space agency does not want to hold.

For NASA, such earmarks require more than just taking the money out of existing programs, mailing a check, and writing off the loss as the cost of doing business with Congress. "We have to make a silk purse out of a sow's ear," says another space agency source, explaining that each beneficiary must write a specific proposal that must be reviewed—and often sent back for revisions. For universities lacking the experience of working within the complex federal guidelines, says one agency official, "there's a lot of handholding. And it comes at a time when NASA's budget is shrinking." Western Kentucky's initial proposal, for example, was "embarrassing" in the vague way it defined how the $1 million would be spent, recalls one official. "We didn't know what to write," McGruder admits. "We didn't have guidelines." Later versions proved better, but the agency will have to go through the same process before disbursing the $1 million allocated in 2000.

Politicians brush aside criticism of earmarking. "We're not spreading the wealth like we should," says Senator Conrad Burns (R–MT), who succeeded in earmarking $2 million in the space science budget for Montana State University in Bozeman to study life in extreme environments. "The MITs of the country have a great lobby compared to Montana State, and we're just leveling the playing field. So maybe earmarks can do some good." McGruder agrees. "There's no question a lot of people don't like [earmarking]," he says. "But overall it is a positive thing."

NASA officials concede that smaller universities are at a disadvantage, particularly in astronomy, where major research institutions dominate the discipline's landscape. "It's hard for a new group to develop observing capability and get into the game," says one. "But the ultimate question is whether this is the right way to do it."

–ANDREW LAWLER

NEUTRINO PHYSICS

Squabbling Kills Novel Korean Telescope Project

HANUL was Korea's ticket to global collaboration in basic research. But that teamwork remains as elusive as the neutrinos it hoped to detect

SEOUL, SOUTH KOREA—The Korean government has ended funding for a novel aboveground neutrino telescope that was also meant to serve as the country's coming-out party for international research collaborations. Last summer's decision to kill the HANUL project has come to light only recently, however, amid a flurry of vituperative exchanges among the participants.

Personal animosity between the project's creator and its principal investigator (PI), a rigid bureaucracy, a slipping schedule, and doubts about its technical feasibility all seem to have a played a role in the project's demise. But researchers also point to what they call the "Korean disease," a zero-sum mentality Koreans blame for everything from unyielding cab drivers to brawling lawmakers. "We have to learn to collaborate and respect each other's opinion," says Chungwook Kim, president of the Korea Institute for Advanced Studies and chair of the government's review of the canceled project. "Real cooperation in experimental high-energy physics in Korea appears to be very difficult."

The idea for HANUL, which stands for High-Energy Astrophysics Neutrino Laboratory but also means "sky" in Korean, came from Wonyong Lee, a Korean-born physicist at Columbia University. The telescope would have employed an unusual aboveground detector smart enough to pick out neutrinos—chargeless and nearly massless particles that can flow through matter like sunlight through glass—that are produced by exploding stars, black holes, and other sources in the distant universe from background noise. In addition to complementing existing experiments in Japan and under the South Pole, HANUL was seen as a way to draw international scientists to Korea and expose local students to cutting-edge research. "The idea was to do something in Korea," says Lee.

But Lee, who came to the United States in 1953 as a college student and has been at Columbia since 1962, is a U.S. citizen, and Korean rules bar foreigners from working as PIs unless they are employed by a Korean institution. So he and his colleagues invited Jin Sop Song, a physicist at Gyeongsang National University in Chinju, to be the PI and recruited other Korean scientists. In late 1997 the team won a $350,000, 2-year grant from the Korea Science and Engineering Foundation (KOSEF) to develop a prototype detector (*Science*, 6 February 1998, p. 802).

Scrap metal. The Korean government has shelved Wonyong Lee's plan to build an aboveground neutrino telescope. A piece of a prototype detector is shown above.

CREDITS: (TOP TO BOTTOM) W. LEE; HANUL/GYEONGSANG NATIONAL UNIVERSITY

The arranged marriage quickly turned sour, however. Observers say there was considerable friction between Lee, who spent a sabbatical year at Seoul National University overseeing the scientific collaborations and the experimental apparatus for a prototype, and Song, who was responsible for overall project management, including finances. Lee says that he chose Song not principally for his knowledge of physics but because he was a Korean citizen with few enemies, and observers say that at meetings Lee assumed the role of project leader. Song and others, according to observers, believed that Lee was acting "too American" and that his blunt style of speaking antagonized people. Song showed his displeasure in small ways, for example, by convening a meeting while Lee was in the United States and sticking to rules that blocked the flow of money to Seoul National, where Lee was working on detector components.

Outside forces were also at work. Government policies also hindered the transfer of money to U.S.-based groups working on parts of the prototype and a visit from a team of Russian scientists. "I couldn't build a home base in Korea," says Lee. "Even setting up an apartment was extremely difficult."

Scientific disputes about the design of HANUL further clouded the picture. HANUL was expected to observe rare collisions between neutrinos and atoms in small tanks of water. Such interactions spawn charged particles called muons, which generate flashes of light as they dart through the water. HANUL would measure the energy of the muons by seeing how much a strong magnet could force them off course. The energy levels, in turn, would let the investigators distinguish muons coming from nearby background radiation from muons spawned by far-traveling neutrinos.

But Haeshim Lee, an astrophysicist at Chungnam University in Taejon and head of the telescope's theoretical division, doubted that HANUL would work, and some experimentalists worried that the magnets would be too costly to build. Haeshim Lee aired his doubts in an angry letter circulated among scientists and government officials in June 1998 and later quit the project. (A toned-down version of his critique was published in the Korean Physical Society's monthly journal in September 1999, prompting coverage of the affair last month in an online newsletter, *Korean American Science and Technology News*, published by Moo Young Han, a physicist at Duke University.)

