U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Test and Demonstration Planning Study

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Advanced Test/Demo Reactor Planning Study

- **FY15 Omnibus Spending Bill**
  "$7,000,000 is for an advanced test/demonstration reactor planning study by the national laboratories, industry, and other relevant stakeholders of such a reactor in the U.S. The study will evaluate advanced reactor technology options, capabilities, and requirements within the context of national needs and public policy to support innovation in nuclear energy."

- **Nuclear Energy Advisory Council (NEAC):** Providing study advice via Nuclear Reactor Technology Subcommittee (NRT).

- **Objective:** provide transparent, and defensible options to address need for, and technology of, a test and or demonstration reactor(s) to be built to support innovation and long term commercialization.

- **Leadership:** Led by joint laboratory team from ANL/INL/ORNL

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Schedule

- Workshop to develop criteria and metrics – April 23/24, 2015
- Begin Technology Assessment evaluation – June 15, 2015
- Form test/demo point design teams – June 30, 2015
- Complete DOE criteria, metrics, weighting review – August 15, 2015
- Distribute annotated outline for ATDR Study – August 18, 2015
- Draft Technology Assessment Report – August 31, 2015
- Begin test/demo point designs – September 1, 2015
- Complete test/demo point designs – January 31, 2016
- Test/demo point design review webinar – February 3, 2016
- Point Design evaluations scored week of February 22, 2016
- Final report incorporate DOE comments – April 30, 2016
- **Draft report under review by NEAC NRT sub-committee**
- **Presentation to NEAC June 17, 2016**

Test vs Demonstration

- **Test – Irradiation Services:**
  - Primarily for R&D
  - Provides appropriate environment
  - Must support development of advanced reactors
- **Demonstration – Technology Validation**
  - Demonstrate integrated reactor technology
  - Demonstrate transient performance
  - Provides flexibility to swap out components
  - Provides feedback on design, construction and operations
- **Terminology developed independent of NRC licensing**

Reactor Development Steps:

US and International Experience for Advanced Reactor Systems

TRL 1-3

Research and Development

- Prove scientific feasibility associated with fuel, coolant and geometrical configuration

TRL 3-5

Engineering Demonstration

- Reduced scale
- Proof of concept
- For concepts that have NEVER been built
- Viability of the integrated system

TRL 6-7

Performance Demonstration

- Establish that scaleup of the system works
- Gain operating experience to validate integral behavior of the system
- Proof of performance

TRL 8-9

Commercial Demonstration

- Full scale to be replicated for subsequent commercial offerings if system works as designed

Deployment Examples

Step in Deployment Path	LWR (example)	SFR		HTGR		LFR		MSR	
	US	US	Int'l	US	Int'l	US	Int'l	US	Int'l
R&D for scientific feasibility	SPERT, BORAX, PBF	SEFOR – (20 MWth), TREAT	CABRI						
Engineering Demonstration	S1W, EBWR	EBR-1 – (1.4 MWth) EBR-11 – (20 MWe)	Dounreay – (14 MWe), Rhapsodie – (40 MWth)	Peach Bottom (40 MWe)	DRAGON (20 MWth) HTR-10 (10 MWth) HTTR (30 MWth) AVR (15 MWe)		Soviet subs[a]	Aircraft Reactor Experiment (2.5 MWth), MSRE (7.4 MWth)[b]	
Performance Demonstration	USS Nautilus, Shippingport	Fermi-1 – (69 MWe) FFTF – (400MWth)	Phenix (233 MWe) Monju (300 MWe) BN-300 & -600 – 300 & 600 MWe) PFR (250 MWe)	FSV (842 MWth)[c]	THTR (750 MWth)[c]				
Commercial Demonstration	Yankee Rowe (485 – 600 MWth)		Superphenix – (3000 MWth) BN-800 (800 MWe)		HTR-PM (200 MWe)				

[A] The Soviet experience with lead-bismuth eutectic cooled submarine reactors is relevant but not directly applicable to the LFR point design, therefore, they are considered engineering demonstration reactors for the LFR.

[B] The Aircraft Reactor Experiment and MSRE were liquid fueled reactors, with different coolant chemistry than the salt-cooled FHR demonstration point design.

[C] FSV and THTR were commercial demonstrations of large HTGRs, however, for modular HTGRs under consideration today, they serve the role of a performance demonstration.

