As seen in the December 2014 issue of **Nuclear News**

PRISM: Redefining the relationship with plutonium

by David J. Powell

The Power Reactor Inherently Safe Module (PRISM), GE Hitachi Nuclear Energy's high-energy (fast) neutron reactor design, has recently gained prominence as a contender to provide a solution to the disposition of the United Kingdom's plutonium stockpile, but the design itself has been in a fairly mature state for several years. It arose from work begun in the 1980s, and extends concepts that were developed starting in the 1950s. Before the newest chapter in PRISM's story is presented, the earlier chapters are summarized to provide some perspective on the current situation.

The story of PRISM dates to the development of the first fast reactors, with which General Electric has been involved since 1951, before its partnership with Hitachi. The work to support the nuclear reactor concept in submarines in the post–World War II era was followed in the 1960s with efforts to bring high-energy neutron technology into the commercial market. This work was focused on prototypes, such as the Experimental Breeder Reactor-II and the Southwest Experimental Fast Oxide Reactor, a sodium-cooled unit that was designed and built by GE for the U.S. Atomic Energy Commission.

In the 1980s and 1990s, through a program administered by the U.S. Department of Energy, GE led an industrial team that pursued commercial deployment of PRISM. The design drew upon three decades of experience with federally backed facilities, including the operation of EBR-II for 30 years. What emerged from this experience, and is embodied today in PRISM, is the safety and operational case for metallic fuel use in sodium-cooled reactors.

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Overview of the reactor

PRISM is a pool-type, metal-fueled, sodium-cooled fast reactor (SFR). It combines technologies that are proven, safe, and mature, with more recent innovations. The design includes passive safety features, employs digital instrumentation and controls, and would be built with modular fabrication techniques to expedite plant construction. Unlike the current generation of light-water nuclear reactors, PRISM uses metallic fuel, an alloy of zirconium, uranium, and plutonium. The fuel rods would be located in a pool of liquid sodium at atmospheric pressure, an arrangement that would ensure efficient heat transfer.

A PRISM module consists of the reactor vessel, reactor closure, containment vessel, internal structures, internal components, reactor module supports, and reactor core. The reactor vessel's outer diameter is 10 meters, and can be shipped by barge and overland transportation. The power level of the core is primarily limited by the shutdown heat removal capabilities of the passive safety systems, with its thermal output at 840 MW and its electrical output at 311 MW.

Two PRISMs are paired to form one power block, which supplies steam for one 622-MW turbine generator. A PRISM-based plant intended for the recycling of used fuel would be made up of six reactor modules and their associated steam generating systems, arranged in three identical power blocks. An unplanned outage in one PRISM module or power block does not affect the plant's electrical output as dramatically as it would in a large single-unit site. Plant electrical output can be tailored to utility needs by the modular addition of power blocks. The commercial PRISM plant, with three power blocks, has a peak electrical output of 1,866 MWe.

