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
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Mission Need Statement
for the Versatile Test Reactor (VTR) Project

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1. STATEMENT OF MISSION NEED

The United States (U.S.) has been an international leader in the development and testing of advanced nuclear reactor technologies since the advent of nuclear power generation. The Department of Energy (DOE) and its predecessor organizations appropriately provided nuclear fuels and materials development capabilities and large-scale testing facilities in support of all currently deployed nuclear reactor technologies. However, the U.S. has not maintained a domestic fast neutron spectrum testing capability for over two decades. This gap in testing capability is severely crippling the U.S. ability to move forward in the development of next-generation nuclear reactors – many of which require a fast neutron spectrum for operation – and equally impacts the U.S. ability to regain technology leadership in this arena. In the meantime, development of next generation advanced reactors technologies is being actively pursued by DOE national laboratories, universities and industry in competition with similar efforts by international private and/or state supported nuclear technology providers.

Common to advanced nuclear reactor technology development is the urgent need for accelerated testing and qualification of advanced nuclear fuels, materials instrumentation and sensors.

The lack of a versatile fast neutron spectrum testing capability is a significant national strategic risk affecting the ability of DOE to fulfill its mission areas. This testing capability is essential for the U.S. to modernize its nuclear energy research and development (R&D) infrastructure for developing transformational nuclear energy technologies. Failure to develop this capability on an accelerated schedule will lead to further degradation of the U.S. ability to develop advanced nuclear energy technologies. If this capability is not available to U.S. innovators as soon as possible, the ongoing shift of nuclear technology primacy to other international states (e.g., China, the Russian Federation) will accelerate, and the opportunity will be missed to re-energize the U.S. nuclear industrial sector. Furthermore, independent of domestic deployment strategies, relinquishing U.S. leadership in advanced reactor technologies will have national security consequences as U.S. influence in global nuclear safety and security policies and their implementation will be severely diminished.

2. ALIGNMENT

The mission of the DOE is to advance the energy, environmental, and nuclear security of the U.S.; promote scientific and technological innovation in support of that mission; and ensure the environmental cleanup of the national nuclear weapons complex. The DOE's FY 2014-2018 Strategic Plan[1] calls out Strategic Objective 2 as:

> *Support a more economically competitive, environmentally responsible, secure and resilient U.S. energy infrastructure.*

The plan adds the following specificity:

> *DOE will continue to explore advanced concepts in nuclear energy that may lead to new types of reactors with further safety improvements and reduced environmental and nonproliferation concerns.*

The Office of Nuclear Energy's (NE) mission is to advance nuclear power to meet the nation's energy, environmental, and national security needs. To accomplish this mission, NE has established research objectives to resolve barriers in technical, cost, safety, security, and proliferation resistance through early-stage research, development, and demonstration to:

- Enhance the long-term viability and competitiveness of the existing U.S. reactor fleet.
- Develop an advanced reactor pipeline.
- Implement and maintain national strategic fuel cycle and supply chain infrastructure.

In support of these research objectives, the mission of the DOE NE Versatile Test Reactor (VTR) program is to provide leading edge capability for accelerated testing and qualification of advanced fuels and materials, enabling the U.S. to regain and sustain technology leadership in the area of current and future advanced reactor systems.

There is bi-partisan support, both in the U. S. House and in the Senate, for nuclear energy research and development (R&D) infrastructure in general and for the VTR concept in particular, accentuating the need for development of the VTR. The Nuclear Energy Research Infrastructure Act[2] (H.R. 4378) directs DOE to construct a versatile, reactor-based fast neutron source and authorizes $35M in FY 2018 and larger amounts in subsequent years. The Nuclear Energy Innovation Capabilities Act of 2017[3] (NEICA, S. 97, enacted into law in September 2018), directs the Secretary of Energy to determine the mission need for a versatile reactor-based fast neutron source operating as a national user facility.

