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The Versatile Test Reactor: Wasting Money While Undermining Nonproliferation Goals

In February 2019, U.S. Secretary of Energy Rick Perry announced the start of a project to build the Versatile Test Reactor (VTR). The VTR will be a type of research reactor known as a "materials testing reactor." The VTR will "produce neutrons to test how fuels, materials, components and instrumentation will perform if used in commercial power reactors."[2] The current project will develop the reactor's design, cost and construction schedule but the final decision to proceed with the VTR will not be made until 2022.[3]

When neutrons are released by fission, they have a high energy and are traveling at high speed. These are said to be "fast" neutrons. All commercial nuclear power reactors, as well as most research reactors contain a light material known as a moderator (usually either water, graphite, heavy water or zirconium hydride) which slows the neutrons. Such reactors are known as "thermal" reactors.[4] The VTR will not contain any moderator resulting in the reactor using fast neutrons and will be a fast reactor.

Fast reactors cannot use water as a coolant and the VTR will use liquid metallic sodium instead. The reactor could be fueled using 20% enriched uranium but the requirements for the VTR have been set in such a way that plutonium will be needed.[5] For the base case it is currently planned to use a metallic alloy as the fuel, which would be 20% plutonium, 10% zirconium and 70% uranium enriched to 5% (i.e. the uranium will be 5% U-235 and 95% U-238).

The U.S. Department of Energy (DOE) has said that the VTR is needed to develop and deploy what it has termed "advanced" nuclear energy technologies. DOE has said that these advanced reactor technologies could be deployed by 2030.[6] It has also said that these advanced nuclear reactor types will be developed "with or without the United States" and if the U.S. does not build

[1] This paper is the product of the author's personal research and the analysis and views contained in it are solely his responsibility. Though the author is also a part-time adjunct staff member at the RAND Corporation, this paper is not related to any RAND project and therefore RAND should not be mentioned in relation to this paper. I can be reached at GregJones@proliferationmatters.com

[2] "Versatile Test Reactor," Office of Nuclear Energy, U.S. Department of Energy, "Frequently Asked Questions: What is a test reactor?" https://www.energy.gov/ne/nuclear-reactor-technologies/versatile-test-reactor

[3] *Ibid.*, "Frequently Asked Questions: Has a decision been made to build a VTR?"

[4] The thermal agitation of the moderator atoms limits how much the neutrons can be slowed. Neutrons moving at this speed are termed thermal neutrons and hence the term thermal reactors.

[5] Specifically, the reactor must provide a neutron flux of "at least 4×10^{15} neutrons/cm^2-sec." "Notice of Intent To Prepare an Environmental Impact Statement for a Versatile Test Reactor," Office of Nuclear Energy, Department of Energy, *Federal Register*, Vol. 84, No. 150, August 5, 2019, p. 38023. https://www.govinfo.gov/content/pkg/FR-2019-08-05/pdf/2019-16578.pdf This requirement can only be met by using fuel containing plutonium. Kemal Pasamehmetoglu, "Versatile Test Reactor Overview," Advanced Reactors Summit VI, San Diego, California, January 29-31, 2019, p. 4. https://gain.inl.gov/SiteAssets/VersatileTestReactor/VTR_OVERVIEW.pdf

[6] "3 Advanced Reactor Systems to Watch by 2030," Office of Nuclear Energy, U.S. Department of Energy, March 7, 2018. https://www.energy.gov/ne/articles/3-advanced-reactor-systems-watch-2030

the VTR "U.S. companies will have no choice but to rely on foreign countries like Russia and China to develop their technologies."[7]

In reality, the VTR will be a waste of money and undermine the broader nonproliferation goals of the U.S. The need for the VTR is doubtful as it is very unlikely that any of these advanced technologies will be deployed on a significant scale even by 2050 and they could easily never be deployed. Further, given the low technological maturity of the technology to be used in the VTR, combined with DOE's desire to build the VTR on what it calls "an accelerated schedule," it is very likely that there will be significant delays and cost overruns. In addition, DOE needs to examine the safety risks of fast reactors, including the VTR, in a realistic and even-handed manner. Finally, the use of plutonium fuel in the VTR will undermine U.S. nonproliferation goals to eliminate the separation of plutonium, plutonium stockpiles and plutonium fuels in non-nuclear weapon states.

