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

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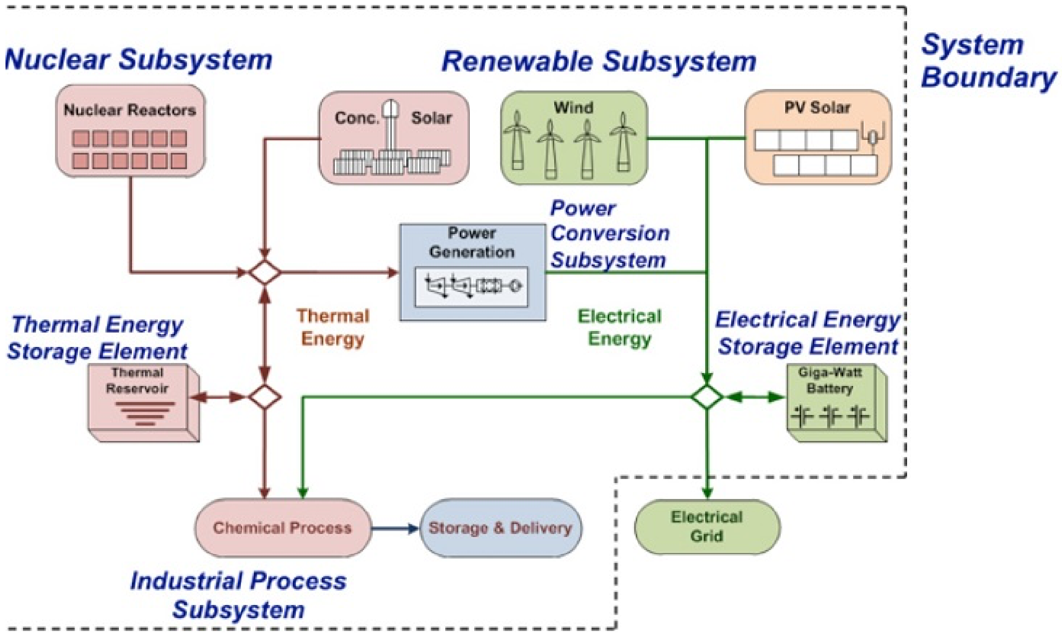
ADVANCED REACTORS - U.S. COMMERCIAL STATUS

