ADVANCED REACTORS & THE ROLE OF VERSATILE TEST REACTOR (VTR) – OVERVIEW

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• The need for clean energy is increasing globally
  • Civilization and environment conflict exhibited by climate change
  • The need for reliable and diverse energy mix
  • Energy equity (food, water, healthcare)

• More than 40 U.S-based companies are developing advanced reactor concepts to meet the needs of future domestic and global clean energy markets
  • > $T market

• Nuclear energy technology leadership and commercial exports are of strategic importance for national security

• For a sustainable energy-environment future, nuclear energy must play an important role within an integrated energy systems tailored to meet the regional energy demands
ADVANCED REACTORS – COMMON FEATURES

- Smaller size with modular construction
  - Economies of scale vs economies of modularity
- Higher efficiency and lower environmental impact
- Enhanced inherent safety
  - Negative reactivity feedback
  - Heat removal by natural circulation
  - Low pressure
- Lower high level radioactive waste
- Applications beyond just electricity production
- Better synchronization with a dynamic energy network within the context of integrated energy systems.
ADVANCED REACTORS – HIGH TEMPERATURE REACTORS

• High-efficiency
• Process heat applications
• Fuel Type: TRISO
• Pebble-bed versus prismatic core design
• Molten salt coolant instead of He
ADVANCED REACTORS – FAST REACTORS

• A number of different designs
  • Sodium
  • Lead or lead-bismuth eutectic (LBE)
  • Helium
• Different fuels and materials
  • Mostly innovative
• Fuel cycle advantages
  • High-burnup (breed and burn)
  • Recycling
ADVANCED REACTORS – MOLTEN SALT REACTORS

- Liquid fuel
- Fluoride Salt (mostly thermal) & Chloride Salt (fast spectrum)
- Li enrichment for controlling Tritium production
- Salt chemistry and fission product clean-up
- Breed & Burn
  - Thorium fuel
ADVANCED REACTORS – MICRO REACTORS

- Niche markets (< 10 MWe)
  - Remote locations
- Transportable
- Nearly autonomous operations
- Heat-pipe cooled designs
INDUSTRY NEEDS FOR VTR

• Commercial interests

• Advanced fuels/materials/instrumentation & sensors are needed for a variety of fast reactor concepts
  • Sodium-cooled reactors (e.g. GEH, TerraPower)
  • Lead/LBE-cooled reactors (e.g. Westinghouse)
  • Gas-cooled reactors (e.g. General Atomics)
  • Molten salt reactors (e.g. TerraPower)

• Accelerated testing of materials for all types of reactors also is needed.

Some concepts may be ready for an initial demonstration unit within 10 years
  • VTR will help with continuous improvements in operations and economics beyond initial demonstration
    • LWR technology evolution history (progress from 60 to 90% availability)
    • Russia building a new test fast spectrum reactor even though they already have 2 commercial scale power plants

Domestic Deployment

Global Market Share (~$1 T)
NATIONAL SECURITY/SCIENCE INTERESTS ON VTR

• State-of-the art knowledge of fast spectrum reactor technologies to keep up with global trends
  • Global safety and security policies
  • Safeguards technologies
• Research on long-term fuel cycles
• Potential scientific research on
  • High energy neutron irradiations
    • Fusion materials
  • Nuclear Physics/ e.g. Neutrino science
  • Safeguards detectors

Science & technology leadership with strong influence on international standards and policies for the civilian use of nuclear energy and associated fuel cycles.