3. CAPABILITIES GAP

3.1 Capability Gap

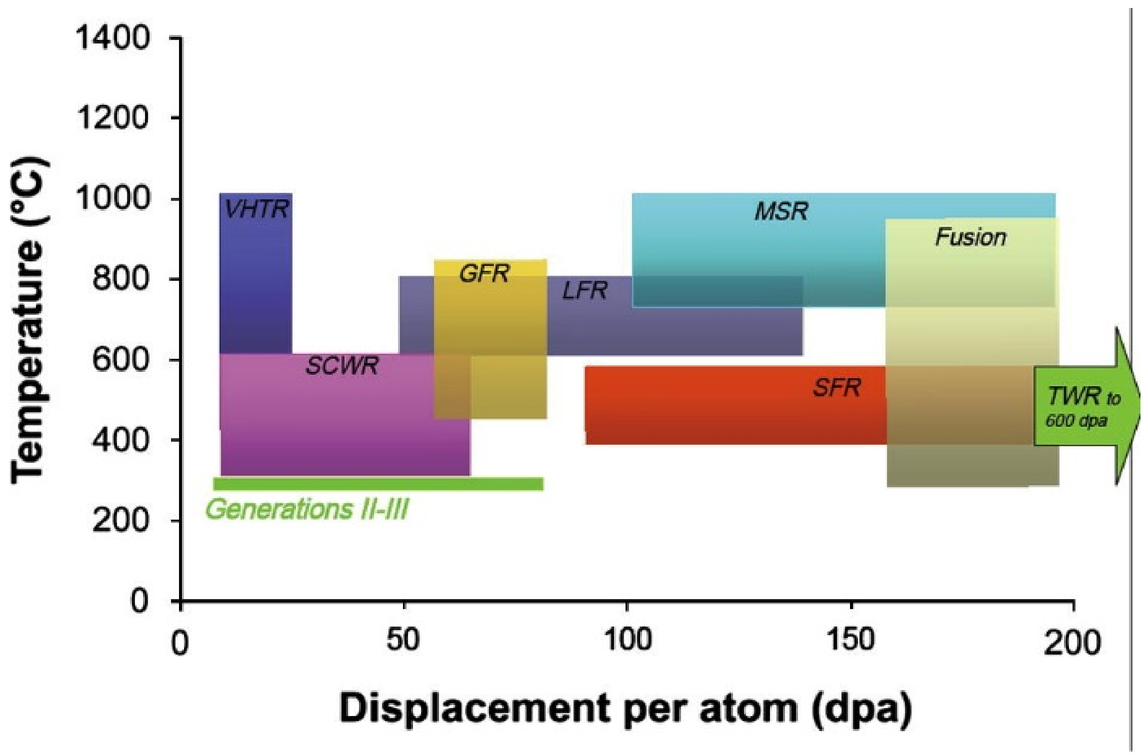
The capability gap addressed by this mission need statement is the current inability to effectively test advanced nuclear fuels and materials in a prototypic fast neutron spectrum irradiation environment at high neutron fluxes. Deployment of this complex testing capability is and has been historically recognized as a DOE mission.

Advanced nuclear fuels with long-life, high-burnup properties and reactor systems structural materials that can tolerate high burnups and high levels of radiation damage are needed for successful development and deployment of advanced nuclear reactor technology options. They are also useful for continued improvements in the existing light water reactor (LWR) fleet. As an example, the U.S. Nuclear Regulatory Commission and international regulatory authorities require comprehensive technical data obtained via prototypic irradiation testing prior to use of advanced nuclear fuels and materials. Furthermore, many Gen-IV concepts using coolants other than water may also require fast neutrons for the study of fuels and corrosion control.[4]

The nuclear industry, which has always provided safe, clean, reliable energy, needs innovation now more than ever before. It is likely that fast spectrum reactors will be deployed in the future as the current fleet of LWRs are decommissioned. Fast neutron spectrum nuclear reactors have the potential to significantly rely on inherent safety characteristics, operate for very long periods of time without refueling, and reduce the volume of newly generated nuclear waste.