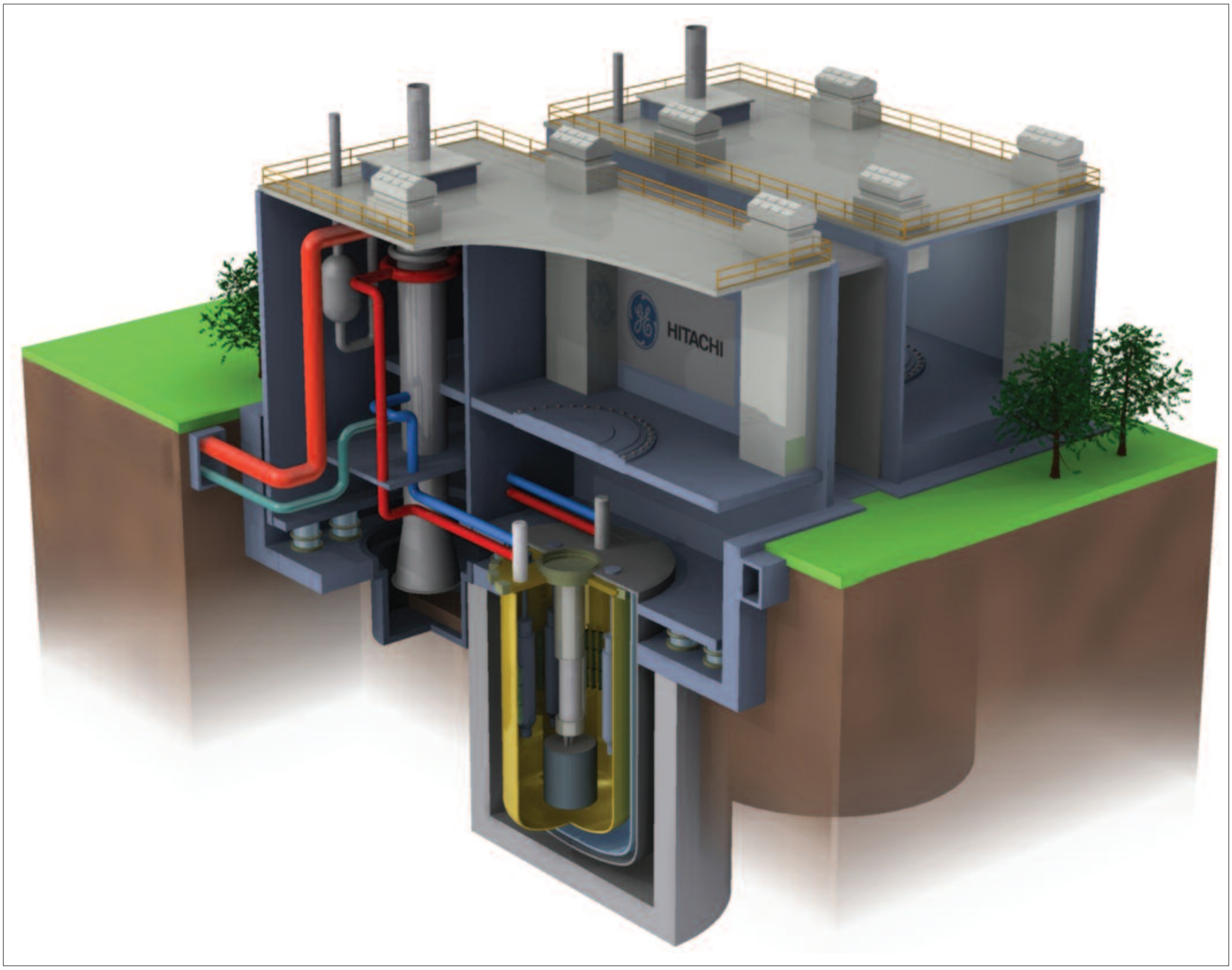
Benefits of PRISM

PRISM's passive safety systems can shut down the reactor, remove decay heat, and cool the containment without automatic or operator actions, eliminating the risk of a loss-of-coolant accident, and thus eliminating the need for many of the safety systems required in loop-type plants. This safety is made possible by the use of metallic fuel, a pool-type containment, and an appropriate level of peak thermal power.

GE Hitachi has often compared modular SFR plants to large monolithic plants, and concluded that PRISM's modular concept has several key features that make it more competitive. The modular approach allows the addition of generating capacity in stages, making construction arrangements more flexible and keeping supply growth in line with demand. Competitive cost is achieved through repeatable factory fabrication, which can improve quality, reduce cost, and shorten construction times. Furthermore, with the modular design and the lower thermal power, Class 1E safety-related emergency power requirements can be met by batteries, eliminating the need for costly emergency off-site or on-site electrical generators.

Benefits beyond electricity

Several new options, nuclear-powered and otherwise, can be pursued to add electricity generating capacity. What has brought new attention to PRISM is the prospect that it can also be used to meet another need: the resolution of the issue of excess separated plutonium in the United Kingdom. In January 2014, the U.K. Nuclear Decommissioning Authority (NDA) noted in a position paper, *Progress on approaches to the management of separated plutonium,* that based on the information provided, PRISM's fourth-generation nuclear power technology was considered a "credible option" for managing the nation's growing plutonium stockpile. The plutonium would become one of the components in the metallic fuel used in PRISM, and what ultimately



A partial cutaway rendering of a two-reactor PRISM block

results from PRISM operation would be material that is proliferation resistant.

In July 2014, GE Hitachi and Iberdrola Generación Nuclear S.A. entered into a cooperation agreement to work toward advancing PRISM technology as a long-term solution for the disposition of the United Kingdom's stockpile. The resulting combination of GE Hitachi's technology with Iberdrola's plant operations and power generation experience could further strengthen PRISM's position as a solution for plutonium reuse. Iberdrola and GE Hitachi are now discussing the potential roles and business arrangements for the joint work on PRISM.

