

Institute president and CEO Marvin Fertel said, “The industry acknowledges DOE’s parallel development of a consolidated interim storage facility for commercial reactor fuel in a willing host community and state, and a separate repository for defense waste. These must be developed in the same time frame.”

A nuclear waste fund meant to pay for a geologic repository holds around \$30 billion collected from utility ratepayers and from interest. Since 1998, when DOE failed to meet the statutory deadline to begin accepting the waste, taxpayers have paid another \$2 billion or so in compensation to nuclear plant operators for their ongoing storage costs.

David Kramer

Naval reactors in need of redesign

Nonproliferation concerns should propel US Navy to switch to safer nuclear fuel, says FAS task force.

For its next-generation submarines and aircraft carriers, the US Navy should develop nuclear reactors that do not require highly enriched uranium (HEU) fuel. That recommendation comes from a new report by a task force commissioned by the Federation of American Scientists (FAS), a think tank on nuclear defense issues. Beginning no later than fiscal year 2017, Congress should increase funding for the Office of Naval Reactors program at the Department of Energy, says the FAS re-

port. That deadline would provide sufficient time to develop a low-enriched uranium (LEU) power plant for boats that will succeed today’s *Virginia*-class attack subs.

Construction of the next-generation boats is expected to begin around 2032. The *Virginia*-class subs are the first series to have reactors that don’t require refueling for the ships’ lifetimes, which are set for 33 years.

The report, *Naval Nuclear Propulsion: Assessing Benefits and Risks*, also recommends that at the 2016 nuclear security summit the US and UK declare their intention to investigate the feasibility of opening their naval fuel cycles to international safeguards.

The use of HEU for warship propulsion reactors not only poses the risk of the fuel’s diversion to weapons use during fuel fabrication and transport, but also creates a potential cover for nonweapons states such as Iran to produce weapons-grade material. Iranian officials have discussed enriching uranium to 60% uranium-235 for naval use. HEU is considered to be at least 20% ²³⁵U. Weapons-grade uranium is generally considered to be 80% or more ²³⁵U. A loophole in the Nuclear Non-Proliferation Treaty exempts HEU produced for naval propulsion from the scrutiny of inspectors from the International Atomic Energy Agency.

Sowing the seeds

No one from the Office of Naval Reactors responded directly to the FAS report; instead, officials there pointed to the office’s January 2014 report to Congress on the feasibility of LEU power plants. That document stated that while

a suitable LEU reactor might be built, its development would require 10 to 15 years and \$2 billion in additional funding. At least another 10 years would be required to deploy it on ships.

Brazil and other nations that aspire to build nuclear-fueled warships present another proliferation risk: “If states want their own nuclear navies they will likely want or need to have their own enrichment plants, thus sowing the seeds for potential future nuclear proliferation, or at least greatly challenging efforts to safeguard many more plants,” the report states.

The US Navy has the world’s largest nuclear-powered fleet, comprising 10 aircraft carriers and 72 submarines. Because of its high neutron flux, HEU allows for the building of compact reactors and thus provides a strong incentive for the navy to continue using it. The US and UK navies are believed to use weapons-grade uranium, enriched to more than 90%, according to the report. India’s and Russia’s navies also use HEU, though their enrichment level likely isn’t as high.

China is believed to use LEU in its nuclear-powered subs. And France’s navy converted from HEU to LEU fuel beginning in the 1990s.

In a paper commissioned by the FAS task force, Alan Kuperman of the University of Texas at Austin said the navy would likely require nearly the same time and resources to develop either an advanced HEU-fueled or an LEU-powered reactor for the replacement subs.

Globally, naval propulsion consumes an estimated 3 metric tons of HEU annually, enough for more than 100 weapons, according to the Kuperman paper. Navies account for about three-quarters of total worldwide usage of HEU.

