Corvallis. "Both the scientific community and the NSF would be better served if the board were more independent." Stan Jaskolski, a retired executive at Eaton Corp. in Cleveland, Ohio, says that the board now lacks the ability "to meet by itself, independent of the management of the foundation, … to discuss key emerging issues and challenges. The system is not broken, but we need to constantly seek to improve it."

Some board members say the recent departure of Marta Cehelsky, the board's longtime executive officer, points up the need for greater autonomy. Soon after Washington became chair, Colwell shuffled the board's staff. Cehelsky is now on leave at the Inter-American Development Bank in Washington, D.C., helping incorporate science into long-term planning, and longtime NSF staffer Gerry Glaser serves as acting executive officer. "I was disappointed when Rita decided to remove Marta," says Diana Natalicio, president of the University of Texas, El Paso, and vice chair of the board. "We lost a person we respected, and one who had a lot of experience. That leaves a void."

Colwell says the move was made with Washington's approval. "It was time for a change," she says. "We agreed that it was time for him to have his own staff." Washington has a different recollection of events. "The idea of changing board personnel was her idea, and the change was made much faster than I would have wanted," he says. "There was some period of transition, but it wasn't ideal."

Although Washington has spent 8 years on the board, the 66-year-old climate modeler says he's still a political naïf who faces a steep learning curve. Dispatched by the board last month to Capitol Hill to learn the legislators' intent, Washington spent most of the time listening. "He was trying to take our temperature," says one House staffer. "He said that some board members think [the changes] are not a bad idea and that the board would continue to talk about it." Washington's assessment is typically understated: "I'm impressed with how seriously people on [Capitol] Hill are taking the board's responsibility to oversee the foundation."

The board's penchant for secrecy has traditionally kept any conflicts bottled up within the board's home at NSF's headquarters in suburban Virginia. But that might be changing. In June the House called on the board to conduct more of its business in public, and Washington says he is already thinking about how to do that. "I want to go back to a time of greater openness in discussing controversial topics," he says.

Washington also takes a philosophical view of possible changes in the board's status. "I think that most of the board still feels that these changes aren't necessary," he says. "But if they get adopted, we can live with them. The important thing is the increased funding for NSF. That's the big news."

The fate of both NSF's budget and the board's authority over it now rests with Congress, which must reconcile competing versions of both spending and authorization bills. Only then will Washington and the science board learn what they have to live with.

—JEFFREY MERVIS

HIGH-ENERGY PHYSICS

Neutrino Hunters Borrow Military Ears—and Eyes

Undersea listening devices and an aging spy satellite are helping physicists look for ultrahigh-energy neutrinos

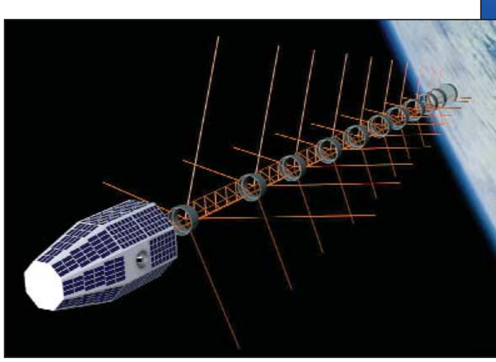
A decade ago, nobody was sure they even existed. Ultrahigh-energy neutrinos, almost-undetectable particles moving so fast that they can carry as much energy as a baseball pitch, were a theoretical possibility—nothing more. Nobody had any way to spot them, and nobody could even guess what an instrument designed to detect them would see.