"Advanced" Does Not Mean Advanced

Naturally one would want nuclear reactors that are "advanced." The implication that the U.S. is falling behind Russia and China in developing advanced reactors sounds concerning. The VTR is being promoted as being necessary to deal with this problem and help keep pace with Russia and China. However, a 2017 report by the Idaho National Laboratory makes clear that "advanced" does not mean advanced, but rather "reactors that use coolants other than water."[8] Falling behind Russia and China in the development of advanced nuclear reactors is concerning but falling behind in the development of nonaqueous cooled reactors leads to the question, "So what?" Nonaqueous cooled reactors have been around for more than fifty years but they have seen little use. Nor, as will be discussed below, are they likely to come into widespread use soon.

In the 1970s, the U.S. was considering the development of a passenger jet that could fly faster than the speed of sound, the Supersonic Transport (SST). The Soviet Union and a UK/France consortium were also developing SSTs and a similar argument was made that the U.S. could not afford to fall behind. In the end the U.S. stopped its SST program as being uneconomical. The Soviet Union dropped out as well but the UK/France consortium continued and they developed the Concorde. While in some ways a remarkable airplane, it was not "advanced" in the way that mattered, i.e. providing economical air travel. The Concorde operated for 27 years as a prestige project but it has now ceased operation. Though air travel has greatly expanded since the 1970s, there are no SSTs in operation today.

Similarly, nonaqueous cooled reactors have a number of characteristics that differ when compared to the current type of commercial power reactors which are mainly light water reactors (LWRs). Some of the characteristics are more favorable and some (including some safety

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[7] Dan Brouillette, Deputy Secretary, U.S. Department of Energy, "DOE: There's a Definite Need for a Fast Test Reactor," Office of Nuclear Energy, U.S. Department of Energy, March 1, 2019. https://www.energy.gov/ne/articles/doe-theres-definite-need-fast-test-reactor

[8] D. Petti et. al., "Advanced Demonstration and Test Reactor Options Study," INL/EXT-16-37867, Idaho National Laboratory, January 2017, p. viii. https://art.inl.gov/ART%20Document%20Library/Advanced%20Demonstration%20and%20Test%20Reactor%20Options%20Study/ADTR_Options_Study_Rev3.pdf

characteristics) are less so. But over the last 50 years their unfavorable economics have meant they have not been used commercially. Advocates for the VTR have not provided any evidence that this has or will change.

The Plutonium Fast Breeder Reactor Dream

During World War II the first nuclear reactors were designed to produce plutonium. It was recognized that if these reactors were modified to increase the temperature of the coolant, then useful amounts of electricity could be generated. The problem was that at the time very little uranium was known to exist in concentrations that could be economically mined. What is worse, nuclear power reactors whose design was derived from plutonium production reactors, as well as the LWRs which are in widespread use today, obtain their energy from mainly the U-235 in the uranium. But natural uranium is only 0.7% U-235 (U-238 makes up 99.3%) and with the known uranium resources of the time, nuclear power's contribution to energy production could not be large.

In the early 1950s, the solution to this problem was believed to be the fast breeder reactor. Current LWRs convert some U-238 into plutonium but these reactors produce less plutonium than they consume U-235. However, reactors can be designed that use plutonium fuel and as they operate, actually convert more U-238 to plutonium than is consumed in the process. The nuclear characteristics of plutonium are such that for this to occur, the use of fast neutrons is required. As a result, water cannot be used as a coolant. Instead reactors were designed that used liquid metallic sodium as a coolant which does not slow down the fast neutrons produced by fission. By "breeding" more plutonium than is consumed, this type of reactor has the potential to utilize a large fraction of the U-238 contained in uranium and could increase the amount of energy extracted from uranium by roughly one hundred-fold.

