that," says Allen, who with Seaman helped organize a conference last fall to discuss implications of abandoning leap seconds (see http://futureofutc.org).

Assessing the implications

At the ITU-R meeting, countries were closely split in favor of, against, and undecided about abolishing leap seconds, with many of the undecided ones saying they were not well enough informed to vote on the proposal. Keeping Earth time and atomic time coordinated has legal, philosophical, financial, and political implications. The UK, for example, which wants to keep leap seconds, has a historic relationship to Greenwich Mean Time, for which UTC is a close approximation. Other countries that wanted to retain leap seconds included Canada, China, and Germany. France, Italy, Japan, South Korea, and Mexico were among those joining the US in preferring to abolish them.

Abolishing leap seconds would have "monumental implications," says David Finkleman of the Center for Space Standards and Innovation, the research arm of Analytical Graphics Inc. Before the ITU-R meets to consider doing so, "we need a more comprehensive and inclusive assessment of the problems people have, why they have them, and how and if they can be fixed."

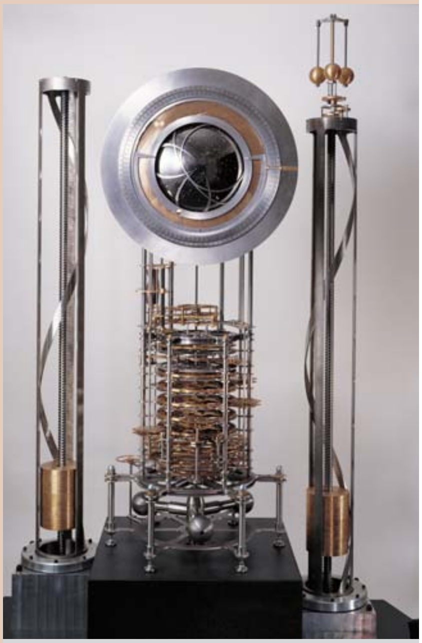
In Allen's view, both sides in the debate over leap seconds exhibit "the technical equivalent of psychological denial. There are a lot of people who are not recognizing the big picture."

Toni Feder

Time for the future

Imagine a clock that keeps time for thousands of years. It ticks every 10 seconds, chimes once a millennium, and self-corrects for variations in Earth's rotation. Such a clock is inventor Danny Hillis's dream, and it's coming alive inside a mountain in West Texas. "I got tired of only working on projects that were rush rush rush to get something done quickly. I wanted to work on something that mattered over the longer term," says Hillis, cofounder of the research and development company Applied Minds. He says the clock is like a time capsule, in that it reaches out to connect with the future.

Nestled in a 150-meter-deep shaft 3.7 meters in diameter, the clock will have a 3-meter, 110-kg titanium pendulum. It will be powered by stainless-steel bellows right below ground that expand and contract as the ambient temperature rises and falls each day. Five-ton weights that hang in the shaft are pulled upward when fed energy from the bellows; it is the weights that require such a long shaft. Visitors will also be able to hand wind the clock.



This 2.4-meter prototype to test some mechanisms for a larger 10 000-year clock chimed at the turn of the last millennium and now stands in the London Science Museum. (Rolfe Horne, courtesy of The Long Now Foundation, http://www.longnow.org.)

The 10 000-year clock will count days with the pendulum and keep on track by noting the Sun's highest position every clear day through a sapphire window to the sky. The clock sets itself to solar noon by checking against a specially shaped cam that encodes the calculated daily time of the Sun's transit for the next 10 000 years. If the Sun is obscured—even for a century or more—the clock can make up for it in intervals of five minutes per clear day.

"When you get into the details, it causes you to think about time differently," says Hillis. For example, leap seconds are important "when you are designing a clock to last 10 000 years." The clock would be off by as much as 30 days at the end of that time if the uncertainties and variability in the length of the day were ignored, he says. (See the story on page 27.) "Global climate change seems like an abstraction, but then you realize that if the worst projections are right, the ice caps will melt and the Earth will spin a little faster, and that makes a difference for how the clock reads. I have to take that possibility into account."

The clock's roughly 10 000 parts will be made from titanium, high-molybdenum stainless steel, ceramics, and other stable materials. "We have pieces of metal, flexures, that bend. We have to make sure they can bend a billion times," says Hillis. "We have to make windows that will stay transparent." Aside from the materials problems, the biggest challenge is aesthetics, he says. "How do you design something that people understand and care about even when the culture changes?"

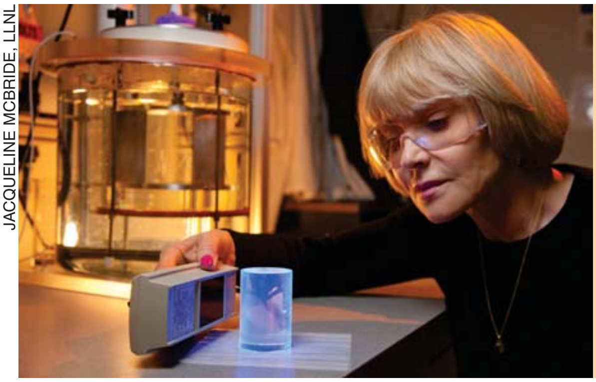
To save energy, the clock will display the time only when asked by a visitor. Those who make the trip to the remote site will be able to climb a long spiral staircase along the shaft wall. They will be able to make the clock chime—a different melody every time. In another mechanical feat, the current positions of the planets and the phase of the Moon will be displayed in one of the clock cavern's chambers; the calculations for the positions of the planets were made by Jon Giorgini of NASA's Jet Propulsion Laboratory.

