scale to be an asset," says Rupp. "In addition, Neal was an active participant in one [the Rice Quantum Center] that served as a model for our strategy."

Asked by *Science* what he considers the biggest issues he will face in his new job, Lane singled out the stiff competition for funding and the paucity of jobs for new Ph.D.s. He said he worries about the impact of these twin problems on those who might be thinking of becoming scientists. His biggest political challenge, however, is likely to be dealing with congressional pressure for NSF to play a larger role in rejuvenating high-tech industry. Massey responded to such pressure last summer by forming a blue-ribbon panel to examine the future of NSF. Although the commission's final report (*Science*, 27 November 1992, p. 1434) proved to be a Rorschach test—each side found support for its vision of what NSF should become—many university officials fear that Congress will again try to steer NSF toward more industrial research. Lane apparently has Gibbons' support in countering that pressure, but he must identify a unique role for the $3 billion agency—one that will ensure its place at the table during a time when the government is reshuffling its research portfolio and rewriting the missions of several agencies.

The Senate is not expected to hold a hearing on Lane's nomination until after it returns from a 4-week August break, but NSF officials are hoping that he can be confirmed by the start of the 1994 fiscal year, which begins on 1 October. Deputy director Fred Bernthal has been acting NSF director since Massey left in March, and he is likely to remain at NSF for several more months until a deputy director is announced and confirmed.

–Jeffrey Mervis

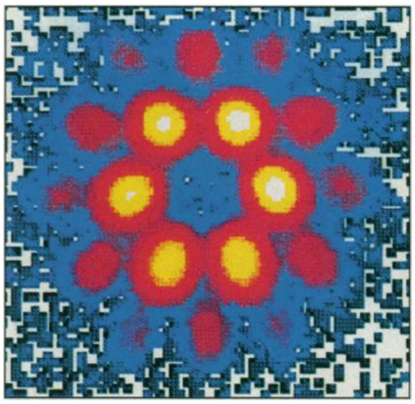
ADVANCED NEUTRON SOURCE

Physicists Band Together to Support a New Megaproject

As the Superconducting Super Collider (SSC) flirts with death in the congressional budget process for a second year, another mammoth science project is coming to life. Just a few days after the House voted to kill the $10 billion particle accelerator last month, it approved next year's funding for a megaproject that is a little cheaper and a lot less familiar: a $2.7 billion nuclear reactor known as the Advanced Neutron Source (ANS), to be built at Tennessee's Oak Ridge National Laboratory as a national facility for probing materials with beams of neutrons. The project's success in the House is a sign that physicists can still make a case for big science—at least when the project has a broad scientific constituency and plausible links to national competitiveness.

The Department of Energy (DOE), which is to fund the reactor, didn't get everything it asked for. The House granted only $22 million of the $39 million requested for 1994, but project supporters say they consider the decision a green light, and they note that prospects look good in the Senate. Says a staffer for Senator James Sasser (D–TN), a strong supporter of the project, "I think it will end up somewhere... around $29 million or $30 million." That will be enough to move ahead with detailed designs for the project, says Oak Ridge physicist William Appleton. Construction should start in about 2 years. When the facility is completed in 2002, says project leader Colin West of Oak Ridge, it will be the world's most powerful neutron source, delivering 10 times the flux of neutrons produced by its nearest competitor, at the Institut Laue-Langevin in Grenoble, France.

The power of that neutron stream to illuminate the internal structure of materials has drawn scientists from a host of different disciplines into the camp of ANS supporters. Indeed, the project received top billing early this year from a broad-based committee of physicists assembled by DOE to set priorities for nuclear physics. Says one supporter, Brookhaven National Laboratory physicist John Axe, "The advanced neutron source will open up a whole new field of neutron spectroscopy involving superconductors." Similar endorsements are coming from polymer scientists, protein chemists, and metallurgists. Concludes Appleton, "I can't imagine how the scientific community can do without a new neutron source." He and his colleagues add that, by advancing materials science, the ANS will benefit industrial competitiveness as well. Says Cornell materials scientist Edward Kramer, "Unlike what we hear about the SSC, which is scientifically interesting but full of hype about 'spinoffs,' there's an awful lot of productive uses for this."



J. W. LYNN AND N. ROSOV, NIST

Scatter shot. Neutrons scattering from magnetic vortices in a sample of niobium yielded this diffraction pattern.

