Nuclear Technology R&D Subcommittee Report

Presentation to the

Nuclear Energy Advisory Committee

Washington, D.C.

July 9, 2018

Al Sattelberger

Subcommittee Members

- Carol J. Burns
- Margaret Chu*
- Michael Corradini
- Raymond Juzaitis
- Chris Kouts
- Ronald P. Omberg
- Joy L. Rempe
- John Stevens
- Dominique Warin
- Alfred P. Sattelberger (Chair)

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Nuclear Technology R&D Subcommittee

- One day meetings on 12/11/2017 and 5/7/2018
- Presentations covered:
  - Budget Updates
  - Versatile Test Reactor (VTR)
  - Accident Tolerant Fuels (ATFs)
  - Advanced Manufacturing, including 3-D Printing
  - Material Protection, Accounting and Control Technologies (MPACT) and Codecontamination (CoDCon) Project
  - Portable Micro Reactors for Remote Applications
  - TREAT Restart
  - NE-4 Education Activities

NE-4

DAS for Nuclear Technology Research and Development

John Herczeg

NE-41
Office of Advanced Reactor Technologies
Alice Caponiti

NE-42
Office of Advanced Fuels Technologies
Bill McCaughey

NE-43
Office of Materials and Chemical Technologies
Patricia Paviet

Budget Highlights

- Interim Storage and Transportation planning scope moved under new Yucca Mountain (YM) and Interim Storage Programs, which plan to restart licensing activities for the YM nuclear waste repository and to initiate a robust interim storage program.
- Significant plus-up in Advanced Fuels
- Significant plus-up in Advanced Reactor Technologies
- FY18 Versatile Test Reactor (VTR) funding at $35M (request $10M)
- $60M for U.S industry awards in support of advanced nuclear technology development

Versatile Test Reactor (VTR)

NEAC Advice:

- The need for a VTR was established through a series of independent surveys of the potential U.S. user community (industry, DOE programs) and support from international partners resulting in a NEAC report (“Assessment of Missions and Requirements for a New U.S. Test Reactor” 2/2017). It states that “The Ad Hoc NEAC subcommittee recommends that DOE-NE proceed immediately with pre-conceptual planning activities to support a new test reactor (including cost and schedule estimates).”

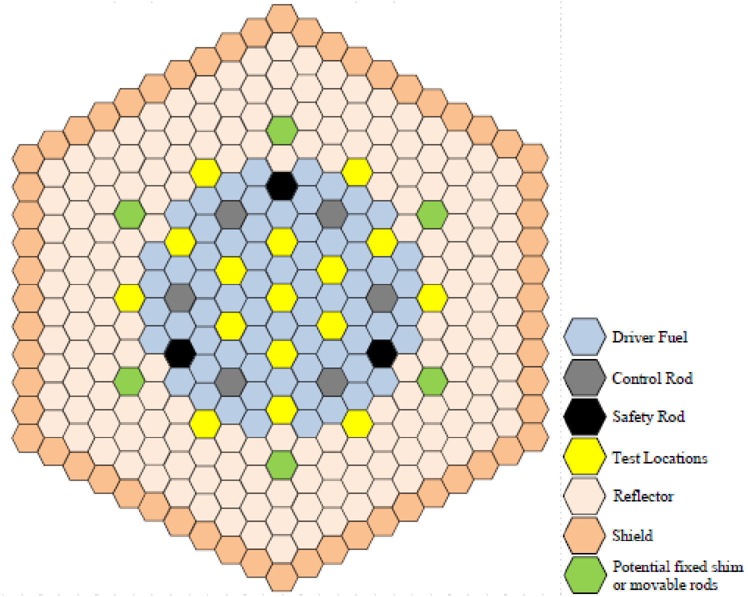
Goals:

- 3 year R&D effort, along with appropriate reviews and planning, leading to an operational VTR by 2026
- VTR would support accelerated development of advanced fuels and materials for U.S. advanced reactor vendors, as well as provide the capability for testing those fuels and materials to support licensing by the NRC.
- VTR with a high fast neutron flux would revitalize our research infrastructure and remove a critical impediment for U.S. developers of advanced nuclear energy technologies.
- Constructed and operated under DOE authority, in close collaboration with NRC.
- $35 million in 2018 Omnibus for VTR’s R&D activities to achieve CD-0 in 1/2019.

