tion, Carol L. Brown of Memorial Sloan-Kettering Cancer Center in New York City received calls from an estimated 75 percent of her patients who were in remission for ovarian cancer, asking about the test. But, as Brown told them, it is "not something that's going to be a commercially available test for, I think, many, many years—if at all," she says.

That's because, surprisingly, the ability to find all cases of cancer is not the best way to judge the value of a screening test. To calculate the likelihood that a positive test indicates cancer, epidemiologists use an equation that includes the test's sensitivity (how well it finds cancer when it is there), its specificity (its ability to diagnose healthy patients accurately) and the disease prevalence. The sensitivity of the new test is 100 percent, the specificity is around 95 percent (63 of 66 healthy patients found), and ovarian cancer occurs in only one in 2,500 women who are older than 35 years in the U.S. each year. Plugging those numbers into the equation shows that for every woman who gets a positive proteomics test result, there is a less than 1 percent chance she has the disease.

If a screened woman gets a positive result, her doctor conducts further analyses, such as a laparotomy, a surgery that opens the abdomen to explore for disease. In public health terms, subjecting 100 women to the anxiety, expense and risks of surgery to find cancer in just one patient is unacceptable. But the only value in the equation that can be improved is the specificity, which is already quite high. Ironically, increasing the test's specificity may mean lowering its overall accuracy, explains Sudhir Srivastava of the National Cancer Institute; in other words, the test would be capable of "finding" cancer in healthy people. But even if little tweaking of the numbers is possible, researchers may be able to give the test to women who are more likely to develop ovarian cancer, such as those with a family history of the disease. "It may be that in the high-risk population, these numbers are approaching acceptability," says Martee L. Hensley of Sloan-Kettering.

There is additional concern that other institutions may not be able to repeat the procedure using their own equipment and software. The unidentified proteins and protein fragments that make up the *Lancet* fingerprint are so small that any slight variations between machines, algorithms or the solutions used to prepare blood samples may skew the results. "So if you ran samples three months ago and got beautiful results, can you repeat that three months later, and can you repeat it on different instruments?" asks George L. Wright of Eastern Virginia Medical School.

Despite the reservations, these results may herald a future in which tests use multiple, not single, biomarkers to spot disease. Researchers are looking at patterns that may identify prostate and breast cancer, among others. Given the heterogeneity of cancer, this approach makes intuitive sense. Declares Wright: "One marker will not be found to improve the early detection, diagnosis, prognosis of any cancer or disease."

Alison McCook is a science writer based in New York City.

TO SCREEN OR NOT TO SCREEN?

Some screening techniques are facing increasing controversy. Experts debate whether mammography and PSA testing hurt more people than they help by detecting cancers at too early a stage, when it is unclear if the disease is benign or requires treatment. A study in the April 4 *New England Journal of Medicine* found that about two thirds of one-year-olds whose urine tests came back positive for neuroblastoma actually had completely harmless tumors.

But testing rates for most cancers remain high, says William C. Black of Dartmouth-Hitchcock Medical Center, because managed care physicians do not have the time to explain the nuances of screening and all are afraid of being sued by cancer patients who did not receive the test. And in the end, doctors can never be sure which patients treated for the disease could have postponed or even avoided the medical intervention. "Ironically, the people who are harmed by the overdiagnosis become the most vocal advocates for screening," Black remarks, "because they think, of course, they've been saved."

WASTE DISPOSAL

Divide and Vitrify

PARTITIONING NUCLEAR WASTE SAVES SPACE, BUT IT ISN'T EASY **BY STEVEN ASHLEY**

The tons of toxic waste left over from nuclear weapons production—including plutonium, uranium, cesium and strontium isotopes, as well as the now radioactive processing additives—sit unremediated in belowground storage tanks and bins at three U.S. Department of Energy sites. Even if the controversial "permanent disposal" effort at the Yucca Mountain repository in Nevada proceeds, there still will not be sufficient room to hold the entire mess.

To cram the waste into what space eventually opens up, nuclear scientists and engineers have been working on various methods to segregate the extremely dangerous wastes from the merely hazardous ones. The idea is to reduce the quantity of the most deadly high-level waste that must be buried, allowing the less threatening low-level waste to be consigned to cheaper belowground storage facilities nearer the surface. Separating out the highly radioactive materials also allows engineers to control the radioactivity and heat generated in the glass media that would store the waste, boosting the safe capacity of storage repositories.