Technologically, the fast breeder reactor is an elegant solution to the problem of the lack of uranium. In the 1960s and 1970s extravagant projections were made as to the fast breeder reactor's future. It was expected that commercial breeder reactors would come into service around 1980 and by 2000 all new reactors would be breeders. Given that oil and natural gas were also expected to be depleted soon, most energy would be produced by breeder reactors. In 1974, the U.S. Atomic Energy Commission estimated that today there would be almost 2,000 gigawatts of breeder reactors in the U.S. alone.[9]

The Reality Behind the Dream

The driving factor behind these plans for the plutonium fueled fast breeder reactor was the belief that supplies of uranium were not very large. However, the only reason that world reserves of uranium were so low in the 1940s and early 1950s is because no one had tried very hard to look for uranium. Before the nuclear age there was no need to do so. In the 1950s, the U.S. used a price incentive program and provided technical information to spur uranium exploration in the

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[9] Albert Wohlstetter, Gregory Jones, and Roberta Wohlstetter, "Towards a New Consensus on Nuclear Technology, Volume I, Why the Rules Need Changing," Pan Heuristics, PH-78-04-832-33, July 6, 1979, p. 16. http://www.npolicy.org/files/19790706-TowardsANewConsensus-Vol01.pdf

U.S. and large quantities of uranium were discovered in the Western U.S.[10] Further oil and natural gas supplies were not nearly so limited as were believed at the time and as energy prices rose it was economical to use less energy more efficiently. As a result, today the total electricity generating capacity of the U.S. is only about 1,100 gigawatts, of which only about 100 gigawatts is from nuclear power. With the greatly reduced demand for nuclear electricity and increased uranium supplies, uranium resources have been more than adequate and the real price of uranium has not increased in 50 years. In this economic environment, there are no commercial breeder reactors in the U.S. or anywhere else in the world.

In 1974 India conducted a nuclear weapon test using plutonium that it had ostensibly produced in anticipation of its use in fast breeder reactors. This event led the U.S. to realize that there were substantial nonproliferation dangers in the use of plutonium as nuclear fuel. Consequently, in 1977 the U.S. adopted a policy against the separation of plutonium, plutonium stockpiles and plutonium fuels in nonnuclear weapon states. The U.S. breeder reactor program ended in 1983. Programs continued in some other countries, most notably France, Japan and the Soviet Union. However, in the twentieth century, little progress was made in developing a commercial breeder reactor.

Still, there were some who could not give up on the breeder reactor dream. In 2000 the DOE initiated the Generation IV International Forum. This was a group of ten countries (now fourteen) which intend to develop what they call "fourth generation" commercial nuclear power systems. In 2002, the forum selected six different types of reactor systems for further development, one of which was a sodium-cooled, plutonium fueled, fast reactor.[11]

The term "Generation IV," like the term "advanced," is a marketing tool rather than a technical description. There is no reason to think that these reactors will produce electricity more economically than current LWRs. There has been no rush to develop and deploy any of these six "Gen IV" reactor types including the sodium-cooled fast reactor. Indeed, a Generation IV International Forum update in 2013 showed that in the eleven years since 2002, little progress had been made in reaching the demonstration phase for any of these six reactor types.[12] For example, the projected demonstration of sodium-cooled fast reactor had slipped nine years from 2021 to 2030.

A slippage of nine years in an eleven year period throws into doubt whether such reactors will ever be built and recent events tend to support this view. In 1994, Japan completed building a small test fast breeder reactor, Monju. This reactor suffered a major accident in 1995 when over three tons of metallic sodium leaked out of the cooling system. Metallic sodium is chemically highly reactive and the oxygen and water in the atmosphere caused the formation of highly caustic fumes. The heat from the reaction was enough to warp several steel structures outside the reactor. In 2016, after various other safety issues, the reactor was shutdown for good. It had

[10] Robert D. Nininger, *Minerals for Atomic Energy*, D. Van Nostrand Company, Inc., 1954.
[11] "A Technology Roadmap for Generation IV Nuclear Energy Systems," GIF-002-00, U.S. DOE Nuclear Energy Research Advisory Committee and the Generation IV International Forum, December 2002. https://www.gen-4.org/gif/upload/docs/application/pdf/2013-09/genivroadmap2002.pdf
[12] "Technology Roadmap Update for Generation IV Nuclear Energy Systems," OECD Nuclear Energy Agency for the Generation IV International Forum, January 2014, p. 9. https://www.gen-4.org/gif/upload/docs/application/pdf/2014-03/gif-tru2014.pdf

barely operated since it first became critical. Japan does not plan to build another fast breeder reactor but had hoped to be involved in France's ASTRID prototype breeder program.