Neutron damage rates are significantly higher for advanced fast neutron reactor systems than those for the current fleet of LWRs. This is because the magnitude of the fast neutron flux is much higher than that for thermal systems and because the fuels are designed for higher lifetime fluence. A water-cooled test reactor cannot support research and development of advanced reactor designs because it is not possible to achieve sufficiently high fast neutron flux (without thermal neutron contamination). This high neutron flux is needed for the development of any fast spectrum reactor system and acceleration of materials irradiations for both thermal and fast reactors.[4]

The required functional testing capability for development of advanced nuclear fuels and materials ranges from 20 displacements per atom (dpa) per year to over 500 dpa as shown in Figure 1.[4] Additionally, to create the prototypic environment needed to qualify advanced nuclear fuels and materials, the irradiation must be performed at elevated temperatures with a fast neutron spectrum (>0.1 million electron volts [MeV]) and with flowing coolants other than water. Current domestic irradiation testing facilities cannot provide a representative, timely irradiation testing environment, and access to very limited international testing facilities is precluded by political, transportation, technical, and cost issues.



Legend:

FUSION, fusion reactor; Generations II-III, advanced light-water reactor; GFR, gas-cooled fast reactor; LFR, lead-cooled fast reactor; MSR, molten salt reactor; SCWR, super-critical water-cooled reactor; SFR, sodium-cooled fast reactor; VHTR, very high temperature reactor; TWR, traveling wave reactor

Figure 1. Temperature/displacement damage (dose) windows for fission and fusion concepts.

NEAC Recommendation

In July of 2016, DOE NE chartered the Nuclear Energy Advisory Committee (NEAC) to independently determine the requirements and overall capabilities (e.g., neutron spectrum/spectra, testing environments, etc.) for a new irradiation test reactor and to perform a comparison with alternative facilities, methodologies, and approaches for meeting these needs and providing these capabilities. The NEAC conducted an independent study (including a user needs assessment) and confirmed that there was a need in the U.S. for fast neutron testing capabilities, but that there is no facility that is readily available domestically or internationally.[5] Subsequently, DOE-NE directed that a research and development (R&D) effort be initiated to create a versatile advanced test reactor (VTR) concept, with associated cost and schedule estimate, to enable a fully informed DOE acquisition decision at the end of three years.[6]

Industry Input

Currently, a number of private entities are working on developing fast reactors for future commercialization. After a series of workshops organized by the DOE's Gateway for Accelerated Innovation in Nuclear (GAIN), the commercial fast reactor development community organized a working group under the Nuclear Energy Institute (NEI). In addition to reactor developers, the NEI fast reactor working group (FRWG) also has active participation from the U.S. utilities, including Southern Company, Exelon, and Duke. The FRWG meets periodically to discuss common issues and make recommendations to DOE through GAIN in areas where federally funded programs can help resolve common challenges.

On February 13, 2017, the FRWG submitted a letter to DOE identifying its R&D priorities within the federally funded nuclear energy programs. Prominent in the list was the need for a fast neutron spectrum test reactor that can support technology development for multiple concepts in the areas of fuels, materials, and sensor development. The letter articulates the difficulties associated with relying on foreign fast-spectrum testing capabilities and the urgent need for domestic capabilities for these commercial efforts to move forward and to be commercially sustainable in the future.

There are industrial entities focusing on the next generation of sodium cooled fast reactors. Examples are Advanced Reactor Concepts (ARC), General Electric (GE) and TerraPower. Westinghouse is working on a lead-cooled fast reactor concept. General Atomics (GA) is working on a gas-cooled fast reactor concept. These are in the early R&D phase. The companies are exploring many innovative technologies, including fuels and materials, to be used in the final design.