Not everyone swallows the competitiveness argument. "I approve of ANS scientifically," says Princeton physicist William Happer, the former DOE energy sciences chief, "[but] the people who are beating us [economically] are the Japanese." And Japan, as Happer notes, doesn't have anything like the ANS. But the competitiveness argument is likely to become a familiar refrain given the project's cost, which makes some other physicists wince. "It blows my mind that it's so expensive," says physicist Robert Park, who heads the American Physical Society's Washington office. Park says he approves of the rationale for the project but opposes it at the current price, well above the few hundred million dollars of early informal estimates. A raft of health and safety regulations has pushed up the cost, says supporters, but some physicists say it might have been kept under control by inviting international participation, or by adopting an alternative technology as the neutron source—not a reactor but a particle accelerator.

Getting to the heart of matter. For now, designs call for a reactor about one-tenth the size of a power reactor, says project director West. Fission in the reactor core will send out a steady stream of neutrons. Slowed by heavy water to little more than walking speed, the neutrons will be carried through guides that work like fiber optic cables—by reflecting the neutrons internally, like tennis balls ricocheting down a pipe—to experiments tens or hundreds of meters away.

There the neutrons will probe the atomic-scale structure of materials in a way that depends on quantum mechanical duality. Like any subatomic particles, neutrons can be thought of as waves as well as particles. When they bombard matter, their wave nature comes into play. The slow neutrons from the ANS will have a wavelength about equal to the spacing between atoms in a typical solid, making the neutrons especially sensitive to atom-by-atom architecture.

X-rays of the same wavelength can also probe matter, and they are on tap at synchrotron research facilities around the world. But they often damage the very structures they're meant to reveal, especially in polymers and biological materials, says West. And while x-rays penetrate just microns, neutrons go a centimeter or more, says Brookhaven's

Axe. "With neutrons you are sure you're studying the bulk of the material."

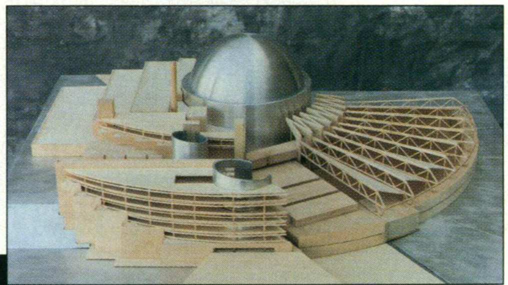
What's more, x-rays, because they interact with electrons, are most informative about heavy elements, which have large complements of electrons. Neutrons, on the other hand, interact with nuclei, so they work just as well for elements at the light end of the periodic table, including the hydrogen, oxygen, and carbon found in organic and biological molecules and other materials such as high-temperature superconductors. Neutrons can also distinguish isotopes —elements with the same number of electrons but nuclei of different sizes. And as a bonus, neutrons are sensitive to magnetic properties because, while electrically neutral, they have north and south magnetic poles.

To extract such information from the scattered neutrons, investigators record the diffraction pattern created as the wavelike neutrons interfere with each other. A neutron-sensitive substance such as helium-3, which emits radioactive fragments when its nuclei absorb a neutron, is the key element in the detector, explains physicist Michael Rowe of the National Institute of Standards and Technology (NIST). Mathematical techniques then transform the diffraction pattern into a picture that can reveal the position of certain key atoms in a molecule, how molecules intermingle, or the tiny voids in porous material.

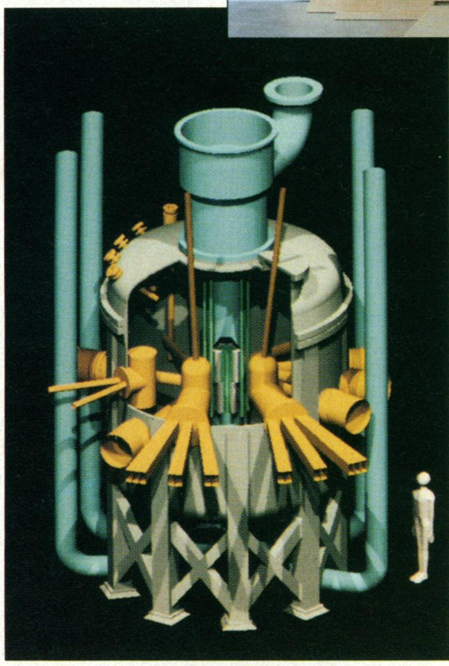
In polymers, for example, neutrons give scientists a unique way to examine how the spaghetti-like molecules intertwine, says West. The trick is to mix in a few polymer molecules "marked" by substituting heavy hydrogen (deuterium) for the ordinary hydrogen in their molecular makeup. To a neutron, hydrogen and its heavy relative look entirely different. As a result, labeling polymers with deuterium is "like painting them red," he says. You can pick out just a single strand, says West, and see how it folds around its neighbors. And the way polymers hang together gives them many of the their properties in bulk—distinguishing steel-strong Kevlar from Handi-wrap.