Strategic Objectives

- **Demonstration Reactors:** fundamental mission is to provide efficient, reliable electricity production without carbon emissions
  1. Deploy a **high temperature process heat application** for industrial applications and electricity demonstration using an advanced reactor system to illustrate the potential that nuclear energy has in reducing the carbon footprint in the US industrial sector
  2. Demonstrate **actinide management** to extend natural resource utilization and reduce the burden of nuclear waste for future generations
  3. Deploy a **small scale demonstration reactor for a less mature reactor technology** with the goal of increasing the technology readiness level of the overall system for the longer term

- **Irradiation Test Reactor:** Built upon a reliable platform
  4. Provide an **irradiation test reactor** to support development and qualification of fuels, materials and other important components (e.g. control rods, instrumentation) of both thermal and fast neutron-based Generation IV advanced reactor systems

Technical Readiness

- Based on assessment of reactor systems at subsystem level
- Leveraging recent detailed assessments performed by Generation IV International Forum, GNEP, and NGNP programs

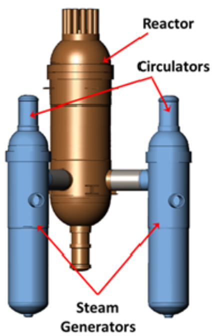
High Maturity
- Modular High Temp Gas-Cooled
- Sodium Cooled

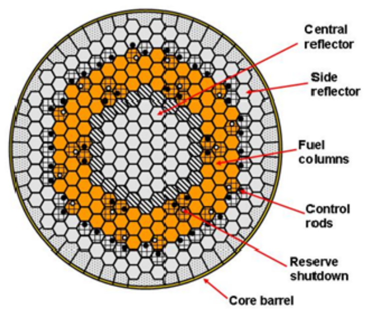
Low Maturity
- Lead Fast
- Molten Salt Fueled
- Fluoride High Temp.
- Supercritical Water
- Advanced Sodium-Cooled and Very High Temperature

Very Low Maturity
- Gas Cooled Fast

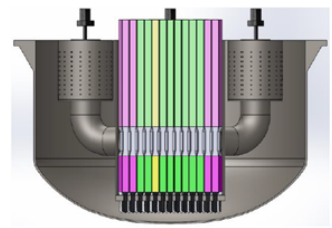
Preliminary Options

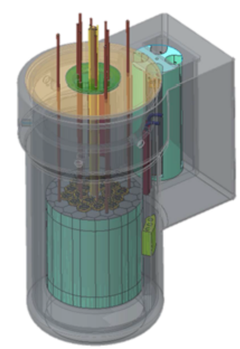
Strategic Objective 1: Process heat demonstration – modular HTGR



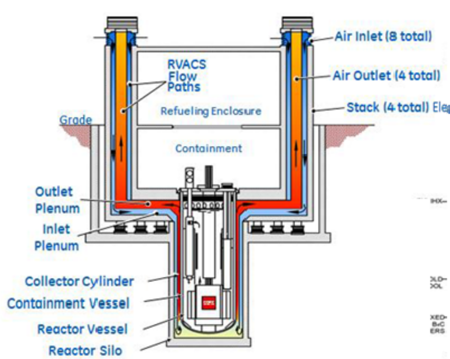


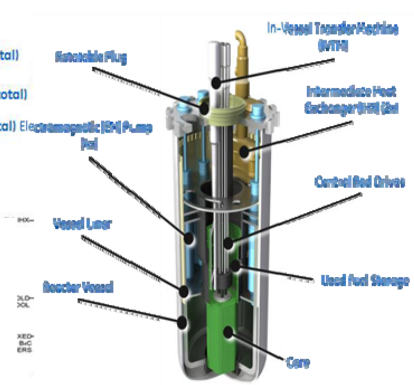
Strategic Objective 3: Demonstrating a Less Mature Technology – FHR or LFR