VTR Draft Requirements/Assumptions

1. Conduct a 3 year R&D effort on core design.
2. Reach fast flux of ~4.E15 n/cm^2-s, with prototypical spectrum
3. Load factor: as large as possible (*maximize dpa/year to > 30 dpa/year*)
4. Provide flexibility for novel experimental techniques
5. Be capable of running loops representative of typical fast reactors *(Candidate Coolants: Na, Lead, LBE, Gas, Molten Salt)* – May be a single location with replaceable loops.
6. Effective testing height ≤ 1 m
7. Ability to perform large number of experiments simultaneously
8. Metallic driver fuel (possible options: HA-LEU, LEU+Pu)

VTR draft core map



Versatile Test Reactor

Recommendations:

- The Subcommittee is encouraged by the two track approach to DOE O413.3B, but recommends that an integrating function be included in the project management so the two tracks can work together as efficiently and effectively as possible.
- It is evident that the Project is in its early planning stages. As it moves forward and matures, the Subcommittee recommends that:
  - The Project develop a best cost estimate and a schedule with an identifiable critical path,
  - The Project review the critical path for potential areas of delay and develop contingency plans in the event such delays should occur,
  - The Project develop an integration function to coordinate the two tracks with the objective of identifying and managing potential delays in advance,
  - The Project execute regulatory engagement throughout the project,
  - The Project develop and then execute an experimenter engagement plan to identify industrial customers, to develop an understanding of their experimental needs, and to prioritize test vehicles and instrumentation design and deployment.
- The Subcommittee looks forward to regular updates with respect to progress on the VTR Project.

Accident Tolerant Fuel (ATF) Program

General Comments/Observations:

- The ATF Program has been tasked by Congress to pursue the development and qualification of ATFs that would enhance the safety of present and future generation LWRs
- Vendors are pursuing a strategy that relies on the ability of ATFs to significantly extend the time before initiation of the exothermic oxidation reaction of the zircaloy cladding used in current LWR fuel.
- The TRLs differ as does the associated qualification approach proposed by each vendor. Ultimately, all 3 vendors (GE, Framatome and Westinghouse) will need to qualify their fuels for high burnup (> 62 GWD/MtU)
- DOE has developed infrastructure to support LOCA testing of irradiated fuel at ORNL, and irradiated fuel material characterization and thermal property testing at INL.
- In 2017, DOE signed a MOU with the NRC whereby NRC could access information from DOE necessary to prepare for licensing ATF concepts, and to help ensure that DOE's R&D program focuses on the key safety issues associated with licensing.

Accident Tolerant Fuel (ATF) Program

Table 2: Recent Alterations to ATF-2 Irradiation

Vendor	Description	ATF-2 Irradiation	
		Described DEC 2017	Described MAY 2018
GE	Iron-Chromium-Aluminum (FeCrAl) Alloy Cladding on UO_2 Fuel	Yes	Withdrawn
	Coated Cladding [ARMOR] on Uranium Dioxide (UO_2) Fuel	Not Planned*	Not Planned
Framatome	Chromium-Coated M5® Cladding on Chromia-doped UO_2 Fuel	Yes	Still Planned
Westinghouse	Chromium-coated Zirlo Cladding on Uranium Disilicide (U_3Si_2) Fuel (EnCore™)	Yes	Still Planned, but with UO_2
	SiC cladding on Uranium Disilicide (U_3Si_2) Fuel	Yes	Being re-scoped
INL Fabrication	Zircaloy clad on UO_2 pellets, “Standard PWR pins” to be irradiated for use in TREAT tests	Not Planned	Now Planned

Accident Tolerant Fuel (ATF) Program

General Comments/Observations:

- Presentations made to the Subcommittee again claimed enhanced safety associated with the use of ATFs, but w/o a description of the data collection plan that will validate these claims.

