Report to NEAC
Nuclear Technology R&D Subcommittee
Meeting of May 7, 2018

Washington, DC
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I. Introduction
The agenda for the May 7, 2018 Nuclear Technology R&D Subcommittee meeting is shown below. The meeting provided members an overview of several research efforts funded by the DOE Office of Nuclear Energy's Nuclear Technology Research and Development Office (NE-4), and related research that is coordinated with NE-4. All members of the Subcommittee were present.

Agenda
Chair: Dr. Alfred P. Sattelberger
Location: Argonne National Laboratory, L'Enfant Conference Room B15 – 6th Floor

8:30	Arrive Argonne Office and Sign-In
8:45–9:00	Executive Committee – Closed Session
9:00–9:30	Budget Update
9:30-10:30	Versatile Test Reactor (VTR) Overview
10:30	Break
10:45-11:15	Versatile Test Reactor (VTR) Overview (cont'd)
11:15-12:00	ART Licensing Support
12:00-1:00	Lunch
12:15-1:00	NE-4 Education Activities
1:00	Break
1:15-2:00	Material Qualification and Timeline ASME
2:00-2:30	Advanced Manufacturing and 3-D Printing
2:30-3:15	CoDCon & MPACT Engagement
3:15	Break
3:30-4:30	SiC and ATF
4:30-5:30	Closed Session

As usual, our report is organized along the lines of the agenda.

II. Budget Update

Bob Rova reviewed the NE-4 FY18 Continuing Resolution (CR) budget and the breakout funding by Campaign (see below) under the CR. Noteworthy were the significant plus up in Advanced Fuels, and a nice increase (to $35M from a request of $10M) for the Versatile Test Reactor (VTR). Bob also highlighted the recent announcement of $60M of U.S. Industry Awards in support of advanced nuclear technology development.

U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Nuclear Technology R&D FY 2018 Funding by Campaign Under CR

Campaign	Funding ($000s) FY 2017	Funding ($000s) FY 2018 Omnibus	Notes
Advanced Fuels	51,250	101,800	Advanced LWR fuels, metallic transmutation fuels, crosscutting capability development
Material Recovery & Waste Form Dev't	16,300	15,620	Aqueous, electrochemical, waste forms, off-gas technologies
Fuel Cycle Options	5,200	4,360	Evaluation and screening, analyses, fuel cycle catalog
Joint Fuel Cycle Studies	7,500	7,500	US-ROK collaboration on electrochemical reprocessing
MPACT	3,800	7,200	Material protection, accounting, and control technologies
Fuel Resources	2,650	0	Uranium from seawater
Integ Waste Mgmt System	21,300	22,500	The Department is directed to continue research and development activities on behavior of spent fuel during storage, transportation, and disposal, with priority on preparation activities to testing high-burnup fuel and post-irradiation examination of spent fuel rods and on the direct disposal of dry storage canister technologies. The agreement does not include defense funds. In lieu of Senate report direction, the aggreement includes $22,500,000 for Integrated Waste Management System activities and further direction.
Used Nuclear Fuel Disposal R&D	50,300	48,650	
NEUP	26,150	33,610	Competitive awards to universities, supporting all of the technical campaigns
Headquarters-Directed Activities	11,100	6,536	Special projects, support services, management reserve
SBIR/STTR	8,600	10,410	Small Business Innovation Research/Small Business Technology Transfer
Program Assess. & Coordination	3,350	1,870	Project management, program support
Total	**207,500**	**260,056**	

III. Versatile Test Reactor

Overview

John Bumgarner (INL), the Project Manager (PM) for the Versatile Test Reactor (VTR), provided an overview presentation of the entire project to the Subcommittee. The overview covered the activities currently performed by the national laboratory team and also included the plan for engaging industry. NE has assigned the VTR project to an experienced PM, who recently successfully completed the restart of the TREAT reactor. The Subcommittee has a number of observations and recommendations that are discussed below.