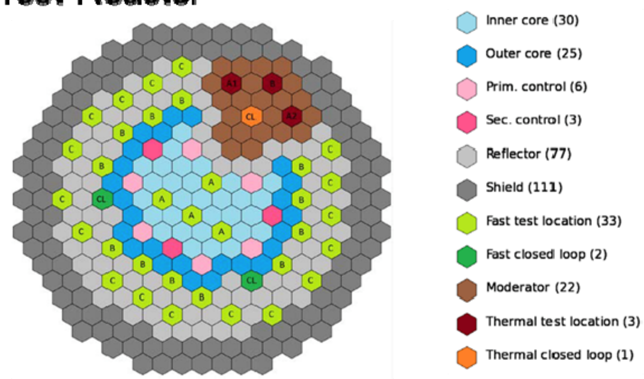


Strategic Objective 2: Resource Utilization and Waste Management – SFR



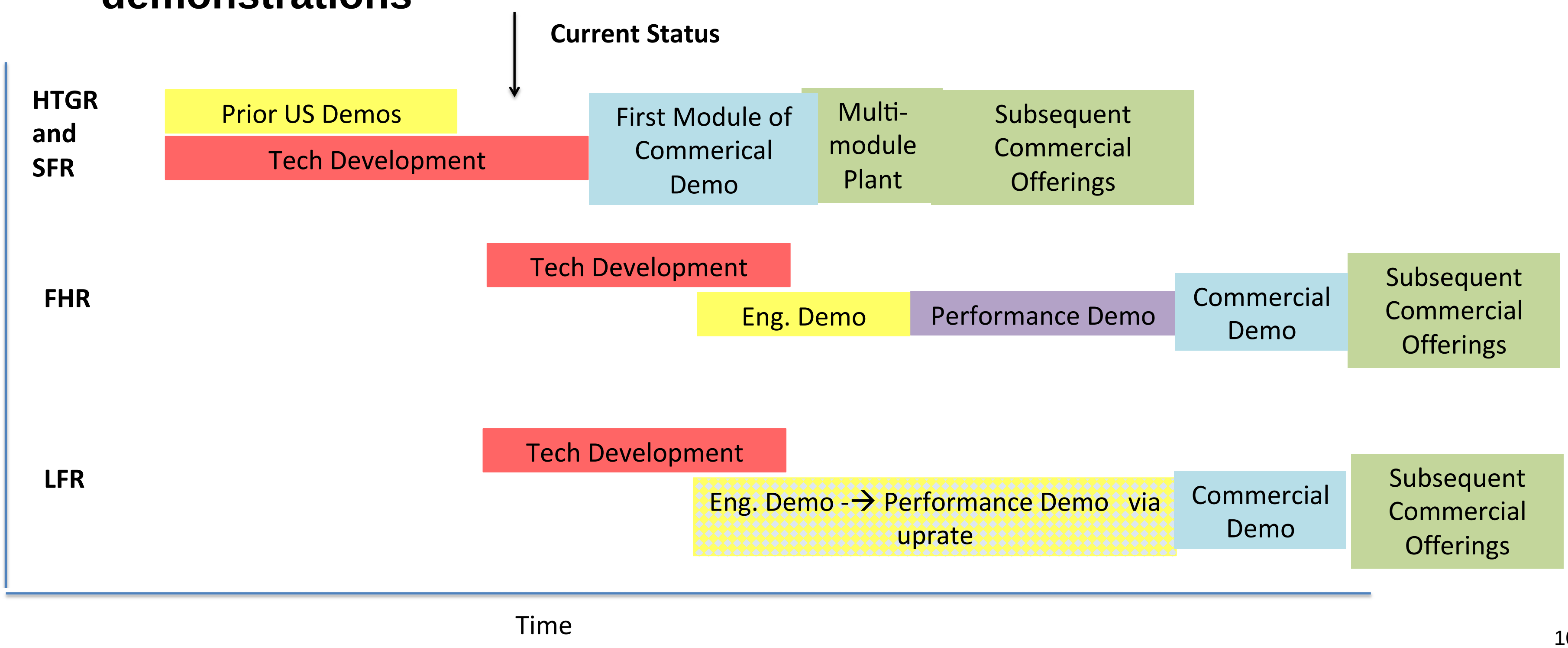


Strategic Objective 4: Test Reactor to Provide Neutrons – Sodium–cooled Fast Test Reactor



Deployment

- Depends on maturity of the concept
- SFR and MHTGR are closest to commercial deployment. Basic technologies have been demonstrated.
- Less mature technologies require additional R&D and early stage demonstrations



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Cost and Schedule

- **Mature Demo Concepts (SFR and HTGR)**
  - Cost to operation of first module for mature concepts is ~$4 billion; schedule is 13 to 15 years, driven by design, licensing and construction. Operation of first module by 2030
- **Less Mature Demo Concepts (LFR and FHR)**
  - Cost is ~$2-4 billion and is highly uncertain and take 20 years to get through initial operation of the demonstration
  - Still will require a prototype in the 2040 timeframe and commercial offerings in the 2050 timeframe
- **Irradiation Test Reactor Options**
  - Cost is ~$ 3 billion with impact of test loops yet to be established; schedule is 13 years driven by design, licensing and construction and not technology

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Licensing

- **For the mature concepts (SFR and HTGR)**
  - Vendors (GE and AREVA) report that they would pursue a commercial Class 103 NRC license.
  - Considerable data exist from past demonstration projects and R&D activities conducted over past 50 years. Safety evaluation reports by NRC exist for each of these technologies
  - Vendors plan on licensing first module using two-step Part 50 process to confirm prior data in an integrated manner. They will gain operational experience from that unit to apply for a design certification and licensing of follow-on modules using one-step Part 52 licensing process.
- **For the lower maturity technology demonstration and test reactors**
  - A Class 104c non-power reactor license is expected to allow for greater flexibility given state of technology. 104b demo power reactor route not available
  - This approach has been used in past for university reactors.
  - Licensing of larger demonstration and test reactors is allowed under this section but has not been exercised under NRC. Last large scale demonstrations were docketed in US (e.g. Fermi-1) before NRC existed (pre-1972).
  - Once these demonstrations get much larger than about 10-20 MWth, expectation is that NRC would likely apply same level of technical review to either "test" reactor or to its commercial counterpart, due to potential public risk from larger source term.