- 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

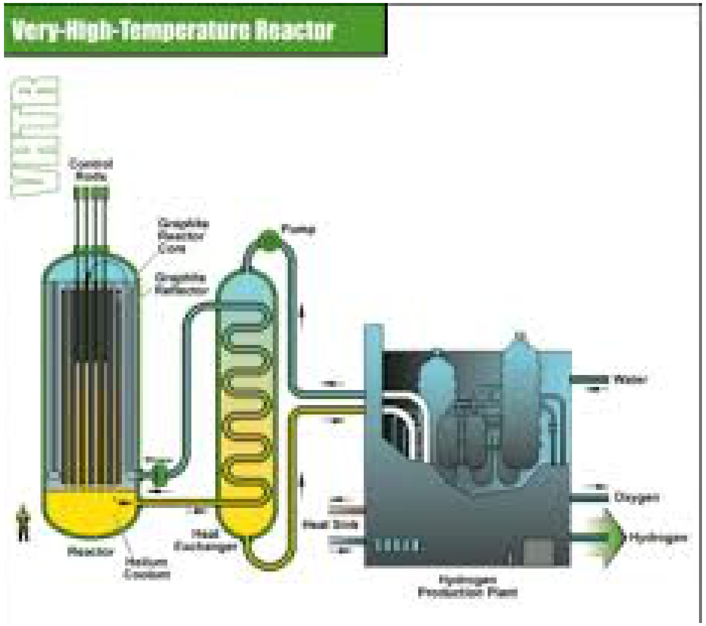
ADVANCED REACTORS – COMMON FEATURES

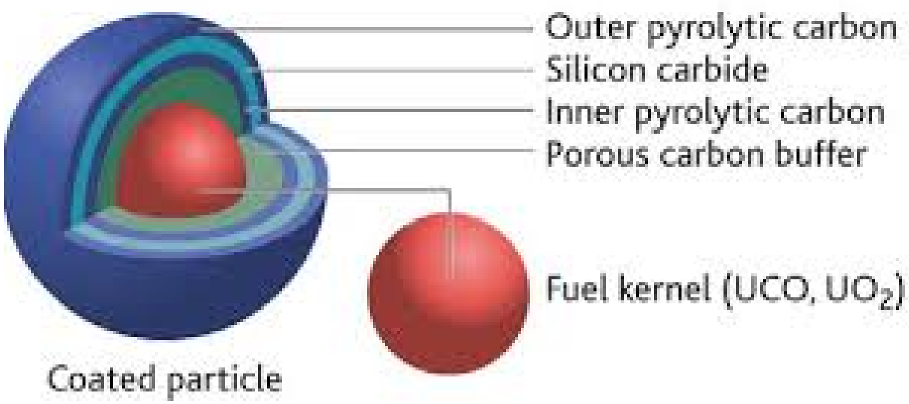
- Smaller size with modular construction
  - Economies of scale vs economies of modularity
- Higher efficiency and lower environmental impact
- Enhanced inherent safety
  - Negative reactivity feedback
  - Heat removal by natural circulation
  - Low pressure
- Lower high level radioactive waste
- Applications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