There are also a number of liquid-fueled molten salt fast reactor designs being explored by the private sector. Examples include the TerraPower molten chloride fast reactor (MCFR) and the Elysium Industries molten chloride salt fast reactor (MCSFR). In addition, Oklo Inc. and Westinghouse are working on fast-spectrum, heat-pipe-cooled micro-reactor designs (< 10 megawatt thermal [MWth]).

The information above is provided as a summary of wide-ranging interests in the field of fast reactor technology. The list of private entities is not meant to be all-inclusive; it only includes the companies represented in the FRWG. The maturity level of the design of each concept varies. Many of these companies aim to achieve the readiness for the first prototype/demonstration unit as quickly as possible (within the next 10-15 years). However, these companies also recognize that, to sustain long-term competitive advantage, a supporting research infrastructure will be necessary. Simply building the first prototype may not be sufficient to gain and sustain adequate market share nationally or globally. The corollary would be U.S. leadership in the LWR industry. Even though LWR technology has been available for many decades, the supporting research infrastructure has enabled an increase in the availability from 60% in the 1960s to more than 90% in the 2000s. There is still ongoing research in test reactors to improve the fuels and materials performance in LWRs.

Congressional Direction

Recognizing the importance of U.S. leadership in advanced reactor development in terms of economic competitiveness and national security implications, there are a number of nuclear-energy-related authorization bills that are being considered at various levels within the U.S. House and Senate. These bills directly or indirectly affect the VTR program. As of September 2018, the Nuclear Energy Research Infrastructure Act[2] (H.R. 4378) directs DOE to construct a versatile reactor-based fast neutron source. This bill authorizes $35M in FY 2018 and larger amounts in subsequent years. The bill has passed in the House and has been referred to the Senate Energy and Natural Resources Committee.

On the Senate side, the Nuclear Energy Innovation Capabilities Act of 2017[3] (NEICA, S. 97) enables civilian R&D of advanced nuclear energy technologies by private and public institutions and directs the Secretary of Energy to determine the mission need for a versatile reactor-based fast neutron source, which shall operate as a national user facility. This bill passed the Senate on March 7, 2018 and the House on September 13, 2018, and was signed by the President on September 28, 2018.

The bi-partisan support both in the House and in the Senate, for nuclear energy R&D infrastructure in general and for the VTR concept in particular, accentuates the need for development of the VTR.

3.2 Strategic Risk

The lack of a versatile fast neutron spectrum testing capability is a significant national strategic risk affecting the ability of DOE to fulfill its mission areas as described in Section 1. The LWR and advanced reactor communities, which are supported by several DOE program areas (e.g., small modular reactor technology development and licensing, LWR sustainability, advanced nuclear technology development) are key to providing a flexible portfolio of energy supply sources. This will ensure national security through energy independence and energy dominance and re-energize the U.S. nuclear industrial sector for domestic deployment of advanced reactors and for access to international markets. Failure to develop a versatile fast neutron spectrum testing capability on an accelerated schedule will lead to further degradation of the U.S. capability to develop advanced nuclear reactors, accelerate the ongoing shift of nuclear technology primacy to other international states (e.g., China, the Russian Federation), and fail to re-energize the U.S. nuclear industrial sector. This testing capability is essential for the U.S. to modernize its nuclear energy infrastructure for developing transformational nuclear energy technologies. Independent of domestic deployment strategies, relinquishing U.S. leadership in advanced reactor technologies will limit U.S. influence in global nuclear safety and security policies and their implementation.

An additional often misunderstood strategic risk is the potential loss of qualified human resources to provide the innovation required for developing advanced reactor designs and subsequent operation. The national commitment to pursue a new nuclear project of the importance of VTR will provide an inestimable incentive for students and young professionals to enter this essential profession and dedicate their careers to ensure international leadership for the United States.