Hillis's vision of a 10 000-year clock inspired others, and in 1996 the nonprofit Long Now Foundation was formed to oversee the project. Amazon.com founder Jeff Bezos is the multimillion-dollar clock's biggest sponsor. The shaft for the Texas clock was drilled last year, and although design problems remain, Hillis says, "we are physically constructing big pieces. Certainly the clock will be built in my lifetime. That's my ultimate deadline."

Toni Feder

New plastic detects weapons materials

Researchers at Lawrence Livermore National Laboratory (LLNL) have developed an inexpensive, nonhazardous plastic for detecting the neutron signatures of nuclear weapons–usable materials. Capable of efficiently distinguishing neutrons from gamma rays, the new polymer scintillator is expected to make practical for the first time handheld radiation detectors for international inspections of uranium enrichment plants and nuclear power reactors. The material could also replace or supplement existing neutron detectors in radiation portal monitors that use scarce helium-3. (See PHYSICS TODAY, May 2011, page 20.)



JACQUELINE MCBRIDE, LLNL

Natalia Zaitseva examines the new plastic developed at Lawrence Livermore National Laboratory. The instrument she holds produces UV light that causes the material to glow blue.

Although plastic scintillators have long been used to detect ionizing radiation, until now scientists did not believe it possible to formulate a plastic that could discriminate neutrons from the far more plentiful gamma rays. Unlike ^{3}He detectors, which pick up thermal, or low-energy, neutrons, the polymer developed at LLNL scintillates with high-energy neutrons, the type emitted by the fissile isotopes uranium-235 and plutonium-239. David Beach, program manager for special nuclear materials movement, radiation detection, and advanced materials at the National Nuclear Security Administration, says those fast neutrons can "punch through" significant amounts of shielding and are detectable up to tens of meters away from their source. Moreover, since the background level for fast neutrons is two orders of magnitude lower than that of thermal neutrons, detecting just a few fast ones, Beach notes, is sufficient to indicate the presence of weapons-usable materials.

Eljen Technology, which manufactures organic scintillators and has produced samples of the plastic for LLNL, is now working to scale up the manufacturing process. An LLNL spokesman says Eljen, located in Sweetwater, Texas, is in licensing negotiations, and two other companies have also expressed interest in licensing the technology.

According to Beach, portal monitors containing the new material could be ready for testing within two years, with handheld detectors to follow. Natalia Zaitseva, the principal investigator on the LLNL team, is confident that the material will also find broad applications in neutron imaging and other scientific applications. "For scientific experiments, it will definitely replace all liquid scintillators," she predicts.

Zaitseva says that scientists who work with neutrons have been contacting her ever since the research was published online in December in the journal *Nuclear Instruments and Methods in Physics Research A*. The paper details how the LLNL team developed a polyvinyl toluene polymer matrix loaded with a scintillating dye, 2,5-diphenyloxazole (PPO). The research team describes how the relative ease of fabrication and the deployment advantages of the plastic compared to liquid scintillators make it suited for use in "large-volume and low-cost neutron detectors."

"The most important part of our work is to show that plastics are capable of doing this," says Zaitseva. For scintillation to occur, she explains, neutrons must interact with two PPO molecules in the plastic's matrix. The team achieved the right distance between the two molecules for scintillation by iteratively increasing the concentration of PPO until the threshold was reached. Zaitseva's team is now striving to develop a plastic that will detect thermal neutrons, the kind that are picked up by the ^{3}He tubes in most portal monitors now in use.

David Kramer

news notes

Reactor resurgence. On 9 February the US Nuclear Regulatory Commission (NRC) approved construction of the nation's first new reactors since 1978. Two Westinghouse AP1000 pressurized water reactors, to be built near Augusta, Georgia, are the first to receive approval under the NRC's new, speedier licensing scheme. Implemented by the Bush administration in 2007, the scheme combines both construction and operational licenses.

Gregory Jaczko, NRC chairman, had indicated reservations about the current licensing procedures in a speech at the annual Platts Nuclear Energy conference just hours before the NRC's 4 to 1 vote was taken. Jaczko cast the sole dissenting vote. In his speech, he asked whether the industry should develop more detailed risk analysis for events such as last year's accident in Fukushima (see PHYSICS TODAY, May 2011, page 18). "We have done a great job of reducing the number of smaller accidents," he said, "but what [Fukushima] tells us is that we have not done enough to prevent the significant accidents."

Assuming legal challenges by environmental groups do not halt construction, the first of the new reactors will come online in 2016, and the second a year later. Another 20 reactors are going through NRC's review process, but few are expected to be built. Two AP1000 reactors are under construction in China. **PKG** ■