• The only fast spectrum testing capability is currently in Russian Federation
• Given concentrated development efforts in Russia, China and India, U.S. leadership and influence is in jeopardy
## Preliminary requirements/assumptions for VTR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target</th>
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<tbody>
<tr>
<td>High neutron flux</td>
<td>$\geq 4 \times 10^{15}$ n/cm$^2$-s</td>
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<tr>
<td>High fluence</td>
<td>$\geq 30$ dpa/yr</td>
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<td>High test volume in the core</td>
<td>$\geq 7$ L (multiple locations)</td>
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<td>Representative testing height</td>
<td>$0.6 \leq L \leq 1$ m</td>
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<tr>
<td>Flexible test environment</td>
<td>Rabbit &amp; Loops (Na, Pb, LBE, He, Salt)</td>
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<td>Advance instrumentation &amp; sensors</td>
<td>In-situ, real time data</td>
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<tr>
<td>Experiment life cycle</td>
<td>Proximity to other infrastructure</td>
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<tr>
<td>Driver fuel life cycle management</td>
<td>Existing facilities as much as possible</td>
</tr>
</tbody>
</table>

### ASSUMPTIONS:
- Mature Technology: Sodium-cooled pool type reactor
- Metallic alloy fuel (HALEU, LEU+Pu, DU-Pu)
- Novel testing capabilities
- Start date: FY2026, Q4
To achieve the lowest risk acquisition, the following principles guide the acquisition:

- Use proven technology and materials with modern design and construction tools
- Reduce scope to the absolute minimum, utilizing or modifying existing facilities
- Streamline acquisition processes to achieve the least overall risk
- Use the best resources
- Understand and mitigate the nuclear design/construction risks.

GE-HITACHI & BECHTEL DELIVERABLES

- Adapt PRISM concept for VTR mission... delete/add/modify SSCs
- Advance conceptual/preliminary design
- High confidence cost assessment
- High confidence schedule assessment
<table>
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<tr>
<th>Milestone</th>
<th>Fiscal Year</th>
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<tbody>
<tr>
<td>CD-0</td>
<td>FY 2019, Q2 (Approved)</td>
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<tr>
<td>CD-1</td>
<td>FY 2021, Q1</td>
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<tr>
<td>CD-2/3</td>
<td>FY 2022, Q4</td>
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<tr>
<td>CD-4</td>
<td>FY 2026, Q4 (FY 2028, Q4 with contingency)</td>
</tr>
</tbody>
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**Research and Development Phase**
- 2017: Program Initiation Completed
- 2018: Mission Need Developed
- 2019: CD-0 Approve Mission Need, for DOE Approval
- 2020: Alternative Selection Completed
  - CD-1/3A Approve Alternative Selection and Cost Range, and Long-lead Procurement Approval, for DOE Approval
- 2022: Reactor Concept Design Initiated
- 2024: Reactor Installation Complete
  - CD-2/3 Approve Performance Baseline and Approve Start of Construction, for DOE Approval
- 2026: Reactor Start-up Initiated
  - CD-4 Approve Start of Operations, for DOE Approval

**Final Design, Construction, and Startup Phase**
- 2026: Start of Operations Complete
- 2027: A fully operational Versatile Test Reactor providing 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 advanced reactor systems.
Summary & Conclusions

• There is a major role to play for advanced reactors in global clean energy future

• There is considerable private and public investment in developing advanced reactors

• There is a clear, compelling mission need for VTR
  • VTR is essential for the U.S. to regain global leadership in the next generation of advanced reactors

• DOE-NE is investing in the R&D infrastructures to assure a sustainable advanced reactor industry in the long-run.
  • Multiple facilities and upgrades for PIE, ATR Upgrades, TREAT already restarted
  • Versatile Test Reactor (VTR) targeted for availability at the end of 2026.

• The radiation monitoring and safety needs for advanced reactors may be considerably different than the needs for LWRs
  • Different Neutron Energy Spectrum
  • Greater Penetration of Reactor Neutrons
  • Different gasses available for activation within primary coolant system (e.g. Argon in primary vessel for VTR)
  • Different fuel forms with associated mechanistic source terms

• VTR can be beneficial for RAMP community
  • Development and Demonstration of Detectors in Fast Neutron Spectrums.
  • Cartridge loop conditions provide opportunity to observe and measure important code parameters.
  • Facility and experiments provide opportunities for code V&V benchmarks.