Gast make the most of a well-appointed hotel lobby to collaborate on a portion of the NEON white paper. Photograph: Sonya Senkowsky.

O'Grady points NEON watchers to the geosciences project Earthscope and to the Consortium of Universities for the Advancement of Hydrologic Science, Inc., as examples of projects with similar scope and design. After an extensive effort, Earthscope received $30 million this past February as part of the FY 2003 budget. A note on its Web site credits "strong and continued support from the community."

"The next part of the roller coaster is this fall," Hayden says, referring to the time frame for approval of the president's FY 2004 budget. "Part of it will depend upon doing what we ecologists are not that good at, and that's lobbying. It will take some people writing legislators to say 'This is important.'"

Gast echoes the sentiment: "If [scientists] think that having these types of research platforms will be valuable, they need to start showing support for it. [NEON] has been criticized for a while: 'We need to do this, we need to do that, you're doing this wrong.' OK, so maybe now it's time to start saying, 'Yes, this is truly a valuable platform to have, and we support what it's doing, and we really, really think that we need this kind of tool.'"

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