3.3 Capability Requirements

The high-level capability requirements for the VTR are driven by the variety of user-needs.[7] Overall the requirements are developed with the following considerations:

- An intense neutron irradiation environment with prototypic spectrum to determine irradiation tolerance and chemical compatibility with other reactor materials, particularly the coolant.

- Testing that provides a fundamental understanding of materials performance, validation of models for more rapid future development, and engineering-scale validation of materials performance in support of licensing efforts.

- A versatile testing capability to address diverse technology options and, sustained and adaptable testing environments.

- Focused irradiations, either long- or short-term, with heavily instrumented experimental devices, and the possibility to do in situ measurements and quick extraction of samples.

- An accelerated schedule to regain and sustain U.S. technology leadership and to 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.

A summary of preliminary requirements is provided in Table 1.[7]

Table 1. Preliminary requirements summary.

REQUIREMENT	TARGET
Provide a high peak neutron flux (neutron energy > 0.1 MeV) with a prototypic fast reactor neutron energy spectrum	$\geq 4 \times 10^{15}$ n/cm^2-s
Provide high neutron dose rate for materials testing [quantified as displacement per atom (dpa)]	> 30 dpa/year
Provide an irradiation length that is typical of fast reactor designs	$0.6 \text{ m} \leq L \leq 1 \text{ m}$
Provide a large irradiation volume within the core region	≥ 7 L

REQUIREMENT	TARGET
Provide innovative testing capabilities through flexibility in testing configuration and testing environment (coolants) in closed loops	Open core, closed loops, rabbits Na, Pb, Pb-Bi, He, Molten Salts loops
In addition to traditional measurement techniques, provide the ability to test advanced sensors and instrumentation for the core and test positions	In-situ and real-time measurements
Make the facility available for testing as soon as possible.	Use proven technologies with high technology readiness level (TRL). Operational by the end of FY2026.
Expedite experiment lifecycle by enabling easy access to support facilities for experiments fabrication and post-irradiation examination	If practical, avoid transportation through public roads.
Provide life-cycle management for the reactor driver fuel while minimizing cost and schedule impacts.	Must be evaluated based on cost and schedule impact with consideration for using existing DOE infrastructure with necessary modifications for fuel life-cycle management.

3.4 High-Level Interdependencies

Several ongoing DOE-NE programs will derive benefit from the development of this capability. A key consideration is that the development of the needed capability should support, be synergistic with, and minimize operational impacts to ongoing programs. The Office of Advanced Reactor Technologies sponsors research, development, and deployment activities through its Next Generation Nuclear Plant, Advanced Reactor Concepts, and Advanced Small Modular Reactor programs to promote safety, technical, economical, and environmental advancements of innovative Generation IV nuclear energy technologies.

The Fuel Cycle Technologies Program will benefit from development of this capability in two R&D campaigns. The Systems Analysis & Integration campaign has developed systematic, transparent, and objective processes to screen and evaluate a wide variety of proposed fuel cycles to identify potential solutions. It evaluates advanced reactor and other nuclear technologies from a nuclear energy system perspective. The Advanced Fuels campaign supports both existing and next-generation reactors by developing accident-tolerant LWR fuel and advanced proliferation-resistant fuels for sustainable fuel cycles.

The Light Water Reactor Sustainability Program is developing the scientific basis to extend existing nuclear power plant operating life beyond the current 60-year licensing period and ensure long-term reliability, productivity, safety, and security. The program conducts research and development projects in the following pathways: Materials Aging and Degradation

Assessment; Advanced Instrumentation, Information, and Control Systems Technologies; Risk-Informed Safety Margin Characterization; and Advanced Light Water Reactor Nuclear Fuels.

Nuclear Energy Advanced Modeling and Simulations (NEAMS) is developing advanced multi-physics and multi-scale modeling tools for advanced reactor fuels and materials. The proposed capability will be needed for the validation of these tools. Additionally, Nuclear Energy Enabling Technologies (NEET) is developing advanced online sensors for fuels and materials testing and reactor monitoring and control systems. The planned capability will also be instrumental in testing these advanced sensors and qualifying them for use in reactor applications.