Recommendations:

- Re-evaluate the current strategy for ATF deployment. The revised strategy should include input from the regulator to ascertain exactly what data are required for rendering regulatory decisions.
- If it is determined that the required data should be obtained from U.S. facilities, then the revised strategy should describe upgrades required at the facilities or their instrumented experimental capabilities. The Subcommittee believes it is unlikely that ATFs can be commercialized w/o implementing this revised strategy.
- Efforts to develop a business case should be expedited to provide confidence that ATF efforts will yield a product that can be commercialized.

Advanced Manufacturing, incl. 3-D Printing

General Comments/Observations:

- Over the past 6 years, the program has funded $15M of work (plus 10 NSUF projects totaling $10M)
- The program is (appropriately) examining a broad range of advanced manufacturing approaches. Methods under evaluation include high-speed welding techniques, high strength concrete and rebar, advances in manufacturing processes (incl. hot isostatic pressing, additive manufacturing, and surface modification methods), as well as improved construction, inspection and testing methods.
- Most projects appeared to focus on development of the manufacturing process. Less mention was made on the qualification of materials for their intended purpose.

Recommendation:

- Review the scope of the program and set strategic directions. Is the purpose to 'seed' innovative techniques or to demonstrate more quantifiable advantages to adoption of one or more methods in particular applications?

MPACT and CoDCon

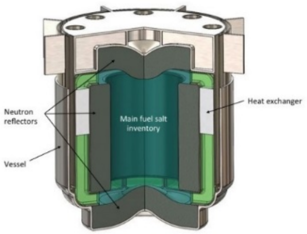
General Comments/Observations:

- The objectives for MPACT include:
  - Develop and demonstrate advanced material control and accounting technologies, addressing important gaps
  - Develop, demonstrate and apply analysis tools to assess effectiveness and efficiency, guide R&D, and support advanced integration tools
  - Perform technical assessments in support of advanced fuel cycle concepts and approaches.
  - Develop guidelines for safeguards and security and apply to new facility concepts
- Complete lab-scale demonstration of an advanced safeguards and security system by 2020.
- CoDCon is a study of the use of on-line process instrumentation to prepare a 70:30 U:Pu MOx material using a co-decontamination flowsheet applied to used commercial nuclear fuel.

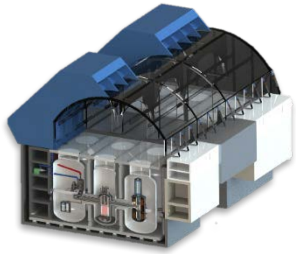
- **Recommendations:**
  - Subcommittee is pleased with progress to date on the CoDCon demo.
  - More lab-scale research is needed before moving to engineering-scale.

Advanced Reactor Technologies Focus Areas

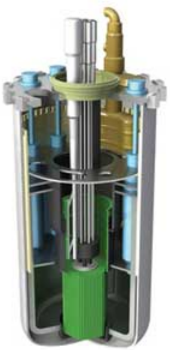
- Advanced Light Water Reactors
- Fast Reactor Technologies
  - Demonstrate feasibility of advanced systems and component technologies
  - Methods and code validation to support design and licensing
  - Advanced alloy materials qualification for metal-cooled systems
- Gas Reactor Technologies
  - Advanced alloy and graphite materials qualification for high temperature gas-cooled systems
  - Scaled integral experiments to support design and licensing
  - TRISO-coated particle fuel development and qualification
- Molten Salt Reactor Technologies
  - Investigate fundamental salt properties
  - Materials, models, fuels and technologies for salt-cooled and salt-fueled reactors
- Cross-Cutting Technologies
  - Advanced energy conversion
  - Supercritical Carbon Dioxide (sCO_2) Brayton Cycle
  - Micro reactors for remote defense and commercial applications



TerraPower MCFR


GA Gas-cooled Fast Reactor


NuScale PWR


GE Hitachi PRISM

Portable Micro Reactors for Remote Applications

General Comments/Observations:

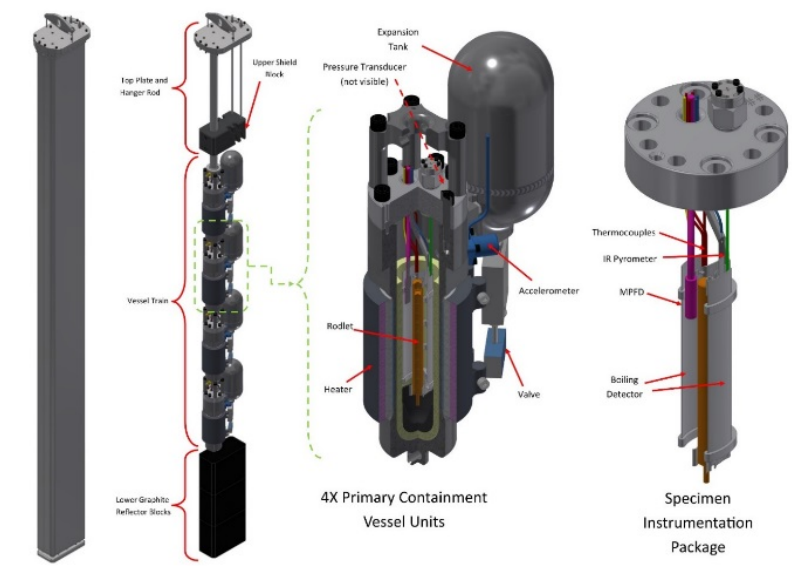
- Deployable nuclear power sources that can be integrated into very small electrical grids, including those in remote locations. A joint Los Alamos-INL design effort was described for a heat pipe cooled, UO_2 fueled reactor weighing less than 50 tons.
- Requirements include:
  - Amenability to rapid deployment, e.g., air transportability
  - Low, scalable power in the range of 2-10 MWe
  - Operational within 3 days of arrival; removal within 7 days of shutdown
  - Inherent safety and security
  - Ease of operation and cost effectiveness

Recommendations:

- In addition to preparing for anticipated regulatory action, the design team should also complete a quantitative Proliferation Resistance and Physical Protection (PRPP) analysis, perhaps in conjunction with NNSA, on the eventual baseline design to facilitate even broader public acceptance of deployed nuclear energy technology.

TREAT Restart

- Achieved criticality on November 14, 2017.
- Calibration and start-up testing continues
- Test vehicles are being developed for transient testing of multiple fuel types in the next few years.



- Over 20 GW Peak Transient Power (120 kW steady-state power)
- Core: Height (4 feet); Diameter (about 6 feet); surrounded by 2 feet graphite reflector
- Fuel: 19 x 19 array (approximately 360 fuel elements) of 4” x 4” fuel and reflector assemblies

TREAT Restart

General Comments/Observations:

- Congratulations to the Resumption Team for achieving the initial criticality of the refurbished reactor one year ahead of schedule and approximately $20M under budget.
- ATFs will require transient testing to establish their safety basis – and to quantify the advantage they represent in safety relative to current fuel designs.
- A number of advanced reactor technologies under development may require transient testing of fuel and components to establish failure modes, failure thresholds, and radionuclide source terms.
- Enhanced utilization of the existing LWR reactor fleet may be enabled via improved transient effect quantification, particularly to support advanced analytical tools.

Recommendation:

- Develop a set of “standardized test vehicles” able to perform testing on a significant variety of fuel samples. The instrumentation supported by each “standardized test vehicle” should be developed with the targeted user-community (vendors and regulators).

NE-4 Education Activities

General Comments/Observations:

- The Gen-IV International Forum (GIF) Education and Training Task Force (ETTF) was established in 2015 to share resources and collaborate in the development of curricula. Patricia Paviet is the current chair.
- ETTF has emphasized identifying and curating web-based training materials accessible in an open forum, and has initiated a set of monthly webinars – one hour on-line lectures by top-level international experts. Webinars can be viewed live and are archived.
- As of May 7, webinars have been viewed a total of 3387 times.

Recommendations:

- The Subcommittee recommends continued support, and exploring the value of this material to educational pipelines through engagement with additional stakeholders.
- The Subcommittee supports the idea of the elevation of the ETTF to a GIF working group, in order to explore bigger projects such as development of online courses (MOOC), books, and coordination of students and postdocs working on GIF-related topics.

Thank you – Questions