ing it? Venter answers this question in several ways. First, he points to the support of Celera's "early access" clients. He says the $5 million annual fees they pay show that, even though genomic data have been available for years, important customers will pay a premium for Celera's work. Second, a lot isn't being given away: Celera intends to patent several hundred human genes and a large set of human single nucleotide polymorphisms for use in individually tailored medicine. Venter hasn't set the terms for data release of three of the four initial genome projects, or for others on a list of possible targets in agriculture, such as the cow, corn, wheat, soya, and apples.

Finally, Venter says he's not interested in exclusivity because he doesn't want to peddle intellectual property. He wants to create "a big information company," not just for sequence data but for the analyses pouring out of his computers—something like Bloomberg News, which distributes financial data over a closed network. His future customers, Venter likes to say, are not just companies and universities, but "anybody with a genome." He wants to reach the masses.

Celera's first customers, however, are elite: They include the pharmaceutical companies Amgen Inc. of Thousand Oaks, California; Novartis Pharma of Basel, Switzerland; and Pharmacia & Upjohn (P&U) of Bridgewater, New Jersey. William Boyle, who heads Amgen's cell biology lab, says it's easy to explain his interest in Celera: "It's not so much what the information is," says Boyle, but "the timing and the pace with which it will become available. … It's getting a first look" at the entire human genome. Over time, Boyle says, Amgen expects to collaborate with Celera in comparative genome projects to elucidate the hierarchy, organization, and function of genes.

Les Hudson, head of global research at P&U, says his company is not interested in raw data but in building tools to analyze diseases. Like the other two early clients, P&U has its own, fenced-off computer server located at Celera, which it can access remotely. Hudson expects that the company's bioinformatics group, located at the Karolinska Institute in Stockholm, will use the system to search genomes for "druggable targets." And Novartis's chief of research, Paul Herrling, says that Celera's "key aspect is speed." Novartis, he adds, will use the collaboration to develop "new high-powered computer tools to analyze and annotate" genomic data.

Venter sees his company as an elaboration of a model "validated" by Incyte Pharmaceuticals of Palo Alto, California. This is the concept that you can make a profit marketing nonexclusive access to genomic data, selling information services rather than information ownership. He says he plans to offer data at "a reasonable price" to everyone—including university scientists and citizens who want to learn about their health. But Celera hasn't disclosed the terms.

Because Celera's plans for releasing human genome data remain cloudy, some researchers suspect Venter is having trouble finding a solution that satisfies the company's business plan. One genome center leader predicts Venter will have to curb his academic ambitions to protect the company's investment in data. Celera may grant access, this researcher predicts, but only to those who sign a contract promising not to share information or use it commercially. Indeed, although Celera originally talked about putting human data in GenBank, the public repository at NIH, NIH officials report that discussions are stalled. NIH's stance on the need to share research tools without such strings, issued last month (*Science*, 28 May, p. 1445), may make it harder to work out an agreement.

The never-ending questions about public data release are irksome to Venter. It is "inappropriate for us to be discussing what might or might not be happening with human data vis-à-vis GenBank right now," Venter says. "We're going to make the data available to the scientific community on our Web site, like we've always promised." At the moment, he says, "our goal is to get *Drosophila* done. We're going to let our accomplishments speak for themselves." He adds: "That's the beauty of genomics: Sooner or later you have to come up with the data. If you do, you win; if you don't, you lose."

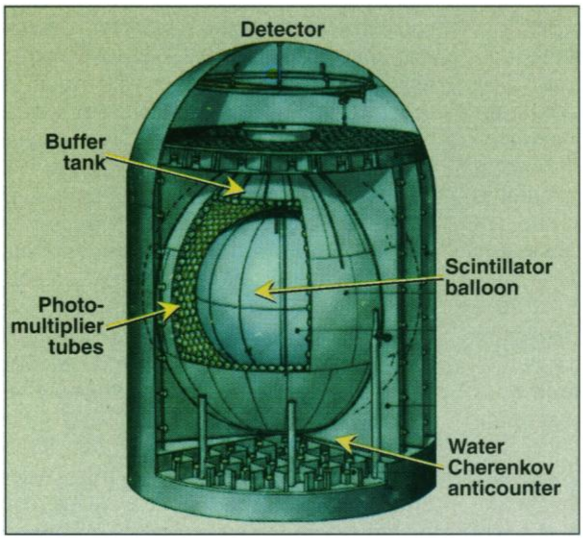
In just 1 month, Celera is scheduled to begin releasing sequence data from the *Drosophila* genome; in 3 months, it plans to start putting human genome data on its Web site. Soon, everyone will be able to judge for themselves who won. —ELIOT MARSHALL