3.5 Status of Existing Capabilities

The U.S. has not had a fast neutron spectrum testing facility for over two decades. The existing U.S. capability for testing nuclear fuels and materials is limited to water-cooled reactors providing thermal neutron spectrum testing capability. For over 50 years, water-cooled test reactors have been the workhorse of nuclear fuels and materials testing for thermal reactor systems.[4] The U.S. relies mostly on irradiations carried out in the Advanced Test Reactor (ATR) at Idaho National Laboratory (INL) and the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) for accelerated testing of radiation tolerance. These reactors are decades old and are called on for many other missions besides commercial nuclear power applications. These material test reactors produce damage rates of up to 10 dpa/yr, which is sufficient to support most thermal reactor development; however, they are already operating near full capacity. To attain peak doses typical of advanced fast reactors (200 to 500 dpa), using a water-cooled test reactor would take 20–50 years.[4] Thus, it is not feasible to attain the required peak dose in a reasonable amount of time using a water-cooled test reactor.

An evaluation of existing domestic and international thermal neutron spectrum and fast neutron spectrum irradiation facilities concluded that domestic thermal material test reactors have severely limited fast neutron capabilities. It also concluded that fast neutron facilities with the appropriate infrastructure exist today only in Russia and India. Concerns over political issues, transportation to and from the U.S., and equivalencies of quality assurance programs make those facilities difficult to rely upon.[4]

In summary, there is no existing capability that can be used to address the U.S. fast neutron spectrum testing gap.

4. POTENTIAL APPROACH

This capability gap can be addressed with a new fast neutron spectrum test facility based on sodium-cooled fast reactor (SFR) technology. With this approach, the new facility could be designed and built using mature SFR technology informed by more than a hundred cumulative years of SFR operating experience and associated lessons learned. This proposed approach would provide a test facility with versatile operational capabilities and maximum mission flexibility.

Several important considerations and constraints were identified for the development of viable alternatives:

- The anticipated operational lifetime of the capability is 40 - 60 years.[7]
- Availability of accessible pre-and post-irradiation preparation and examination facilities is a required analytical capability[7] and a potential constraint in the detailed analysis of alternatives to be conducted in support of Critical Decision (CD)-1. Proximity to existing fuel fabrication, experiment manufacturing, fuels and materials characterization, and post-irradiation examination capabilities provides for optimized benefit of the new capability. Easy access to these facilities reduces the transportation difficulties and accelerates the testing program.
- DOE regulation of the capability is required to minimize regulatory uncertainty and enable timely development, approval, and maintenance of the safety basis.
- Teaming with industry to identify and develop mitigations for supply chain challenges is essential to minimize the well-recognized issues associated with new nuclear facility builds and support re-energization and revitalization of the U.S. nuclear industry.
- If uranium is used solely or in combination with other fissile materials for reactor fuel, uranium enrichment levels will be limited to less than 20% to comply with international agreements.
- Congress has dictated that the initial target date for operational readiness for the fast neutron spectrum capability is FY 2026.[3] Mature technologies are required for a rapid deployment and reliable operations of an irradiation test reactor within this time frame.[4]