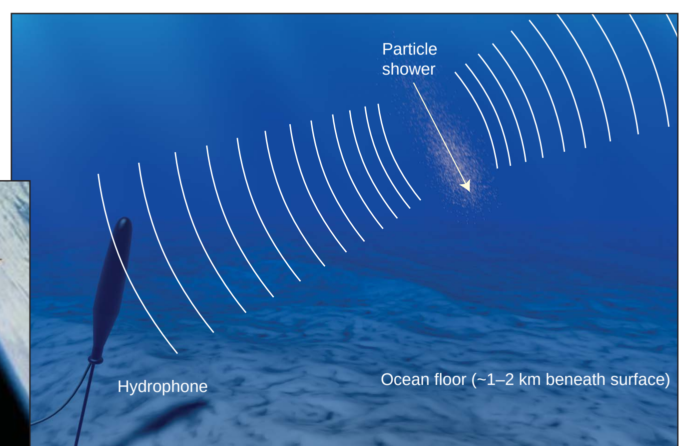
But that's ancient history. Now physicists are firmly convinced that Earth is constantly being bombarded by ultrahigh-energy neutrinos, which are part of the debris generated when extremely energetic cosmic rays slam into the atmosphere, water, or rock, creating showers of particles. The neutrinos could give physicists valuable clues to the source of the cosmic rays that spawned them—one of the most vexing unknowns in modern astrophysics.

Several experiments that can sense ultrahigh-energy neutrinos are planned, but they are years away. However, scientists are already searching for the particles, thanks to military hardware designed to snoop on a Cold War enemy. Using data from sources such as a submarine-listening facility and an aging spy satellite, a handful of shoestring projects are quietly paving the way for higher profile efforts soon to come—and could well beat them to the punch.

"They're extremely nice and cooperative," says physicist Giorgio Gratta of Stanford University of his U.S. Navy benefactors, who have given his lab at Stanford and physicists at the Scripps Institution of Oceanography in La Jolla, California, access to a 250-square-kilometer array of underwater microphones, or hydrophones, based at the Atlantic Undersea Test and Evaluation Center (AUTEC) in the Bahamas. During the Cold War, the U.S. and Soviet navies sprinkled such acoustic arrays throughout the world's oceans in hopes of tracking enemy submarines. Now Gratta and colleagues think they might pick up the much subtler acoustic waves generated when particle showers triggered by incoming neutrinos heat up seawater, causing it to expand.

To make an audible click in the ocean, a neutrino must carry a huge amount of energy: 10^{16} electron volts (eV), enough, perhaps, to knock an ant into the air. Until recently, most astrophysicists didn't think such neutrinos existed; no cosmic rays packed enough of a wallop to create them. But in





High and low. A spindly satellite (*left*) and underwater microphones (*right*) are serving as makeshift particle detectors.

CREDITS: (LEFT TO RIGHT) LANL; ILLUSTRATION: C. SLAYDEN the past few years, cosmic ray observatories such as the HiRes project in Utah have shown, to scientists' surprise, that cosmic rays with energies of 10^{20} eV and above do exist (*Science*, 19 May 2000, p. 1147), although how they form and where they come from remain a huge mystery.

"With the very existence of cosmic rays going out to 10^{20} eV, there have to be high-energy neutrinos out there, too. It's inescapable," says John Learned, an astroparticle physicist at the University of Hawaii, Manoa, and a pioneer in the field of ultrahigh-energy neutrinos.

Unfortunately, the current generation of neutrino detectors—Super-K, the Sudbury Neutrino Observatory, and other underground devices—are too small to see ultrahigh-energy neutrinos. To catch such rare particles interacting with matter, physicists need to watch an enormous patch of sky, ice, or water—the bigger, the better. That limitation gave Gratta an idea. The ocean, he mused, is plenty big—and the Navy already has listening posts in place. Gratta called the Office of Naval Research, the Naval Postgraduate School in Monterey, California, and other facilities in hopes of tapping into the flood of data coming in from those arrays. He eventually reached AUTEC personnel, and his team started listening for neutrinos.

"The AUTEC array has been in place for 30-odd years, working beautifully," says team member Mike Buckingham, an acoustician at Scripps. "It's quiet; it's fairly well shielded from shipping noise. You get natural sounds from surface processes, like breaking waves and bubbles, and biological sounds from marine mammals."