France had a small prototype breeder reactor, Phenix, which started operation in 1973. France then built a full-scale breeder reactor, the Superphenix. It started operation in 1986 but was shutdown in 1996 due to court challenges. Phenix, which had experienced unexplained power surges was shutdown in 2009. France's breeder program then depended on its plans to build another prototype breeder, ASTRID. However, in August 2019 it announced that it had abandoned these plans. This decision effectively ended the breeder reactor program not only in France but also in Japan.

India is building its Prototype Fast Breeder Reactor (PFBR). It was originally planned to start operation in 2010 but now the PFBR will not start until 2020 at the earliest. Only Russia has two breeder prototypes in operation, the BN-600 and BN-800. Russia had planned to build a full-scale breeder reactor, the BN-1200, which was to start operation in 2030. However, in August 2019, Russia announced that the BN-1200 is now planned to start operation in 2036.

Given the large number of delays and reactor shutdowns, the plutonium fast breeder reactor is no closer to reality today than it was 40 years ago. Yet the sodium-cooled fast reactor has had by far the most development effort of any of the six "Gen IV" reactor types. It is hard to see how the DOE can claim as a justification for the VTR that "Many of the advanced reactor designs that will likely produce power in the future will be fast reactors."[13] If there are not going to be any commercial fast nuclear power reactors, there is no need for the VTR.

Versatile Test Reactor Design Not Technically Mature

The DOE mission need statement for the VTR has stated that its capability requirements should include:

> An accelerated schedule to regain and sustain U.S. technology leadership and enable the competiveness of U.S-based industry entities in the advanced reactor markets. This can be achieved through use of *mature technologies* for the reactor design (e.g. sodium coolant in a pool-type, metallic-alloy fueled fast reactor) while enabling innovative experimentation.[14] [Emphasis added]

Elsewhere the mission need statement calls for "Use of proven technologies with high technology readiness level (TRL)."[15] Specifically DOE has said, "The current VTR concept

[13] "DOE: There's a Definite Need for a Fast Test Reactor," Office of Nuclear Energy, U.S. DOE, March 1, 2019. https://www.energy.gov/ne/articles/doe-theres-definite-need-fast-test-reactor
[14] "Mission Need Statement for the VERSATILE TEST REACTOR (VTR) PROJECT: A Major Acquisition Project," Office of Nuclear Technology Research and Development, Office of Nuclear Energy, U.S. Department of Energy, December 2018, p. 9. https://s3.amazonaws.com/ucs-documents/nuclear-power/FOIA-Approved-Mission-Need-Statement-for+Versatile-Test-Reactor-Project.pdf
[15] *Ibid.*, p. 10.

would make use of the proven, existing technologies incorporated in the small, modular GE Hitachi Power Reactor Innovative Small Module (PRISM) design."[16]

The UK has recently independently evaluated the GE Hitachi PRISM design and found it to be anything but mature. The UK has had an extensive nuclear power program and has extracted a total of about 120 metric tons of plutonium from their reactors' spent fuel. Like most countries, the UK, at one time, planned to use this plutonium in breeder reactors but its breeder reactor program ended in 1994. The task has fallen to the UK Nuclear Decommissioning Authority (NDA) to devise a method to dispose of the vast stockpile of plutonium.