Fast neutron spectrum testing facilities using mature sodium-cooled fast reactor technologies have been successfully constructed and operated domestically and internationally (e.g., Experimental Breeder Reactor II [EBR-II], U.S.; Fast Flux Test Facility [FFTF], U.S.; and BOR-60, Russian Federation).[5] Existing and legacy test facilities present a wealth of knowledge for sodium-cooled fast neutron spectrum test reactor design, construction, and operation, and provide a history of prototypic test environments representative of the capability needs presented herein. However, as noted in the previous section, existing operating domestic irradiation testing facilities are not capable of filling the capability gap as described in this document, and international facilities are precluded from consideration due to several problematic issues in regard to access, transportation, and technical equivalencies. Furthermore, taking no action cannot meet the mission need for the reasons articulated in the previous section. Therefore, two potential approaches are identified to meet the mission need described in this document. These include construction of a new sodium-cooled fast neutron spectrum test reactor facility or refurbishment and reactivation of an existing decommissioned sodium-cooled fast neutron spectrum test facility (i.e., FFTF). Based on a preliminary analysis, refurbishment and reactivation of FFTF has been evaluated and was removed from consideration as a viable alternative for pre-conceptual planning activities.[8] This preliminary evaluation will be reviewed as part of an Independent Analysis of Alternatives required prior to CD-1.

As previously noted, a wealth of information exists for sodium-cooled fast reactors. The SFR has been under development by the U.S. government since the inception of nuclear electricity production in the 1950s. Experimental and demonstration facilities were built and operated starting in the early 1960s with EBR-II in Idaho and the Fermi-1 power plant in Michigan, both of which generated electricity. The FFTF is a deactivated 400 MWth SFR in Washington State that was used for materials irradiations.[4] There are no unusual nuclear safety issues, safeguards and security issues, nor major design process constraints associated with the execution of this mission need using a sodium-cooled fast reactor technology approach. DOE expectations for safety in design will be detailed as part of the CD-0 package submittal and a safety design strategy developed and approved in support of CD-1.

In February 2017, the Department of Energy Office of Nuclear Energy's (DOE-NE) Nuclear Energy Advisory Committee (NEAC) released a final report evaluating the needs and requirements for a new U.S. test reactor.[5] This report received unanimous approval by the NEAC members with the key recommendation of the report being that "DOE-NE proceed immediately with pre-conceptual design planning activities to support a new test reactor (including cost and schedule estimates)." Subsequently, DOE-NE directed that an R&D effort be initiated to create a Versatile Advanced Test Reactor (VTR) concept with an associated cost and schedule estimate that will enable a fully informed DOE acquisition decision at the end of three years.[6]

An initial evaluation of alternatives during the pre-conceptual design planning activity indicates, congruent with the conclusions of the test reactor options study[4] and the NEAC recommendation,[5] development of a well-instrumented sodium-cooled fast neutron spectrum test reactor in the 300 MWth power level range providing a flexible, reconfigurable testing environment for known and anticipated testing is the most practical and cost-effective strategy to meet the mission need and address constraints and considerations presented in this document. DOE will conduct an independent analysis of alternatives as part of the CD-1 process.

It is anticipated that the VTR, coupled with the existing supporting R&D infrastructure, will provide the basic and applied physics, materials science, nuclear fuels, and advanced sensor communities with a unique research capability to enable a comprehensive understanding of the multi-scale and multi-physics performance of nuclear fuels and structural materials to support the development and deployment of advanced nuclear energy systems.

5. RESOURCE AND SCHEDULE FORECAST

The cost range and schedule estimates in this section are based on current DOE laboratory and industry estimates for advanced reactor development and deployment, as well as legacy DOE construction data and lessons learned from similar fast neutron spectrum test reactors.

5.1 Cost Forecast

A rough-order-of-magnitude cost range has been developed[9] to acquire the capability to address the stated mission need. The cost range was generated using six independent approaches:

1. The 400 MWth FFTF design and construction effort in the 1970s with actual costs escalated to 2018 dollars and the equipment costs scaled using best engineering judgment.
2. A 1994 proprietary advanced conceptual design effort with estimated costs escalated to 2018 dollars and equipment costs scaled using best engineering judgment.
3. A reactor technologies capital cost estimation algorithm applied to the VTR design concept using best engineering judgment.
4. A 2008 proprietary advanced conceptual design effort estimated costs escalated to 2018 dollars and equipment costs scaled using engineering judgment.