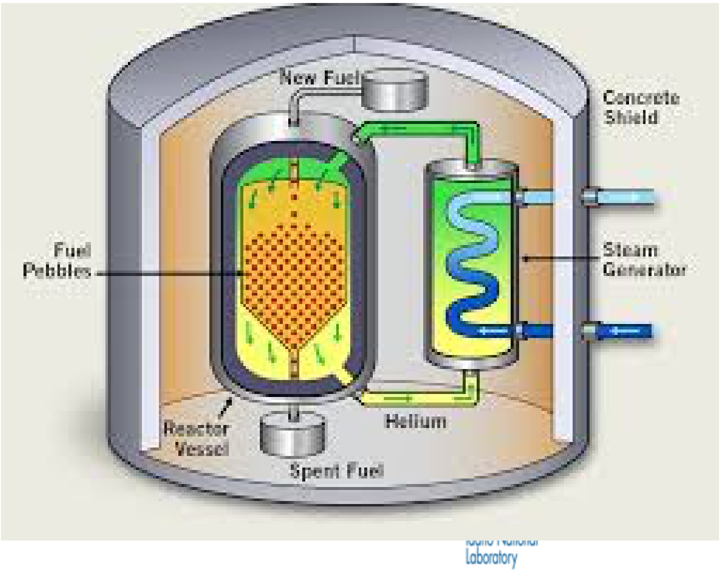


ADVANCED REACTORS – HIGH TEMPERATURE REACTORS

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

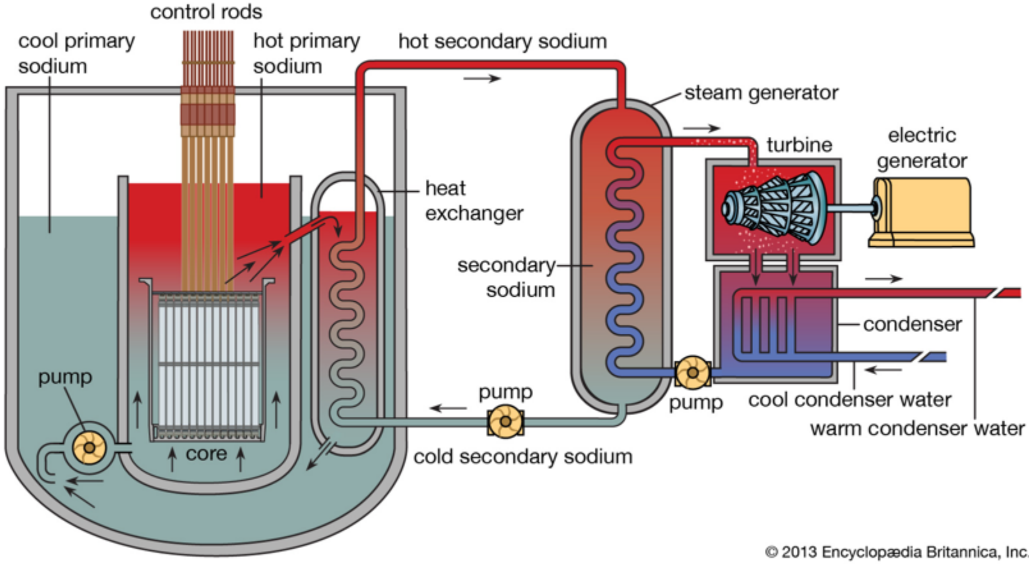






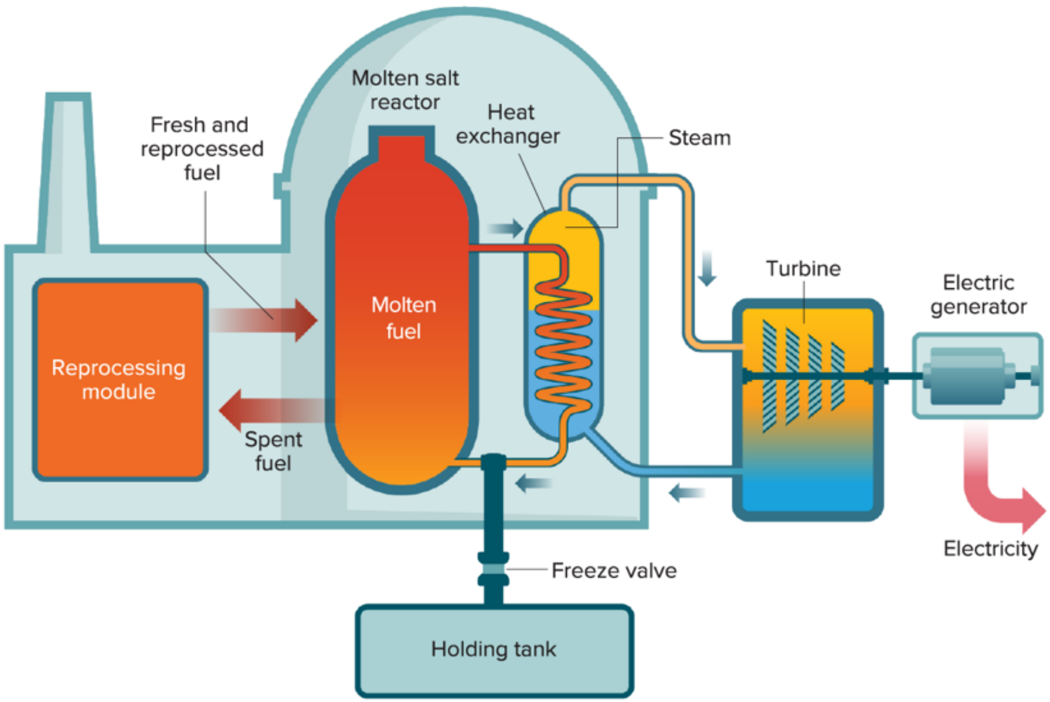
ADVANCED REACTORS – FAST REACTORS

- 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



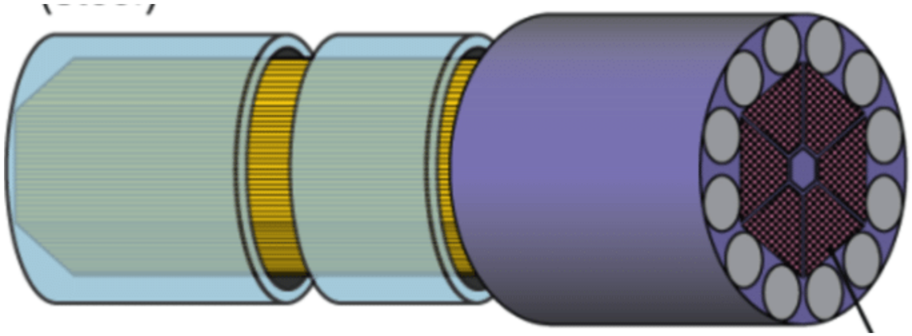
ADVANCED REACTORS – MOLTEN SALT REACTORS

- 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.

→ Domestic Deployment

→ Global Market Share (~$1 T)

- **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

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NATIONAL SECURITY/SCIENCE INTERESTS ON VTR

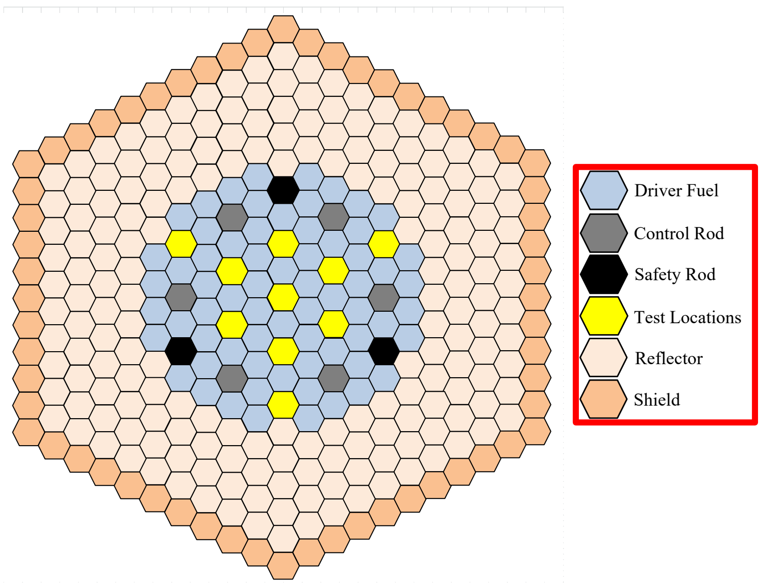
- State-of-the art knowledge of fast spectrum reactor technologies to keep up with global trends
  - Global safety and security policies
  - Safeguards technologies
- Research on long-term fuel cycles