PARTICLE PHYSICS

Experiment Uses Nuclear Plants To Understand Neutrinos

Physicists hope a novel facility being built in a Japanese mine will shed light on the elusive neutrino—and Earth's radioactive heat source

Neutrino research and nuclear reactors go back a long way. The first neutrinos ever detected, in a 1956 Nobel Prize–winning experiment by physicists Clyde Cowan and Frederick Reines, emanated from a nuclear plant. But since then the relationship has cooled. In recent years, physicists trying to understand these elusive particles have targeted the high-energy neutrinos coming from space or from accelerators at high-energy physics labs because of the logistical problems of siting detectors at the right distance from enough reactors. Now the old flame is reviving in a Japan–United States collaboration that is building a massive underground snare for neutrinos emitted by Japan's nuclear power plants, which may hold the key to neutrino puzzles that are hard to unlock with other approaches.



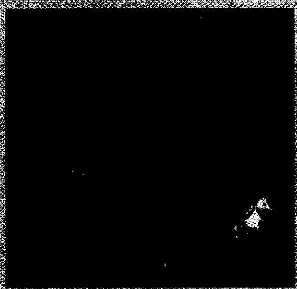
Mining knowledge. This detector in a Japanese mine will use a special chemical soup to capture evidence of neutrinos.

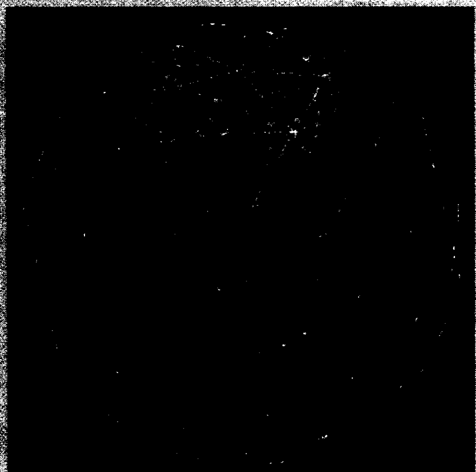
CREDIT: KAMLAND COLLABORATION

Called KamLAND (Kamioka Liquid scintillator Anti-Neutrino Detector) and located beneath the mountains of central Japan, the detector will catch antineutrinos—the antimatter counterparts of neutrinos—from the country's 51 nuclear power reactors, as well as neutrinos directly from the sun. By studying how the neutrinos behave on their way to the detector, the project members hope to add to recent evidence that neutrinos—assumed until recently to be massless—do have mass. And because nuclear reactors produce neutrinos in similar energy ranges to those produced in the sun, KamLAND may help physicists explain the so-called solar neutrino deficit: the shortfall—by up to one-half—

SNO Closes In on Solar Neutrino Riddle

The first neutrinos have been spotted colliding with heavy water molecules in a giant tank at the bottom of an Ontario nickel mine. Announced last week, the events mark the inauguration of the Sudbury Neutrino Observatory (SNO), a new facility that physicists hope will finally solve the solar neutrino problem, which has been haunting the field for decades.





Tracks in the SNO. A neutrino colliding with heavy water in SNO's giant tank *(top)* generated secondary particles that cast a glow on photodetectors *(above)*.

Generated by the sun's nuclear processes, nearly a billion solar neutrinos—ghostly subatomic particles that can easily pass through Earth without hitting anything—shower down on each square centimeter of the planet's surface every second. Although neutrinos come in three "flavors," electron, muon, and tau, existing detectors can only see the electron variety, and they only see half as many coming from the sun as theorists had predicted. To resolve this discrepancy, physicists have proposed that half of the neutrinos switch flavors, or "oscillate," on their way from the sun's center to Earth. Other neutrino experiments have been gathering indirect evidence for oscillations by comparing the number of neutrinos from a known source with the number observed in a detector, and a new project in Japan called KamLAND could firm up the case (see main text). But SNO should provide the most direct test yet of the theory.

The key is its ability to see several varieties of solar neutrinos at once. SNO contains 1000 tons of ultrapure heavy water, water in which the hydrogen atoms have been replaced with deuterons, whose nuclei have a proton and a neutron. When an electron neutrino collides with a heavy water molecule, it can split apart the neutron and the proton and eject an electron. Other neutrino flavors split the nuclei but don't scatter electrons. By counting both neutrons and electrons, SNO should be able to measure both the total number of incoming neutrinos and the fraction of electron neutrinos, says physicist and SNO spokesperson David Wark of Oxford University in the United Kingdom. If SNO finds that the shortfall of electron neutrinos is made up in other flavors, it will provide strong support for oscillations.

"It is an extremely important experiment," agrees physicist Paul Langacker of the University of Pennsylvania, Philadelphia. "They will very likely ascertain definitively whether neutrino oscillations are taking place." Unfortunately, physicists will have to be patient: Neutrinos collide with matter so rarely that SNO will detect only some 20 neutrinos every day. As a result, says Wark, "it will be at least a year" before SNO has an answer.