5. An analogous reactor technology cost model developed for a LWR test reactor escalated to 2018 dollars and equipment costs scaled using engineering judgment.
6. An analogous reactor technology cost model developed for a high-temperature gas reactor escalated to 2018 dollars and equipment costs scaled using engineering judgment.

The cost range is comprehensive, covering the reactor, fuel, support facilities, construction cost, and startup costs. To ensure that all costs were accounted for, a representative DOE site was assumed to develop scope and cost estimates for a postulated specific location. The cost range for the test facility and support facilities is $3.3B to $4.5B, and it is anticipated that the peak annual funding need would be $650M (2018 dollars). The top end of the range accounting for uncertainty in Hazard Category 1 nuclear reactor facility design and construction.

5.2 Schedule Forecast

A notional preliminary schedule of milestones for the VTR project, consistent with the funding profile in Section 5.3, is given below in Table 2.

Table 2. Notional preliminary milestone schedule for the VTR project.

Critical Decisions (CD)	***Fiscal Year***
CD-0, Approve Mission Need	*January 2019*
CD-1, Approve Alternative Selection and Cost Range *CD-3A, Approve Long-Lead Procurements*	*FY 2020*
CD-2/3, Approve Performance Baseline/Approve Start of Construction	*FY 2022*
CD-4, Approve Project Completion/Start of Operations	*FY 2026*

5.3 Funding Forecast

A five-year funding profile, developed for planning purposes only, is shown below in Tables 3a and 3b. The profile is based on the high end of the project cost estimate. Total estimated funding required for the effort to advance the project from CD-0 to CD-1 is $120M.

Table 3a. Initial five-year funding profile estimate. Net Present Value FY-2018.

Fiscal Year	***FY19***	***FY20***	***FY21***	***FY22***	***FY23***	***Total ($M)***
OPC	65	55	20	40	110	290
TEC – PED Phase		85	380	235		700
TEC – Construction Phase		5	250	375	540	1170
Total Project Cost ($M)	65	145	650	650	650	2160

Table 3b. Initial five-year funding profile estimate (Escalated to year of execution using an annual escalation rate of 3.23%).

Fiscal Year	***FY19***	***FY20***	***FY21***	***FY22***	***FY23***	***Total ($M)***
OPC	65	55	25	45	125	315
TEC – PED Phase		90	405	260		755
TEC – Construction Phase		5	265	410	615	1,295
Total Project Cost ($M)	65	150	695	715	740	2,365

Legend: OPC, other project costs; TEC, total estimated cost; PED, project engineering and design

References

1. DOE/CF-0067, U. S. Department of Energy, Strategic Plan, 2014-2018.

2. H.R. 4378, "Nuclear Energy Research Infrastructure Act," 2018.

3. S.97, "Nuclear Energy Innovation and Capabilities Act," 2017.

4. INL/EXT-16-37867, ADVANCED DEMONSTRATION AND TEST REACTOR OPTIONS STUDY (pp., 26, 78, 79, 102, 134, 135)

5. Nuclear Energy Advisory Committee, *Assessment of Missions and Requirements for a New U.S. Test Reactor*, February 2017. (pg. 20)

6. Dr. John Herczeg, DOE NE-4, to Rick Provencher, Manager, DOE Idaho Operations Office, Fiscal Year (FY) 2017 Program Guidance – US Test Reactor R&D Initiative, United States Government Memorandum, March 6, 2017.

7. INL, *Versatile Irradiation Test Reactor User Needs Assessment*, INL/MIS-16-40582, January 2017 (pp. 1, 3).

8. Kemal O. Pasamehmetoglu, INL, to Dr. John Herczeg, DOE NE-4, "Contract No. DE-AC07-05ID14517 – Preliminary Evaluation of the FFTF Restart Alternative, Revision 1", CCN243271, August 22, 2018.

9. INL, *Cost Estimate Range for the Versatile Test Reactor for the Mission Need Document*, TEV-3508, September 2018.