GE Hitachi (GEH) proposed building two PRISM reactors to reuse this plutonium. However, in March 2019, the UK NDA rejected this proposal saying:

> PRISM fast reactors were put forward by GEH as commercially viable, "ready to deploy" and capable of quickly dispositioning the complete plutonium stockpile. However, the studies undertaken by NDA with GEH over the past few years have shown that a major research and development programme would be required, indicating *a low level of technical maturity* for the option with no guarantee of success.[17] [Emphasis added]

UK NDA raised particular concerns about the fabrication of the unusual fuel required by the PRISM design.[18] It considered the work up to now "preliminary" and said that the building of a fuel fabrication facility without "further plutonium-active testing" was a "major technical risk" which GEH intended be borne solely by the UK NDA.

The UK NDA has good reason to be concerned about the fabrication of plutonium fuel. The UK built the Sellafield MOX Plant to produce fuel which was a mixture of plutonium and uranium oxides (MOX). Though there was far more commercial experience producing this kind of fuel compared to the PRISM metallic fuel, the plant was a complete failure. Despite being designed to produce 120 metric tons of MOX fuel per year, during its operational life of ten years (2001-2011) it produced a total of only 13.8 metric tons (only about one percent of its design capacity).[19] Nor has the U.S. had better luck. In October 2018 the U.S. National Nuclear Security Administration terminated work on a partially built facility in South Carolina which was intended to turn former weapons plutonium into oxide fuel to be burned in commercial LWRs.[20]

DOE's plans to produce the fuel for the VTR are very preliminary and non-specific:

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[16] "Notice of Intent To Prepare an Environmental Impact Statement for a Versatile Test Reactor," Office of Nuclear Energy, Department of Energy, *Federal Register*, Vol. 84, No. 150, August 5, 2019, p. 38023. https://www.govinfo.gov/content/pkg/FR-2019-08-05/pdf/2019-16578.pdf

[17] "Progress on Plutonium Consolidation, Storage and Disposition," UK NDA, March 2019, p. 11. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791046/Progress_on_Plutonium.pdf

[18] The plutonium, uranium, zirconium metal alloy described earlier.

[19] "Sellafield MOX Plant—Lessons Learned Review," Department of Energy and Climate Change, United Kingdom, July 18, 2012. http://fissilematerials.org/library/2012/07/sellafield_mox_plant_lessons_l.html

[20] "NRC terminates US MOX plant authorization," *World Nuclear News*, February 13, 2019. http://world-nuclear-news.org/Articles/NRC-terminates-US-MOX-plant-authorisation

> Nuclear materials for the VTR driver fuel could come from several locations including from within the DOE complex, commercial facilities, or possibly foreign sources. The nuclear materials and zirconium would be alloyed and formed into ingots from which the fuel would be fabricated. The alloy ingots could be produced at one of the locations providing the nuclear materials or the materials could be shipped to a location within the DOE complex for creating the alloy. DOE anticipates fabricating the driver fuel from ingots at the Savanah River site or the Idaho National Laboratory.[21]

DOE is also vague about how the spent fuel will be disposed. It says it will not be reprocessed but rather "conditioned for disposal."[22] DOE has not stated how this will be accomplished given that the more reactive metallic fuel is a less suitable waste form than the stable ceramic oxide fuel that is used in commercial nuclear power reactors.

Clearly the GEH PRISM technology and especially the technology required to produce the plutonium fuel for the VTR, is nowhere close to being mature. The use of this reactor design, especially on an "accelerated" basis, runs a substantial risk of major delays and cost overruns.

Fast Reactor Safety Issues

The PRISM design has certain safety features that are superior to the design of the current LWR power reactors. In particular the core is submerged in a large pool of metallic sodium. It has a high heat storage capacity and combined with a passive heat removal system, the reactor would be able to survive the loss of emergency power which was the cause of the Fukushima accident. This has led at least one advocate for the VTR to claim "these reactors can't melt down.[23] Unfortunately this is untrue.

One of the problems with the PRISM design is its use of metallic fuel. This fuel has a much lower melting point (about 1,500^{o} C) compared to the melting point of the oxide fuels (about 3,000^{o} C) that are used in LWRs. There are reasons other than just the loss of power that the cooling of the fuel might be interrupted and if it is the metallic fuel will melt far more readily. Such an accident occurred more than 50 years ago at the Enrico Fermi Unit 1 near Detroit. This was a small prototype sodium cooled fast breeder reactor which used a uranium molybdenum alloy fuel similar to the fuel proposed for the VTR. A piece of metal broke off from the interior of the reactor and blocked the coolant flow resulting in the partial melting of two of the reactor's fuel elements. There was no release of radiation off-site but the reactor was shut down for nearly four years as a result of the damage.