Right now, the team is calibrating the instrument and characterizing that background noise to figure out whether AUTEC is capable of picking up the sound of a passing neutrino. One technique involves dumping weighted light bulbs overboard and checking how the hydrophones pick up the pops when the bulbs implode, about 100 meters down. By calculating the energy and depth of the implosions, the team can measure the array's sensitivity. Such low-tech methods help make the AUTEC project a bargain, Gratta says. "It's extremely cheap. The budget for the last 2 years has been $5000." A similar Russian project is under way off the coast of the Kamchatka Peninsula, Learned says.

Even as scientists exploit the military's underwater ears, they also are taking advantage of eavesdroppers in space. The Fast On-orbit Recording of Transient Events (FORTÉ) satellite was designed at the Los Alamos and Sandia national labs and launched in 1997 to help enforce a nuclear test ban. But for neutrino hunters, the ungainly looking spacecraft is a "wonderful, fortuitous thing," says Learned.

FORTÉ is an enormous antenna designed to pick up electromagnetic pulses, such as those created when a nuclear weapon detonates. It also picks up lightning strikes and other brief pulses of electromagnetic energy, such as those given off by a neutrino particle shower. Nikolai Lehtinen and Peter Gorham of the University of Hawaii, Manoa, got access to the data from September 1997 through December 1999, when the relevant antennae failed. "In the database there are around 4 million events, and we're looking at these events, trying to distinguish them from lightning," Lehtinen says. The team is focusing on electromagnetic waves issuing from the Greenland ice shelf. Limiting the search to signals from Earth's surface, Lehtinen explains, filters out air showers due to cosmic rays, which never survive long enough to hit the ground. Although it's too early to say for sure that Lehtinen has detected an ultrahigh-energy neutrino, there is a promising candidate event.

Even if AUTEC and FORTÉ never spot a neutrino, they have given physicists a head start in their search to detect ultrahigh-energy neutrinos. "It would cost millions and millions of dollars to build these things," Learned says. Even a null result will teach physicists about background noise that will affect future searches in the ocean or from high above Earth. And if they succeed, it will be an unexpected bonus from technologies designed to spot lumbering submarines and gigantic explosions rather than wispy particles.

–CHARLES SEIFE

FLORAL EVOLUTION

A Compromise On Floral Traits

Biologists are looking beyond pollinators to more subtle influences to learn how colorful, shapely flowers evolved

Late this summer, Candace Galen crouched in a Rocky Mountain meadow, watching bees dart from flower to flower. Most evolutionary ecologists would have admired this precise pollination dance—the close fit between bee and blossom. But Galen was waiting for a thief.

A nectar thief, to be exact. Galen, an ecologist at the University of Missouri, Columbia, studies the alpine skypilot (*Polemonium viscosum*), a purple perennial wildflower. Her research shows that pollinating bees are not the only ones pursuing the flower. Small, stealthy ants also devour the flower's nectar—and inflict a surprising amount of damage in the process. In fact, Galen suggests that both bee pollinator and ant predator might have inspired the skypilot's shape. "We know that flowers are compromise structures," Galen says. "And this is a good example."

Unpicky pollinators. Whether naturally shaped or experimentally altered, the flowers of a Mediterranean lavender were equally popular with pollinators.

"Compromise," as Galen puts it, is fast becoming the new buzzword as researchers uncover the details of floral evolution. Many scientists have long explained flower fashions rather simply: From richly red bee balm to the cornflower's spiky crown, popular theory has gone, each flower has evolved the right color and shape to attract effective pollinators. The yucca plant, for instance, turns its flowers upward at dusk, to be pollinated exclusively by the yucca moth, which rolls up its heavy pollen like a snowball.

But today, a growing number of scientists are looking for more subtle evolutionary forces—from nectar thieves and herbivores to environmental demands and developmental changes—that might also sculpt floral traits. "We're taking a more pluralistic view," says evolutionary ecologist Sharon Strauss of the University of California, Davis. And they're raising some eyebrows in the process.

Some pollinators, according to the new work, might not deserve their starring evolutionary roles. Reporting last year in the *Journal of Evolutionary Biology*, Carlos Herrera of the

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