Physics issues

A second FAS-commissioned paper, by Alireza Haghighat of Virginia Tech and colleagues, cautioned of unintended consequences from using LEU-fueled reactors. Two separate physics issues with LEU cores—the addition of a fuel effect in the reactivity feedback mechanism and xenon poisoning—would necessitate operator intervention, such as the withdrawal of control rods, when the reactor power changes. Neither issue occurs with an HEU core, the Haghighat paper states, so no operator intervention is required.

An LEU reactor of size and power comparable to the HEU version would likely require refueling, which presents the risk of radiation exposures and acci-



The *Virginia*-class attack submarine USS *Mississippi* arrives in Pearl Harbor. Office of Naval Reactors officials say the development of a reactor fueled by low-enriched uranium for the next-generation attack sub to succeed the *Virginia*-class would require 10 to 15 years and \$2 billion.

US NAVY/STEVEN KHOR

dents, warn Haghighat and colleagues.

The FAS report recommended further in-depth examinations of the issues raised in the Haghighat paper.

David Kramer

news notes

HAWC inauguration. With its 300th detector tank in place, the High-Altitude Water Cherenkov Observatory (HAWC) marked its completion on 20 March. Located at an altitude of 4100 m on the flank of the Sierra Negra, an extinct volcano east of Mexico City, the observatory keeps a constant lookout for high-energy gamma rays; data-taking began in August 2013 with a partial array (see PHYSICS TODAY, October 2013, page 22).

HAWC detects Cherenkov radiation from charged particles speeding through its 190 000-liter tanks of water. The particles originate from high-energy (100-GeV to 100-TeV) gamma rays colliding with the atmosphere.

Among the HAWC goals are to map TeV sources in the Milky Way and detect transient emissions from active galaxies and other sources. Unlike most Cherenkov telescopes, which are more sensitive but can only observe small patches of the sky, “we look at the entire overhead sky, so we have a reasonable chance of catching a gamma-ray burst,” says spokesman Jordan Goodman of the University of Maryland at College Park. HAWC will also watch for signals

of dark matter in dwarf galaxies and of primordial black holes. It will collect about 2 terabytes of data each day.

The US–Mexico facility was completed on time and on budget, with the US ponying up about three-quarters of the \$14 million in construction and Mexico covering the rest. The HAWC collaboration includes scientists from 15 institutions in the US and 14 in Mexico, plus a few participants from Poland and Costa Rica. Images of the site are

updated roughly every 20 seconds at <http://www.webcamsdemexico.com> (click on Pico de Orizaba). TF

Job hunting for physicists. Physics professors often know little about career paths outside academia. And students may not know what jobs to look for or how to market themselves. A short and easy fact sheet sets out to help faculty and career counselors help physics bachelor’s recipients find and get jobs that use their skills. The guide is part of the Career Pathways Project conducted by the Education Division and the Statistical Research Center of the American Institute of Physics.

One challenge in the search is that job titles often don’t include the word “physics”; the fact sheet lists more than three dozen examples, from programmer to product manager. Another challenge is that hirers may not know what skills a physics graduate has.

The sheet encourages students to stress their specific skills and capabilities, rather than to rely on their degree qualification, to catch the eye of prospective employers. Typical abilities honed during the undergraduate physics experience might be critical thinking, inventiveness, problem solving, computer programming, and teamwork.

The fact sheet also includes a list of online databases to help physics bachelors in their job search. *Connecting Physics Students to Career Opportunities* is available at <http://www.aip.org/statistics/reports/fact-sheet-connecting-physics-students-career-opportunities>. TF ■



HAWC

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► Science and the Media

Journalist Fareed Zakaria argued in a recent *Washington Post* column that US educators focus too much attention on science, technology, engineering, and mathematics and too little on the humanities and liberal arts. Media analyst Steven Corneliussen examines Zakaria’s column and the criticism it attracted.



◀ The Dayside

In his blog, PHYSICS TODAY’s online editor Charles Day writes about three music albums each entitled *Physics*, an alternative approach to describing astronomical observations, and his search for physics at a festival devoted to the popular arts.

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