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[21] "Notice of Intent To Prepare an Environmental Impact Statement for a Versatile Test Reactor," Office of Nuclear Energy, Department of Energy, *Federal Register*, Vol. 84, No. 150, August 5, 2019, p. 38024. https://www.govinfo.gov/content/pkg/FR-2019-08-05/pdf/2019-16578.pdf

[22] *Ibid.*

[23] James Conca, "Should the U.S. Build a Fast Nuclear Test Reactor or Continue to be Beholden to Russia?" *Forbes.com*, July 26, 2018. https://www.forbes.com/sites/jamesconca/2018/07/26/should-we-build-a-fast-nuclear-test-reactor-or-continue-to-be-beholden-to-russia/#3efccdbc82bb

A major meltdown in a fast reactor would have consequences more serious than those from a similar meltdown in an LWR. As was discussed above, thermal reactors use a moderator and sustaining the nuclear chain reaction requires that the fuel and the moderator be interwoven. If the fuel in a thermal reactor melts, then the moderator is excluded and the nuclear chain reaction stops. In a fast reactor, the melting of the fuel would lead to the exclusion of the coolant, increasing the rate of the chain reaction complicating efforts to bring the accident under control.

There are a number of other safety concerns. The decrease in the delayed neutron fraction associated with the use of plutonium fuel makes the control of the reactor more delicate. The chemical reactivity of the sodium coolant if it leaks out of the reactor as happened in the accident at Monju, can damage equipment and generate toxic fumes. The fast neutrons in the reactor damage structural materials in a much shorter time than do thermal neutrons.

It is clear that fast reactors, including the VTR, have significant safety pluses and minuses that will have to be carefully evaluated. It is not clear that DOE is up to the task. In the mission need statement for the VTR, DOE has claimed "The nuclear industry, which has always provided safe, clean, reliable energy…"[24] This apparent denial of the serious accidents that occurred at Three Mile Island, Chernobyl and Fukushima raises concerns as to whether DOE can get beyond its role as an advocate for nuclear power to examine the safety of fast reactors in a realistic and even-handed manner.

Plutonium Fuel and U.S. Nonproliferation Concerns

As was discussed above, the requirements for the VTR appear to have been deliberately set so as to require the use of plutonium fuel. Plutonium is a well-known nuclear weapon material. This includes so-called reactor-grade plutonium.[25] In 1974 India conducted a nuclear weapon test using plutonium that it had ostensibly produced to use as fuel in fast breeder reactors. This event led the U.S. to realize that there were substantial nonproliferation dangers in the use of plutonium as nuclear fuel. As a result, in 1977 the U.S. adopted a policy against the use of plutonium separation, plutonium stockpiles and plutonium fuel in nonnuclear weapon states. This U.S. policy has not been universally accepted but the lack of progress in the development of breeder reactors has lessened some of the resistance. Still, there are concerns that countries might use plutonium produced by their commercial power reactors to acquire nuclear weapons and that breeder reactor development might be used as a cover to acquire or retain plutonium that has been separated from commercial reactors' spent fuel. Two countries of current concern are Japan and South Korea.

Japan has already separated large quantities of plutonium for its breeder reactor program. It currently has nine metric tons of separated plutonium (enough for over 1,000 nuclear weapons)

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[24] "Mission Need Statement for the VERSATILE TEST REACTOR (VTR) PROJECT: A Major Acquisition Project," Office of Nuclear Technology Research and Development, Office of Nuclear Energy, U.S. Department of Energy, December 2018, p. 5. https://s3.amazonaws.com/ucs-documents/nuclear-power/FOIA-Approved-Mission-Need-Statement-for+Versatile-Test-Reactor-Project.pdf

