

reactions?” Other possible explanations for plate boundaries having slippery faults involve localized weak minerals, chemical reactions, and the dynamics of rupturing.

“We will be able to exhume fault zone materials and measure composition, strength, deformation mechanisms. We will hold these materials in our hands for the first time,” says Zoback. Lab tests on the sample cores, combined with the long-term observations in the borehole, he says, “will help us answer specific questions about the physics of faulting. Whatever we find, it will help us begin to constrain the hypotheses.”

Synergies

All elements of EarthScope are tied together by the compelling science questions, adds NSF’s Whitcomb. “The aim is to be able to solve the dynamic equation for Earth as a whole.”

An example of the different projects working together would be the use of portable GPS receivers and seismometers around the San Andreas fault to get a broader view than

from the borehole alone. “There are issues of how stress and strain move along and between faults,” says Hickman. “SAFOD will have instruments in the borehole, and the PBO instruments will give us a bigger picture of the deformation field.” Similarly, he adds, “seismic images from USArray can tell you there is an area with low velocity—it could be soft rock or it could be hard, fractured rock with high fluid pressure. It’s not until you drill with SAFOD that you can distinguish. By combining the tools, you can scale up from the borehole to get a full, three-dimensional picture of the San Andreas fault and its environment.”

In its full vision, EarthScope includes a fourth component: An interferometric synthetic aperture radar (InSAR) satellite for imaging surface deformation. The satellite would sweep over the same area perhaps every eight days to get deformation measurements accurate to a centimeter roughly every 30 meters. The high spatial resolution “would complement the PBO remarkably well,” says Bernard Minster of the Scripps Insti-

tution of Oceanography. So far, though, NASA has repeatedly declined to fund such a satellite. Still, says Minster, “I am reasonably optimistic that it will happen.” An InSAR satellite would cost about \$350 million or \$400 million, he adds. “That’s dwarfed by the costs associated with earthquake risks.”

EarthScope also plans to involve the public. High schools could, for example, host the traveling USArray seismic stations. “That’s a great opportunity,” says Roberta Rudnick, a geochemist at the University of Maryland, College Park, and a member of the EarthScope science and education committee, which advises NSF and serves as a liaison between the agency and the scientific community. “But it’s only a start. The interesting thing is, the MREFC is paying strictly for equipment. Just like the science, the education and outreach is going to come from proposals from the community. The vision is that EarthScope will become widely known in the US—and the whole world.”

Toni Feder

MIT Study Sees Nuclear Power as Green Weapon Against Global Warming

Although the public doesn’t yet view nuclear power as a way to mitigate global warming, an MIT study says a global tripling of nuclear power generation could avoid nearly 2 billion tonnes of carbon emissions annually.

While new nuclear power plants are not economically competitive with fossil fuels, an MIT interdisciplinary research group is recommending limited federal support of new nuclear power plants as a way to reenergize the industry and lessen the potential impact of global warming. The report, *The Future of Nuclear Power*, acknowledges the stagnation of the field in recent years, but concludes that “the nuclear option should be retained, precisely because it is an important carbon-free source of power.”

The MIT study, cochaired by institute professor John Deutch and physics professor Ernest Moniz, notes that during the next 50 years, “unless patterns change dramatically, energy production and use will contribute to global warming through large-scale greenhouse gas emissions—hundreds of billions of tonnes of carbon in the form of carbon dioxide.” The nuclear scenario offered by the study would expand current global nuclear-generating capacity “almost threefold, to 1000 billion watts by the year 2050. Such a deployment would avoid 1.8 billion tonnes of carbon emissions an-

nually from coal plants, about 25% of the increment in carbon emissions otherwise expected in the business-as-usual scenario.” (See report at <http://www.mit.edu/afs/athena/org/n/nuclearpower>.)

The study comes when Bush administration officials are talking about a nuclear power “renaissance,” and the US nuclear industry is calling for 50 new commercial reactors by 2020 (see *PHYSICS TODAY*, April 2002, page 54). Indeed, Deutch said officials in both Congress and the administration paid “complete attention” to his briefings. “I think [the report] is influencing their thinking about parts of the nuclear program, although I don’t say that they agree with all of our recommendations.”

Moniz, an Undersecretary of the US Department of Energy (DOE) during the Clinton administration, said that in addition to the usual players in the nuclear power world, “those in the environmental community with a deep

concern about climate change are really paying attention to the report. The Energy Future Coalition [a nonpartisan, Washington, DC-based think tank] deferred to our report in its discussion of nuclear power. Overall, we’re gratified by the level of interest.”

Nuclear interest growing

Although interest in commercial nuclear power seems to be growing, the barriers to a rebirth of the industry are significant. The report notes that, “for a large expansion of nuclear power to succeed, four critical problems must be overcome.”

The first of those problems is cost. Based on numbers from “actual experience” instead of engineering projections, the study says that a new nuclear power plant costs 6.7 cents per kilowatt-hour of electricity. Plausible but unproved reductions in capital and operating costs could lower that to 5.1 cents. Pulverized coal costs 4.2 cents, and natural gas ranges from 3.8 to 5.6 cents, depending on the highly variable gas market. If the high initial cost of a nuclear power plant can be lowered, and if coal and gas are subject to a carbon tax, then nuclear



Deutch

power becomes more competitive. With a \$100 per tonne tax on emitted carbon, coal would cost 6.6 cents per kilowatt-hour and natural gas would range between 4.8 and 6.7 cents, the report says.