Biochemists, too, hold high hopes for the ANS. Genentech's Anthony Kossiakoff hopes to use the ANS to study the way proteins perform their intricate chemical functions. Often, he says, transfer of hydrogen atoms holds the key. "A lot of protein chemistry involves shuttling of hydrogen ions among active sites," he says. And hydrogens show up much better with neutrons than with x-rays. Add to that the prospect of using the ANS to produce radioactive isotopes for medicine, test the ability of materials for power reactors to stand up to neutron bombardment, and probe the workings of high-temperature superconductors, and the ANS seems assured of eager users.

Existing neutron sources at Oak Ridge, Brookhaven, and the Institut Laue-Langevin can already do some of these jobs, but they are decaying and produce far fewer neutrons than the ANS will, says Kossiakoff. "The increased flux [expected from ANS] will allow us to do things we never dreamed of doing before." For one, it will make it possible to extract a readable signal from smaller samples—and for Kossiakoff, that means the opportunity to study many proteins that would have been out of reach of weaker neutron sources. Protein crystals, he explains, can be agonizingly hard to grow. "I once took a whole year to grow a crystal [large enough to probe with an existing neutron source]," he says. Other substances, too—liquid crystals, high-temperature superconductors, and magnetic materials—often come in quantities too small to be studied effectively at present neutron sources.



OAK RIDGE NATIONAL LABORATORY



Going to the source. Neutron guides *(yellow)* emanate from the reactor in artist's conception of the Advanced Neutron Source *(top)*.

Too high a price? All that comes at a high price, as critics like Park point out. Supporters respond that there's little room for cost-cutting, given environmental and safety regulations. Adds NIST's Rowe, "I'd like to see it cost less, as everyone else does, but I believe this is a necessary facility." Even the supporters aren't in complete accord, however. Princeton's Happer, for example, favors the ANS but says the facility should have been conceived as an international project —a view privately shared by many members of the DOE panel that endorsed the project last January. But the project wasn't set up that way, says DOE physicist Lou Ianniello, because it isn't as big as SSC or the space station, and "it's more closely related to industrial economic competitiveness."

And then there are advocates of an alternative sort of neutron machine known as a spallation source, which makes its neutrons not by nuclear fission but by accelerating beams of protons and crashing them against a target. Panel members recommended building both a reactor and a spallation source, but they put the reactor first. Only reactors can make medical isotopes and test the effects of radiation on materials, says project director West. For probing materials, each type of source has advantages, but the higher overall flux of neutrons from the reactor is an overriding one, says Cornell's Kramer. "Most people feel a reactor source is preferable if you are going to build just one."

Not so, says physicist Joyce Goldstone of Los Alamos National Laboratory, who works on a small spallation source there. First of all, she says, an accelerator has safety and environmental advantages over a reactor. And she adds that reactor neutron sources can't get much more powerful than the ANS, while nobody yet sees a limit to the potential of spallation sources. As a result, she argues, experience gained now with the technology might pay off when researchers plan still more powerful sources. But Happer thinks such a radical change in the project's technical direction is unlikely. It's partly a cultural thing, he says: Most researchers in neutron scattering are used to working with reactor sources and are intimidated by complex, computer-intensive accelerator technologies. "People pushing spallation are much younger and more computer literate," says Happer.

Far more scary to ANS proponents than any technical challenges, however, are the political hurdles the project will have to face as its annual costs rise. As the project moves toward completion, it will require more than $200 million per year, not $22 million, admits West. He's optimistic that the money will be appropriated as needed. But Kramer worries that "in the worst possible world, we would build [the ANS] halfway and then abandon it." Happer says the gloomy outlook for the SSC makes him wonder whether Congress can sustain a commitment to any expensive science project, no matter how worthy. "I can hardly believe we may terminate a big project like SSC and start a new one like ANS," he says. "It sounds loony to me."

–Faye Flam