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Nuclear Power Plants on New Submarines May Last 40-Plus Years

January 21, 2015 | *National Defense Magazine*

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The Navy hopes to have the first replacement for the Ohio-class ballistic missile submarine on duty by 2031. When that vessel is launched, the onboard nuclear power plant is expected to last its entire 40-year service life.

That is seven years longer than the current reactors aboard U.S. submarines.

“Our goal for the new submarines is to have a life-of-the-ship reactor,” said Frank G. Klotz, National Nuclear Security Administration administrator and the Department of Energy’s undersecretary of nuclear security. NNSA is responsible for developing government-owned nuclear power plants.

There are two primary reasons the NNSA is undertaking the new core design, he told reporters in November.

“It is extraordinarily important on cost because one of the largest elements of the total operational cost of a submarine over its life has been replacing the core when that has come due. It is very expensive,” he said.

“The other aspect is that when you go into the deep overhaul that is necessary to replace the core, you’re taking a submarine out of service for a long time. So if you have a life of the sub or a life of the ship core, then you avoid both cost, and you avoid both extensive downtime as you refuel the reactor,” Klotz said.

The savings could be substantial.

Olivia Volkoff, a spokeswoman for the program, said: “Eliminating the refueling through insertion of a life-of-the-ship core allows the Navy to meet the strategic deterrent mission with two fewer SSBNs and saves about $40 billion in ship acquisition and lifecycle costs over the life of the program.”

The Virginia-class attack submarines were the first to have a core reactor designed to last the life of the vessel, which for it, is about 33 years.

The Ohio-class replacement submarines, which will carry the nation’s sea-launched nuclear missiles, will be considerably larger than the Virginia-class ships.

The NNSA and the Navy are facing a tight deadline for developing the new power plant. Fiscal year 2031 is when the fifth Ohio-class SSBN retires, which will leave the Navy with a force of nine ships. If the lead replacement is not ready to take over by that date, it would leave the Navy one below its mandated requirement to have at least 10, Rear Adm. David C. Johnson, program executive officer for submarines, said in a speech last year.

As the first ship in its class, it will need a three-year test-and-evaluation period to assess its performance, including shake down deployments to spot and then correct any shortcomings. There must be independent certifications of the readiness of the crew and weapon systems. That takes the timeline back to about 2027, he said.

It will take seven years to build the lead ship. That is an aggressive schedule given the Ohio-replacement will be the largest submarine ever built in the United States. That time frame is shorter than the previous three lead ship submarine builds: the Ohio, Seawolf and Virginia. The lead Virginia-class ship was 40 percent of the size of the Ohio replacement, and it took 86 months to build, Johnson noted.

In the next five and a half years, the program must execute the design phase, carrying out research and development and construction preparation activities. About 83 percent of the designs must be complete at the start of construction.

Under the New START Treaty, SSBNs will be responsible for approximately 70 percent of the nation's deployed nuclear warheads.

The program is now almost five years into development. The ship construction design phase is set to begin in 2017. The early stage work done in that period is crucial to deliver the first submarine on time and on budget, Johnson said.

The power plant program is progressing on time, Volkoff said. "Reactor design work is ongoing and in conjunction with reactor equipment procurement in fiscal year 2019 [and] supports a fiscal year 2021 ship construction start," she said in a statement.

This program leverages the ongoing work to refuel a land-based prototype at New York-based Knolls Atomic Power Laboratory's Kesselring site, where the NNSA carries out research and development for the program.

"We continue to work with our partners in the executive and legislative branches to ensure the program is supported," she said.

Bryan Clark, a senior fellow for the Center for Strategic and Budgetary Assessments, who served in the Navy as an enlisted and officer submariner and as chief engineer and operations officer at the Navy's nuclear power training unit at Goose Creek, South Carolina, said one of the Navy's goals with the Virginia-class attack submarines was to completely leave the business of refueling reactors.

“It is really expensive. It generates a lot of radioactive material that has to be disposed of and handled. So it was really a big burden on the Navy in terms of cost to have to refuel the reactors,” said Clark. Over the past few decades, the NNSA has made incremental progress making the reactors last longer. While it is responsible for developing and maintaining the reactors, the Navy must integrate them into the larger power plant.

The Sturgeon-class attack submarines had to refuel every eight years, or three to five times over its lifespan. The Los Angeles-class, the Navy’s next fast attack sub, refueld only once or twice over its 33-year lifecycle. The Virginia-class managed to do away with the process altogether, he noted.

Along with the high cost of refueling, which is anywhere from $600 million to $800 million, “It also saves the time that would have been lost when the ship is doing a refueling overhaul, which generally takes a couple of years,” he added.

There are only a few shipyards, Clark said, that can carry out refueling: Portsmouth Naval Shipyard, New Hampshire, Norfolk Naval Shipyard, Puget Sound Naval Shipyard and Pearl Harbor.

They are busy doing all the other refurbishment work required in the Navy, including long maintenance overhauls that have nothing to do with refueling, as well as carrier refueling and overhaul, Clark said. The yards are “jammed up and overwhelmed,” he said.

The shipyards are busy and behind on most of their work because some of the carrier overhauls have taken longer than the Navy anticipated, he said.

“Right now carriers are the priority so they always get pushed out as fast as possible, where the submarines often end up being the last in line,” he said. Refueling subs can take longer than two years because they become stuck back behind carriers, he said.

Nuclear power plants aboard submarines are the most expensive and difficult to maintain because of the tight space. To make them last longer, it requires more highly enriched uranium than what would be needed at a land-based plant, he added. Managing them is exacting work. Officers do not want a submarine to run out of fuel before the end of its service life.

Energy is created by the fission process, in which the fuel decays, creates heat, then steam, which turns the turbines. The process creates poisons as a byproduct, which pollutes the cell and makes it less efficient.

“Over the years you have to pull the rods out higher and higher to expose more of the fuel because the fuel on the bottom of the core gets used up, or all these fission products are keeping it from reacting efficiently,” Clark said.

“You will eventually be at the point where there are so many fission product poisons and the fuel used up enough where you’re not getting efficient fissioning, and the heat generation is not efficient and core has to be replaced,” he added.

Making the reactors last longer requires dispersing the poisons in the fuel cell in such a way that it minimizes their impact on the fuel, he said.

The Ohio-class replacement submarine will have some challenges if it wants to deploy with a power plant that lasts 40 to 42 years. That is almost 25 percent more efficiency than what the Virginia-class submarines possess, he noted.

“It is a bigger submarine, so it will require a bigger plant,” Clark added. “And that is a significant time increase in terms of how long the reactors have to run without being refueled,” he said.

Success will depend on how precisely engineers can place the fuel and other components inside the reactor in order to maximize the availability of the fuel before it gets clogged up with poisons and other byproducts, he said.

The NNSA has some advantages. There are technologies outside the world of nuclear fission that have advanced considerably since the 1990s, when the agency designed the Virginia-class nuclear power plant, Clark said.

“With nanotechnology you are able to precisely control the exact structure of the fuel cells. And with computer modeling and new processing power you can really look at this stuff at a high level of resolution and detail,” Clark said.

“Those two things will allow engineers to hand-tool the fuel construction in a way that is going to make it last a lot longer than previous generation’s power plants,” he said.