But dividing the bad from the not-as-bad has not proved simple. The DOE sites—namely, Savannah River in South Carolina, Idaho National Engineering and Environmental Laboratory (INEEL) and Hanford in Washington State—store various types of nuclear waste that require specially tailored separation technologies.

TOXIC BREW of radioactive waste lies just 10 feet below technicians working to replace a pump in a million-gallon storage tank at the Hanford site in Washington State.

DEPARTMENT OF ENERGY OFFICE OF RIVER PROTECTION

"When the Bush administration first arrived, it called for a review of the DOE's entire $300-billion Environmental Management program, which had been planned to run until 2070," explains Mark A. Gilbertson, director of the DOE's Office of Environmental Management. "As much as 50 percent of the cost of disposing of high-level waste is tied to pretreating it or the subsequent immobilization of it." Last year, Gilbertson says, his office spent about $16 million to find ways to hike the efficiency of nuclear waste handling and lower the environmental risks.

At the Savannah River site, where the bomb waste is highly alkaline, engineers had been removing cesium 137 from the soluble portion of the tank wastes through chemical precipitation. Unfortunately, that approach had to be halted because the process liberated flammable benzene gas. Bruce A. Moyer, group leader for chemical separations at Oak Ridge National Laboratory, and his team have developed a safer alternative that may soon be adopted. In their procedure, expensive "designer" solvent molecules called calixarenes selectively glom on to cesium, allowing it to be removed from the liquid. The cesium would then be stripped off chemically from the calixarene molecules, which could then be reused.

Meanwhile the nonsoluble sludge still in the tanks, which contains strontium 90 and transuranic elements (a mix of radioactive species heavier than uranium), would be washed with sodium hydroxide to remove bulky constituents such as aluminum, thus reducing the total mass. The sludge would at this point be added to the extracted cesium, and the mixture would be vitrified (turned into stable borosilicate glass logs) encased in stainless-steel canisters and then entombed.

Things are somewhat different at the Idaho facility, where the nuclear waste is stored in bins in the form of an acidic granular solid called calcine. Although technologies exist to separate the cesium, strontium and transuranics, each requires its own procedure, raising costs and slowing throughput, says R. Scott Herbst, consulting engineer at INEEL. Looking for a better option, INEEL scientists are studying a single-step chemical extraction process that is conceptually not unlike the Oak Ridge technique. Developed at the V. G. Khlopin Radium Institute in St. Petersburg, Russia, the procedure employs three compatible solvents that act simultaneously. "We still don't understand how this unitary process works, but it's worth following up since it would be substantially cheaper than the previous three-step procedure," Herbst states.

Hanford has the most complex hot refuse: it consists of a mix of wastes from many nuclear fuel reprocessing projects. Engineers are currently planning a two-stage ion exchange process to extract radioactive cesium and technetium from the soluble part of the alkaline tank waste. In this process, columns of polymer resin beads attract the harmful elements, which are later removed from the beads with acid.

A still speculative method may supplant that approach, however. Since 1998 Archimedes Technology Group in San Diego has been developing a filtering method that works via atomic mass rather than chemical properties. The technique, which borrows from fusion energy research, takes advantage of the fact that 99.9 percent of the radioisotopes in the waste are heavy elements, says company head John R. Gilleland. Radio waves would vaporize the waste, which would then be sent into a magnetic bottle containing a thin, trapped plasma. A radial electric field would then cause the plasma and most of the waste ions to "orbit" along a spiral path inside the

TAKING OUT THE NUCLEAR TRASH

The Department of Energy is trying to speed up the process of high-level waste disposal. In March the Bush administration committed an additional $450 million beyond the $2 billion already budgeted for 2003 as part of a scheme to halve the planned 70-year cleanup time at the Hanford site. Construction is slated to begin late this year on a giant vitrification plant to convert around 10 percent of Hanford's highly radioactive waste into borosilicate glass logs, which would be buried deep underground for 10,000 years or more.