—MARK SINCELL

Mark Sincell is a free-lance science writer in Tucson, Arizona.

in the observed versus expected number of neutrinos from the sun. As a bonus, KamLAND could also yield clues to the distribution of radioactive elements in Earth's crust and how their decay contributes to the heat generated within the planet.

"KamLAND is a great experiment," says John Bahcall, a neutrino expert at the Institute for Advanced Study in Princeton, New Jersey. He is particularly excited about the ability to investigate the solar neutrino anomaly under what amounts to laboratory conditions, that is, knowing the conditions under which the neutrinos were created: "I never expected to live to see a laboratory test of a solar neutrino explanation."

KamLAND is a collaboration of three Japanese and 10 U.S. institutions, led by the Research Center for Neutrino Science of Tohoku University in Sendai. It uses a mine cavern occupied by Kamiokande, an earlier neutrino detector that has been succeeded by Super-Kamiokande, now running in a separate cavern in the same mine. The detectors made worldwide headlines last year by offering evidence of mass for at least one of the three flavors, or types, of neutrinos. Both of these detectors consisted of huge tanks of water outfitted with photomultiplier tubes, which pick up the flash of light generated when an occasional high-energy neutrino interacts with a proton in the water.

In contrast, KamLAND will use 1200 cubic meters of a liquid scintillator, a chemical soup that luminesces in response to neutrinos at lower energies. The liquid is confined in a 13-meter-diameter spherical balloon surrounded by layers of inert oil and water intended to cut background noise. With 1280 photomultiplier tubes to pick up the luminescence, KamLAND will cost an estimated $20 million, all coming from Japan's Ministry of Education, Science, Sports, and Culture (Monbusho). U.S. collaborators have asked the Department of Energy for $7.8 million to provide another 650 photomultiplier tubes, which would increase the sensitivity of the detector.

After it starts taking data in 2 years, KamLAND could bolster the neutrino mass claims from Super-Kamiokande. Those claims were based on signs that muon neutrinos made by cosmic rays colliding with air molecules were "oscillating," or changing into another type, on their way to the detector—something the laws of quantum mechanics forbid if both particles are massless. But Super-Kamiokande's case for oscillations had a weak point, because it relied in part on calculations of how efficiently cosmic rays should produce neutrinos in the atmosphere.

A number of so-called long-baseline experiments are attempting to remove the uncertainty by sending streams of neutrinos generated in accelerators through a near detector to a far detector so the neutrinos can be counted at both ends of their trip. These experiments, however, are aimed at the muon neutrino and energy ranges associated with atmospheric neutrino oscillation. KamLAND will focus on electron antineutrinos and the solar neutrino anomaly.

Atsuto Suzuki, a professor of physics at Tohoku University and head of the collaboration, says there's no need to place a detector at the source because the neutrino-producing reactions of commercial nuclear reactors are well understood. Instead, Suzuki and his colleagues will simply compare the number of electron antineutrinos detected at KamLAND with the number made by the

CREDITS: SNO COLLABORATION

reactors to determine whether some of them are oscillating into undetectable muon antineutrinos. "It's an amazing coincidence that Kamioka is just the right distance from these reactors" for the oscillations to show up if neutrinos do indeed have mass, says Stuart Freedman, a physicist at Lawrence Berkeley National Laboratory in California and one of the U.S. spokespersons for the collaboration.

Evidence of oscillations may shed light on the solar neutrino deficit. The current favorite explanation for the deficit is that the missing solar neutrinos, on their way to Earth, are oscillating into flavors not seen by the detectors. But theorists have four different scenarios for how this might happen. Suzuki says that KamLAND will be able to investigate all four, using the reactor neutrinos for one and its observations of solar neutrinos to examine the others. KamLAND also will be sensitive to critical neutrino energies that have eluded previous detectors.

In addition, KamLAND will be looking downward at Earth's own internal processes. The decay of radioactive isotopes of uranium and thorium is one of the major sources of Earth's internally generated heat, but nobody knows just how much heat this source produces or how the uranium and thorium are distributed within the crust and mantle. Fortunately, the low-energy antineutrinos generated by this decay fall within KamLAND's range of sensitivity, and their signature can be distinguished from reactor antineutrinos. By tracking neutrinos coming from the deep Earth to their origins, investigators hope to get a better fix on the nature and location of the planet's internal heat source.

Suzuki expects KamLAND to yield most of its useful data within the first few years, although the experiment is capable of running for a decade or longer. If it succeeds, it will add another link to the chain that connects neutrinos with nuclear reactors.