To overcome the high risk of being first to build a new commercial reactor, the report calls for the federal government to “provide a modest subsidy [in the form of a production tax credit] for a small set of ‘first mover’ commercial nuclear plants to demonstrate cost and regulatory feasibility.” The report urges other steps to overcome the regulatory uncertainties facing nuclear power.

The second problem confronting commercial nuclear power is safety, and the report calls for maintaining the current standard of “less than one serious release of radioactivity accident for 50 years from all fuel cycle activity.” The standard “implies a tenfold reduction in the expected frequency of serious reactor core accidents,” a reduction that “should be possible to achieve in new light-water reactor plants.”

The nuclear power industry concedes that public confidence in nuclear power was seriously eroded by the 1976 nuclear accident at the Three Mile Island reactor in Pennsylvania and by the Chernobyl reactor meltdown in 1986 in Ukraine. Public resistance to nuclear power has played an important part in the industry’s stagnation, so safety has to be a central concern in renewal efforts.

The third hurdle that nuclear power advocates must overcome is radioactive waste. According to the report, “the management and disposal of high-level radioactive spent fuel from the nuclear fuel cycle is one of the most intractable problems facing the nuclear power industry throughout the world. No country has yet successfully implemented a system for disposing of this waste.”

The report’s authors believe geologic waste repositories can work, but they point to the one site being studied in the US, Nevada’s Yucca Mountain, as an example of the difficulty of the problem. Despite 15 years of effort, Yucca Mountain still hasn’t been licensed, and even if it is, “new repository capacity equal to the nominal storage capacity of Yucca Mountain would have to be created somewhere in the world every three or four years” if nuclear power is significantly expanded, the report says.



Moniz

The report recommends that, in addition to Yucca Mountain, DOE launch a research program to “determine the viability of geologic disposal [of waste] in deep boreholes.”

The fourth challenge to nuclear power expansion is proliferation. “The current international safeguards regime is inadequate to meet the security challenges” of a dramatically ex-

panded use of nuclear power, the report states. “The reprocessing system now used in Europe, Japan, and Russia that involves separation and recycling of plutonium presents unwarranted proliferation risks. We conclude that, over at least the next 50 years, the best choice to meet these challenges is the open, once-through fuel cycle.”

The transmutation debate

Perhaps the most critical analysis of the MIT report came from physicist Burton Richter, director emeritus of SLAC. Richter, who is chair of the Accelerator Transmutation of Waste subcommittee of DOE’s Nuclear Energy Research Advisory Committee, wrote a six-page paper detailing disagreements with the recommendations on future directions of nuclear energy R&D.

“I agree with most of it,” Richter said of the report. But in his work on

the DOE advisory committee, he said he has “come to believe that transmutation [the transformation of one element into another by bombardment of nuclei with particles] has real potential.” Richter noted that waste from the once-through fuel cycle recommended by the report “requires isolation from the environment for on the order of 300 000 years.” Transmutation, Richter said, “has the potential to reduce the required isolation time to on the order of a thousand years, greatly reducing concerns about unlikely geophysical events.” Moniz responded that the report advocates more research money for transmutation, but the horizon for that technology is too distant to play a role in current efforts to revive nuclear power. Richter said the MIT study should have placed greater emphasis on the cost of carbon sequestration for fossil fuels, which would level the economic playing field and make nuclear power competitive with fossil fuels. Moniz said the authors of the study used a “merchant plant model,” meaning they determined costs based on private sector financing. “We based conclusions on actual experience,” he said.

Deutch said he hopes the nuclear report is the first in a series of MIT studies on various energy issues. “I think carbon sequestration would be the next study we’d like to take on,” he said.

Jim Dawson

Baja Site Vies to Host Telescopes

The growing name recognition of San Pedro Mártir is both evidence of, and a catalyst for, astronomers in Mexico and the US eyeing the Baja California site as a possible new hot spot for ground-based telescopes.

The site has been home to Mexico’s national observatory since the 1970s. The largest and newest of its three telescopes is 2.1 meters in diameter and has been in use for more than two decades. But over the past couple of years, momentum has been mounting to develop the 2800-meter-high site, which is located about 300 kilometers southeast of San Diego, midway between the Pacific Ocean and the Gulf of California. San Pedro Mártir, proponents say, could rival any existing telescope site.

Turning San Pedro Mártir into a world-class astronomy site got a boost early this year when two groups in Mexico merged their previously competing plans for large optical telescopes. Astronomers at the Institute of Astronomy, Optics, and Electronics in Puebla bring to the table an agree-

The jury is still out on San Pedro Mártir’s becoming a major ground-based astronomy site, but it’s in the running thanks to its clear skies, proximity to the US, and other scientific and political virtues.

ment with the University of Arizona’s Steward Observatory to cast an 8-meter-class mirror, while the Institute of Astronomy at the National Autonomous University of Mexico (UNAM) runs the observatory at San Pedro Mártir. Now the project leaders are seeking additional partners and deciding whether to build a single-mirror or binocular telescope.

Another boost came from outside Mexico. With several large projects in the works in the US, astronomers “are taking a fresh look at where would be the optimum place to site a facility,” says the National Optical Astronomy Observatory’s Alistair Walker, cochair of the site selection committee for the Thirty Meter Telescope (see PHYSICS