- Potential scientific research on
  - High energy neutron irradiations
    - Fusion materials
  - Nuclear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

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



ASSUMPTIONS:

- Mature Technology: Sodium-cooled pool type reactor
- Metallic alloy fuel (HALEU, LEU+Pu, DU-Pu)
- Novel testing capabilities
- Start date: FY2026, Q4

Reactor design support contract

To achieve the lowest risk acquisition, the following principles guide the acquisition:

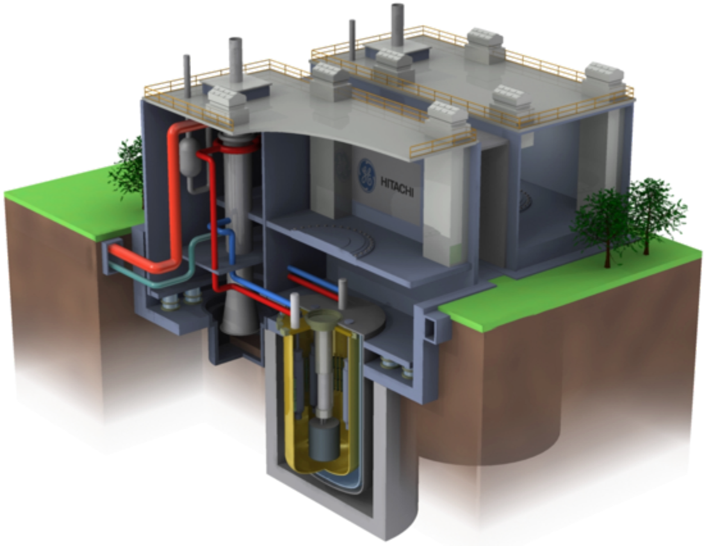
- Use proven technology and materials with modern design and construction tools
- Reduce scope to the absolute minimum, utilizing or modifying existing facilities
- Streamline acquisition processes to achieve the least overall risk
- Use the best resources
- Understand and mitigate the nuclear design/construction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