Also, in November, the DOE announced a grant whereby GE Hitachi and Argonne National Laboratory will develop and modernize next-generation probabilistic risk assessment methodologies for PRISM.

As 2014 concludes, GE Hitachi continues to work with the NDA on a number of technical and commercial activities to further develop the shared understanding and refine the commercial proposal to deploy PRISM as a life-cycle solution for the accumulated plutonium.

The disposition challenge

The United Kingdom currently stores over 100 tons of civil (reactor-grade) plutonium at the Sellafield site in West Cumbria, representing the largest such quantity anywhere in the world. The amount is also growing, and is expected to reach 140 tons when reprocessing operations cease. There are real costs each year in the safe and secure storage of the plutonium. The widespread consensus is that storage cannot continue indefinitely, and that a long-term management solution is needed.

The NDA and the Department of Energy & Climate Change (DECC) have reviewed various options for permanent storage, and their clear conclusion is that plutonium reuse is the right answer for the country. Adrian Simper, director of strategy at the NDA, has stated that the current storage regime "is not a satisfactory end point. We must find a solution for dealing with this material. . . . We have significantly enhanced our understanding of the pros and cons of the different systems of disposing of U.K. plutonium, [but] it's too early to choose yet—this is a marathon, not a sprint" ("Delegates focus on use of plutonium," *News & Star*, Nov. 28, 2013).

Pu: Redefining the relationship

Viewing plutonium as a problem is understandable given the challenges that long-term storage poses, but plutonium is undoubtedly also an energy resource. That is why it was recovered in the first place. PRISM allows for maximizing the potential of plutonium's use as an energy resource by simultaneously processing plutonium and generating clean energy at a high level of efficiency.

Over its estimated 60-year operating life, a PRISM plant can deal with all of the stored plutonium oxide powder (including impure plutonium) with minimal need for chemical pre-cleanup or discharge of contaminants. Spent PRISM fuel could be recycled for complete consumption and elimination of the plutonium, or it could be given a more conventional disposal, as the spent fuel is virtually unusable for weapons proliferation purposes.

PRISM's design has been optimized to minimize the cost of fabricating the metallic fuel and to operate so that a relatively small plant size can consume the plutonium—and in shorter time, because of greater incorporation of plutonium in the fuel, and simplified fuel manufacturing and reactor construction processes (all of which reduce costs even further). PRISM could, therefore, conceivably make all of the United Kingdom's plutonium proliferation resistant in 30 years, which GE Hitachi maintains would be significantly sooner than any alternative. Meanwhile, as a resource, the plutonium can generate low-carbon baseload power for decades in the future, enhancing the United Kingdom's energy security and shrinking the country's carbon footprint.

PRISM's own footprint is also small, and the plant could be built near Sellafield and close to the existing plutonium storage facilities. This would eliminate the need for the transport of plutonium or plutonium fuels, and thus reduce proliferation risks and security threats. Based on the assumption of a single PRISM power block, GE Hitachi projects that PRISM would operate for 60 years at a peak power level above 600 MWe, while completing the mission of plutonium disposition. The technology's efficiency allows for a range of flexible commercial models, which are currently under discussion with the NDA to maximize value for British taxpayers.

Should the NDA elect to move forward with PRISM, the benefits could be huge. Aside from the immediate economic benefits, stemming from a plant's creating what could be thousands of permanent and construction jobs, the Cumbria coast would host the world's first use of a technology in which many other countries have expressed interest. The region's position as a global center of nuclear industry excellence would be reaffirmed and West Cumbria would be perfectly positioned to become a hub for the next generation of nuclear technology and R&D.

GE Hitachi has hosted a conference to introduce potential local suppliers to the PRISM concept, and has signed memoranda of understanding with the University of Manchester, the National Nuclear Laboratory, and the CAP (Costain, Arup & Pöyry) Alliance to work on further development of the effort to bring PRISM to Sellafield.

The choice is simple: Continue down the same path for used nuclear fuel that has been followed for the last 50 years, or develop an approach that brings the benefits of nuclear energy to the world while also reducing proliferation concerns of plutonium management. For the United Kingdom, the plutonium stockpile poses a unique challenge. For GE Hitachi, it presents a unique opportunity. PRISM offers an efficient, clean, and long-term answer to the problem of plutonium management.

For further information about PRISM, please visit GE Hitachi's website at <www.gehitachiprism.com>. NN