[25] Gregory S. Jones, *Reactor-Grade Plutonium and Nuclear Weapons: Exploding the Myths,* Nonproliferation Policy Education Center, 2018. https://nebula.wsimg.com/3fd1e3cfbbf101d6c4f562e17bc8604c?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1

in Japan and another 36.7 metric tons stored in the UK and France.[26] Though the prospects for Japan's breeder reactor program have faded, pressure on Japan to develop nuclear weapons has grown. In particular, the pressure has come from North Korea's nuclear weapon and ballistic missile tests and candidate Trump's suggestion that Japan and South Korea should develop their own nuclear weapons (a suggestion that has been retracted by President Trump). As a result, there has been increased concern about Japan's large separated plutonium stockpile and calls for Japan to eliminate its stocks of separated plutonium. The use of plutonium fuel in the VTR undermines this effort.

South Korea does not have any stocks of separated plutonium. It does have a large commercial nuclear power program and the spent fuel from these reactors contains about 100 metric tons of plutonium.[27] Candidate Trump's call for South Korea to develop it own nuclear weapons combined with North Korea's nuclear weapon and ballistic missile tests (which threaten South Korea even more than they do Japan) has led to open discussions in South Korea about obtaining its own nuclear weapons. Breeder reactor development could be used as a cover for South Korea to obtain separated plutonium for nuclear weapons. The use of plutonium fuel in the VTR enhances the credibility of this cover.

To make matters worse, the U.S. is taking on both Japan and South Korea as collaborators to perform research in the VTR.[28] In January 2019 a memorandum of understanding with South Korea was in final review and in June 2019, a memorandum of understanding was signed with Japan.

The use of plutonium fuel in the VTR helps provide cover for Japan to retain and for South Korea to obtain separated plutonium which could be used to produce nuclear weapons. This is an additional reason why the VTR should not be built.

Conclusions

The need that the VTR is intended to meet does not exist. Commercial nuclear power reactors that use nonaqueous coolants (so-called advanced reactors), will certainly not start operation by 2030. Though much effort has been taken to develop such reactors in the last 50 years, they are no closer to development today than they were 40 years ago. Given the recent cancellation of fast breeder reactor programs in Japan and France and the delays to the programs in Russia and India, such reactors may well never be deployed commercially.

Despite DOE's claims that the technology to be used in the VTR is mature, an independent evaluation by the UK NDA found "a low level of technical maturity." The UK NDA raised particular concerns about the manufacture of the fuel, calling it a "major technical risk." DOE's

[26] "The Status Report of Plutonium Management in Japan-2018," Japan Office of Atomic Energy Policy, July 30, 2019. http://www.aec.go.jp/jicst/NC/iinkai/teirei/3-3set_20190730.pdf

[27] David Albright et. al., "Civil Plutonium Stocks Worldwide: End of 2014," Institute for Science and International Security, November 16, 2015, p. 4. https://isis-online.org/uploads/isis-reports/documents/Civil_Plutonium_Stocks_Worldwide_November_16_2015_FINAL.pdf

[28] Kemal Pasamehmetoglu, "Versatile Test Reactor Overview," Advanced Reactors Summit VI, San Diego, California, January 29-31, 2019, p. 8. https://gain.inl.gov/SiteAssets/VersatileTestReactor/VTR_OVERVIEW.pdf

plans for the manufacture of this fuel are very preliminary and nonspecific and its plan to build the VTR on an accelerated schedule runs a high risk of major delays and cost overruns.

Though the technology used in the VTR has some safety advantages, it has some significant disadvantages as well. DOE needs to move beyond its role as an advocate for nuclear power and examine the safety of fast reactor technology options in a realistic and even-handed manner.

The use of plutonium fuel in the VTR undermines U.S. nonproliferation goals to eliminate the separation of plutonium, plutonium stockpiles and plutonium fuels in non-nuclear weapon states. To make matters worse, the U.S. is taking on both Japan and South Korea as collaborators to perform research in the VTR, which could help provide cover for potential nuclear weapon programs in these two countries.

The VTR will be a waste of money and undermines U.S. nonproliferation goals. This reactor program should not continue.