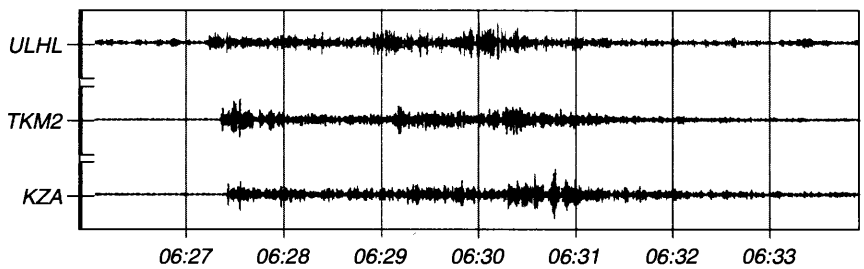
–DENNIS NORMILE

CENTRAL ASIA

Survival Test for Geophysics Center

In the mountains of Kyrgyzstan, a research station that monitors earthquakes and nuclear tests faces an uncertain future

BISHKEK, KYRGYZSTAN—When the ground trembled beneath the Lop Nor nuclear test site in western China on 27 January, the shock waves lit up a string of sensors in Central Asia and jolted an international scientific network to life. Within seconds the recordings were uploaded to a Russian satellite and sent via the Internet halfway around the world to the United States, where analysts began decoding the seismic signatures. Did China resume nuclear testing after signing the Comprehensive Test Ban Treaty in 1996, 2 months after its last blast? Or was the power unleashed by a natural event: an earthquake or a meteorite strike, perhaps? The answer was important to security and diplomacy—even before allegations of espionage in U.S. weapons labs suggested that China has acquired knowledge to upgrade its nuclear arsenal.



Quake, not nuke. The three KNET stations nearest China's Lop Nor test site recorded these signals on 27 January and transmitted them to the United States in a matter of seconds.

Thanks to 10 sensors in mountainous Kyrgyzstan, one of 15 countries created after the breakup of the Soviet Union, scientists were able to determine quickly that the event was an earthquake measuring 3.9 on the Richter scale. The seismic patterns recorded by the network, about 1200 kilometers west of Lop Nor, "provided essential information for detecting and discriminating the earthquake," says Frank Vernon, a research seismologist at the University of California, San Diego, who oversees the Kyrgyz Broadband Seismic Network (KNET). The nonclassified data helped reassure treaty-monitoring agencies that they weren't seeing an encore to last year's Indian and Pakistani nuclear tests, which KNET tracked as well.

But, in spite of such successes, the seismic sentinel faces an uncertain future. KNET is currently operating with stopgap funds from the U.S. State Department, which run out on 1 July. A proposal to maintain KNET is pending at the U.S. Civilian Research and Development Foundation (CRDF), a nonprofit in Arlington, Virginia. And the array is not the only important geophysics facility in Kyrgyzstan that's in jeopardy. When the U.S. government stepped in last year to prop up KNET, it also helped set up an International Geodynamics Research Center (IGRC), based at a Russian field station outside Bishkek, the Kyrgyz capital. Initial funding for the center is also drying up. Now, geophysicists are waiting to hear whether the U.S. National Science Foundation (NSF) or other agencies will ante up funds to help keep the center afloat.

Geophysicists who study the rapid mountain building in the mighty Tien Shan range, which dominates Kyrgyzstan and spills into neighboring countries, have a big stake in the outcome of these two funding decisions. The seismic network churns out a wealth of data for research as well as treaty monitoring, and Western researchers say the center provides an invaluable base to study a region where the crust is deforming at an intriguingly fast rate because of stresses generated as India plows into Asia. "This is a pretty exciting part of the world," says David Simpson, president of IRIS, a Washington, D.C.–based consortium of universities involved in seismological research. "They have magnitude 6 [earthquakes] like California has magnitude 3's," says Steve Roecker, a geophysicist at Rensselaer Polytechnic Institute in Troy, New York. If the funding for either facility ends, says Vernon, "I am afraid that the earth science community will lose a valuable resource which, once lost, cannot be resurrected."

The fact that there are valuable research resources at all in Kyrgyzstan owes a lot to a Russian geophysicist named Yuri Trapeznikov. In 1978 Trapeznikov, of the Institute of High Temperatures (IVTAN) in Moscow, was tapped to open a field station in Bishkek to study rock layers in the Tien Shan using a device called a magnetohydrodynamic generator. Developed at a Soviet military institute, the machine shoots huge bolts of current into the ground that can travel tens of kilometers through the crust to receiving instruments. Changes in electrical resistance give clues to the forces compressing the rock layers. "IVTAN is a world leader" in these sorts of measurements, says Vernon.

CREDIT: J. EAKINS, C. GEDDES, F. VERNON/IGPP/UCSD