Worried about the status of the project, KOSEF called an emergency meeting in April 1999. Lee and other division heads urged agency officials to replace Song and to give the project greater flexibility. KOSEF declined to act on Song's status, with one official explaining that "we manage the research budget, not the team itself." But in June it cut off funding for HANUL, noting that the scientists had not chosen where to assemble the prototype and could not meet an August deadline for its completion.

"I don't know what to say. I'm just so disappointed," says Jewan Kim, a physicist at Seoul National University who had helped build support for HANUL. "We had many meetings, but people just don't agree. There's nothing you can do about it." Song blames the project's failure on disagreements over physics and cost, on stifling bureaucratic requirements, and on a "lack of warm personalities."

Others regret the loss of a chance to explore neutrino energies in a range between those covered by two other major experiments, the massive Super-Kamiokande underground water detector in Japan and the larger but less acute AMANDA project in Antarctica, which monitors a huge volume of ice. "The HANUL project was trying to make a bridge between these two techniques. It certainly was worthwhile," says Francis Halzen, a physicist at the University of Wisconsin, Madison, and a co-PI for AMANDA.

Five months after losing funding, Lee still hopes to resurrect HANUL elsewhere and somehow include Korea in it. He says that the experience leaves him eager to find international collaborations that can improve Korea's academic environment: "Korea needs more pure research projects so that young people can learn to think for themselves. I thought that, in a small way, I could accomplish that. But I guess the project came a little too early."

—MICHAEL BAKER

Michael Baker is a writer in Seoul.

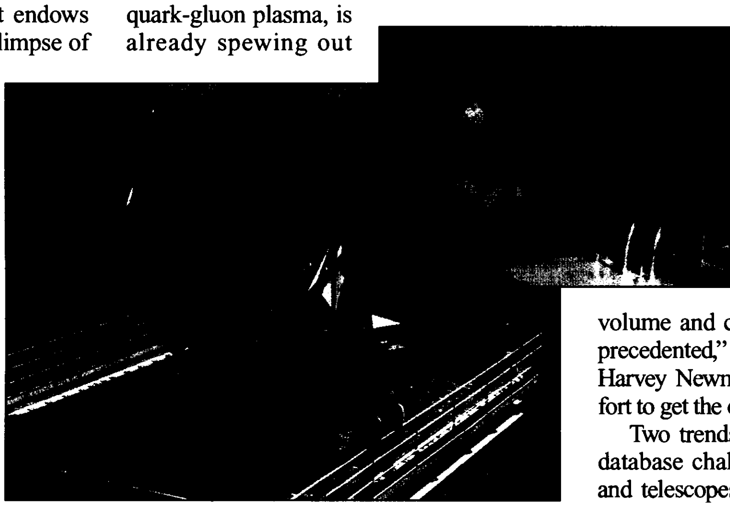
COMPUTER SCIENCE

Physicists and Astronomers Prepare for a Data Flood

New accelerators and sky surveys that will spew data by the terabyte are spurring a search for new ways to store and disseminate the flow

The end of a millennium is a time for warnings, and some scientists are joining in: They are predicting a flood. But unlike most millennial doomsayers, the scientists are looking forward to being inundated. Their flood is a torrent of data from new physics and astronomy experiments, and they hope it will sweep some long-awaited treasures within reach, such as the Higgs boson, a hypothetical particle that endows everything else with mass, and a glimpse of life-supporting planets in other solar systems. The greater the torrent of data, the better the chance that scientists will pull these and other prizes from it—providing they can find ways to store and channel the flow.

The quantities of data expected in the next decade will be staggering. Planned experiments at the Large Hadron Collider (LHC), a giant particle accelerator due to be up and running in 2005 at CERN, the European particle physics center near Geneva, "will write data to a disk-based database at a rate of 100 megabytes per second," says Julian Bunn of the California Institute of Technology's (Caltech's) Center for Advanced Computing Research, "and we expect these experiments to run for 10 to 15 years." That is over 100 petabytes of data, roughly the equivalent of 10 million personal computer hard disks. (A petabyte is 10^{15} bytes.) RHIC, an accelerator at Brookhaven National Laboratory in Upton, New York, that collides heavy nuclei to create a primordial state of matter called quark-gluon plasma, is already spewing out data at a rate of nearly a petabyte a year—about 1000 times the volume of data in the largest biological databases.



Data maw. The Sloan Digital Sky Survey's 2.5-meter telescope at the Apache Point Observatory in New Mexico. In the inset, astrophysicist Rich Kron adjusts optical fibers that feed light to instruments analyzing light from many objects at once.

Astronomy is contributing to the torrent as well. Johns Hopkins University astrophysicist Alex Szalay expects the Sloan Digital Sky Survey (SDSS), which aims to image 200 million galaxies and measure distances to a million of them, to produce about 40 terabytes of information. (A terabyte is 10^{12} bytes.) Several planned sky surveys at other wavelengths, such as radio and infrared, will contribute tens of terabytes more.

Organizing the data and making them available to the global community of scientists without swamping computers or networks will require rethinking the ways data are stored and disseminated. Researchers at institutions including Johns Hopkins, the Fermi National Accelerator Laboratory (Fermilab), Caltech, and Microsoft Corp. are now doing just that. By sorting the data as they flood in and dynamically reorganizing the database to reflect demand, they hope to provide prompt, universal access to the full data archives. "The volume and complexity of the data are unprecedented," says Caltech particle physicist Harvey Newman. "We need a worldwide effort to get the computing capacity."

Two trends have converged to create the database challenge. New particle detectors and telescopes are starting to rake in data at an unprecedented rate. And the experiments themselves have ever larger numbers of far-flung, data-hungry collaborators. The full data sets will have to be stored in central

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