DOE

BEA

GEH

Bechtel



Courtesy of GE-HITACHI

GE-HITACHI & BECHTEL DELIVERABLES

✓ Adapt PRISM concept for VTR mission… delete/add/modify SSCs

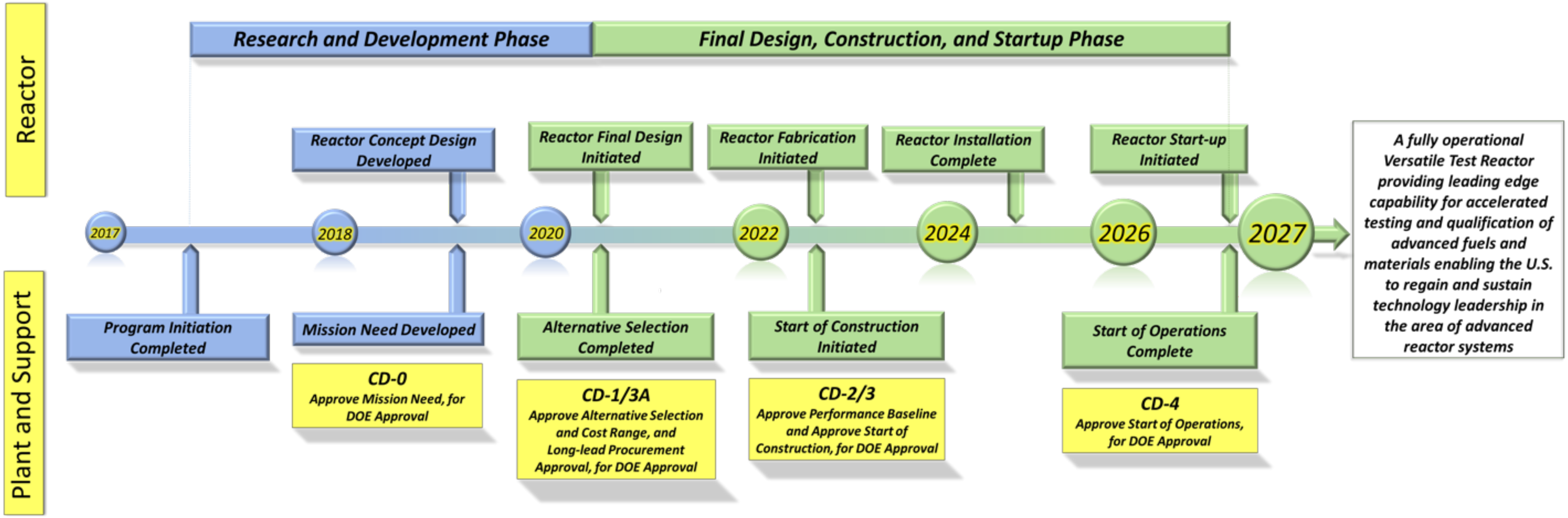
✓ Advance conceptual/preliminary design

✓ High confidence cost assessment

✓ High confidence schedule assessment

VTR Project Schedule Estimates

Milestone	Fiscal Year
CD-0	FY 2019, Q2 (Approved)
CD-1	FY 2021, Q1
CD-2/3	FY 2022, Q4
CD-4	FY 2026, Q4 (FY 2028, Q4 with contingency)