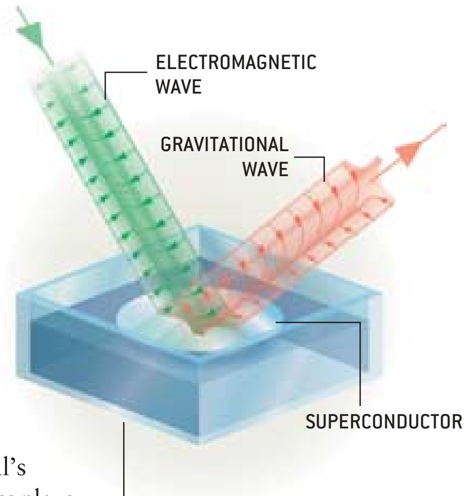
cylindrical chamber. Ions below a certain mass would be confined to the magnetic field lines and travel to the ends of the chamber; the specially tuned magnetic field, however, could not hold the heavier ions (namely, the radioactive species), which would drop to the sidewalls for later removal. The Archimedes filter should be a high-throughput process, thereby saving time and money, but testing of a full-size prototype will not be done until 2003.

Splitting the atom has resulted in many long-term political, environmental and management headaches. Splitting the waste promises to offer a bit of relief.

PHYSICS

A Philosopher's Stone

COULD SUPERCONDUCTORS TRANSMUTE ELECTROMAGNETIC RADIATION INTO GRAVITATIONAL WAVES? BY GEORGE MUSSER



GRAVITY TRANSDUCER would reflect incoming electromagnetic radiation (*green*) as gravitational waves (*orange*). The radiation must be polarized in a so-called quadrupole pattern.

Raymond Chiao remembers the day, during his childhood in Shanghai, when his brother built a crystal radio set and invited him to try it. "When I put the earphones on, I heard voices," he says. "That experience had something to do with my going into physics." Chiao has since become well known for his work in quantum optics at the University of California at Berkeley. Now he is preparing an experiment that, if it works (a not insubstantial if), would be the biggest invention since radio.

Chiao argues that a superconductor could transform radio waves, light or any other form of electromagnetic radiation into gravitational radiation, and vice versa, with near perfect efficiency. Such a feat sounds as amazing as transmuting lead into gold—and about as plausible. "It is fair to say that if Ray observes something with this experiment, he will win the Nobel Prize," says superconductivity expert John M. Goodkind of the University of California at San Diego. "It is probably also fair to say that the chances of his observing something may be close to zero."

Chiao presented his hypothesis at a March symposium celebrating the 90th birthday of Princeton University physicist John Archibald Wheeler (the paper is available at arXiv.org/abs/gr-qc/0204012).

His analysis, like most discussions of gravitational radiation, proceeds by analogy with electromagnetic radiation. Just as changes in an electric or magnetic field trigger electromagnetic waves, changes in a gravitational field trigger gravitational waves. The analogy is actually quite tight. To a first approximation, Einstein's equations for gravitation are a clone of Maxwell's equations for electromagnetism. Mass plays the role of electric charge, the only difference being that its value must be positive (at least in classical physics). Masses attract other masses via a "gravitoelectric" field. Moving masses exert forces on moving masses via a "gravitomagnetic" field. Gravitational radiation entwines gravitoelectric and gravitomagnetic fields.

Over the years a number of physicists have suggested that if a superconductor can block magnetic fields—giving rise to the famous Meissner effect, which is responsible for magnetic levitation over a superconductor—then it might block gravitomagnetic fields, too. When Chiao adds the gravitomagnetic field to the standard quantum equations for superconductivity, he confirms not only the gravitational Meissner-like effect but also a coupling between the two breeds of magnetic field. An ordinary magnetic field sets electrons in motion near the surface of a superconductor. Those electrons carry mass, and so their motion generates a gravitomagnetic field.

Thus, an incoming electromagnetic wave will be reflected partly as a gravitational wave, and vice versa. The same should occur in any

MAKING WAVES

Like an ordinary magnetic field, a gravitomagnetic field exerts a force on moving masses at right angles to their velocity. The rotating earth, for example, generates a gravitomagnetic field that torques satellite orbits, as observations over the past several years have confirmed. The Gravity Probe B satellite, scheduled for launch early next year, should precisely measure this effect, which is also known as the Lense-Thirring effect, or "frame dragging."

Even if Chiao's contraption works, it wouldn't allow the generation of antigravity fields, as Russian materials scientist Eugene Podkletnov, then at Tampere University of Technology in Finland, controversially claimed to have observed in 1992 (see www.sciam.com/askexpert/physics/physics29a.html). Antigravity requires canceling out a powerful, static gravitoelectric field, yet superconductors have no effect on such fields.

SAMUEL VELASCO