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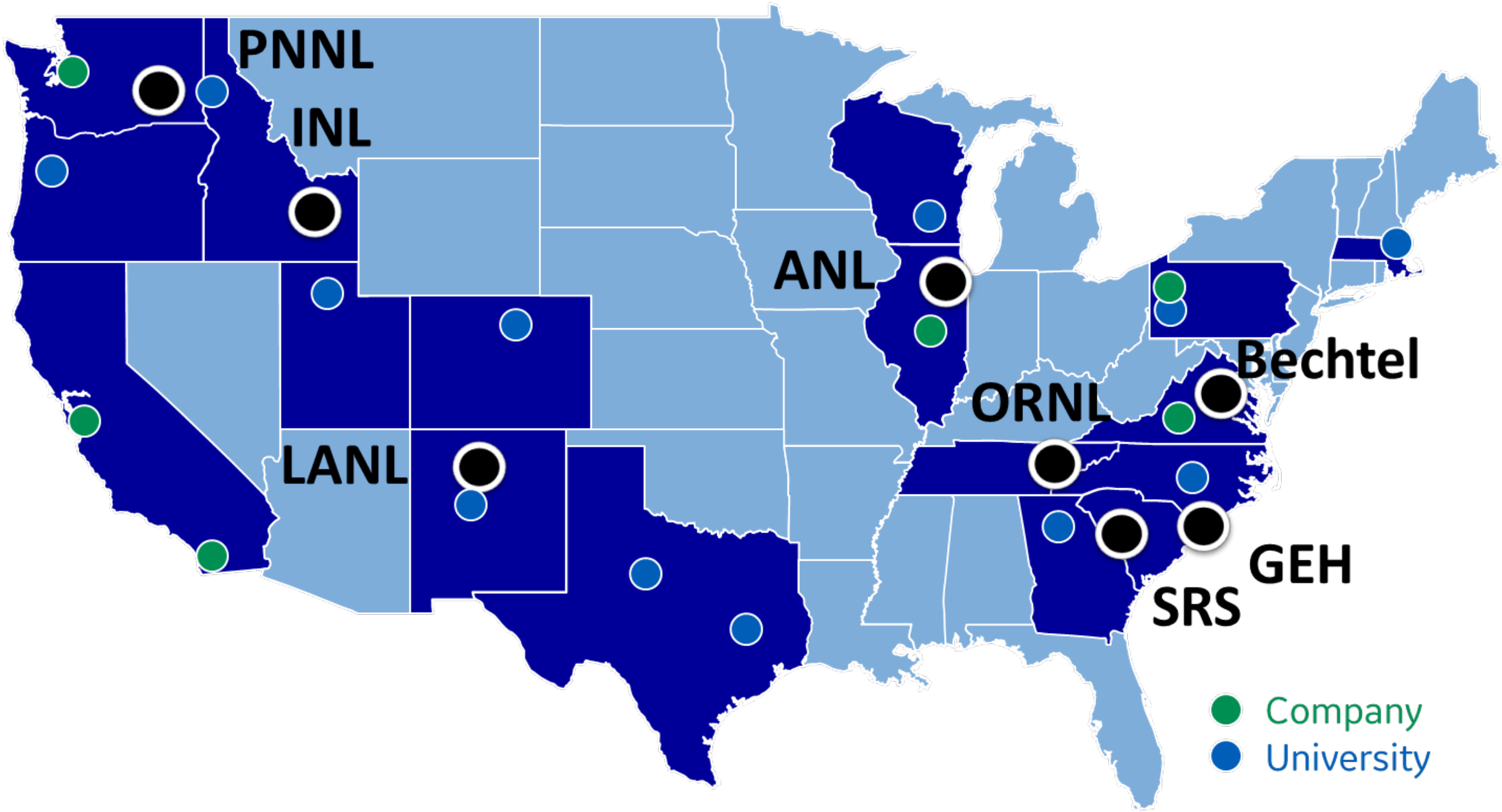
Current National VTR Team



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.