Observations

With respect to beneficial results expected from experiments in the VTR, the Project has developed a testing strategy to raise the Technology Readiness Levels (TRLs) associated with the major advanced reactor technologies, specifically those needed for the Sodium-Cooled Fast Reactor (SFR), the Lead-Cooled Fast Reactor (LFR), the Gas-Cooled Fast Reactor (GFR), and fast-spectrum Molten Salt Reactor (MSR) concepts, and available for Modular High-Temperature Gas Reactor (MHTGR) and thermal-spectrum Molten Salt Reactor (MSR) concepts. Insofar as conducting the experiments themselves, the Project is in the process of developing concepts for a variety of test vehicles or test devices. Examples include Open Test Assemblies (OTAs); Instrumented Sub-Assemblies; Cartridge Test Vehicles which will be located inside an OTA and which can test for a variety of coolant systems; and a Rapid Radioisotope Retrieval System (aka a Rabbit System) which will be capable of conducting experiments to produce isotopes with short half-lives. Although all this is necessary in order to have a reactor capable of conducting a successful testing program, it appears that the Project does not have a complementary engagement plan for interacting with the experimenter community. The Subcommittee observes that such a plan is necessary to allow the Project and the experimenter community to engage in a mutually effective and supportive dialogue. The objective of this engagement plan would be to identify the customers, to define the experiments needed by these customers, to prioritize test vehicles and instrumentation needed for those customer-driven experiments, and to develop the start of a business case. The Advanced Reactor Technologies (ART) campaign structure with National Technology Directors (NTDs in gas-reactor, fast-reactor, and molten-salt-reactor, with associated technology roadmaps) and cross-cutting Technology Area Leads (TALs in energy conversion, advanced materials and special purpose applications) should be excellent resources to help the VTR team establish an experimenter engagement plan.

The Project plans to implement DOE Order 413.3B (Program and Project Management for Acquisition of Capital Assets) and to do so with a unique and innovative two track approach. The objective of this approach is to expedite the research, development, design, procurement, and construction so that the reactor can be operational within ten years. Track 1 will focus on the reactor core, fuel, and major components, such as sodium systems, including sodium heat transport systems, and refueling systems, i.e., technology and equipment that is unique to the reactor system. Track 2 will focus on the building structure necessary to have a complete fixed asset and fully operational facility. This parallel approach will allow the two quite different aspects of the VTR design/build effort to proceed in parallel with quite possibly unique schedule advantages.

To start the process of engaging industry and the capabilities that only industry can provide to design and build the VTR, the Project has a near-term plan to solicit Expressions of Interest (EOIs) in order to identify interested organizations with capability and experience in the design/build area. Having identified those organizations, the Project plans to follow this up aggressively with a series of Requests for Proposals (RFPs).

Insofar as expediting the regulatory review effort, the Project has taken the initial steps of engaging DOE-ID. Adaptation of NUREG 1537 for non-water reactors was mentioned, but without discussion of how the NRC and advanced reactor community should be involved in the adaptation. Such a plan would allow the Project and the regulator to engage in a mutual planning effort which could have distinct schedule advantages and significantly reduce project risk.

Recommendations

Although the PM gave a compelling, comprehensive, and confident presentation, the Subcommittee has a number of recommendations as follows:

(1) The Subcommittee is encouraged by the two track approach to 413.3B, 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,

(2) The Subcommittee also recommends that a regulatory engagement plan be developed to begin pre-application licensing discussions with the regulator with respect to the timing and content of the required safety case,

(3) It is evident to the Subcommittee that the Project is in its early planning stages. As the project 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.

IV. ART Licensing Support

Observations

The Office of Nuclear Energy (NE) has entered into constructive and valuable collaborations with the Nuclear Regulatory Committee (NRC) staff and industry stakeholders to develop modernization practices that would improve the licensing process, and that would promote risk-informed and performance based approaches for advanced reactor designs. These approaches would enable more streamlined licensing timelines in the overall framework of 10 CFR Parts 50 (i.e., construction permit and operating license) and 52 (design certification and combined operating license).

Industry is leading, and DOE is cost-sharing the preparation and approval of “Licensing Modernization Project” guidance that addresses: identifying licensing basis events, safety classification and performance criteria, and defense-in-depth criteria. These would apply to SMR LWRs, as well as advanced designs featuring non-LWR coolants. These are to be formalized in a Draft Regulatory Guide in 2018. This joint effort has already resulted in the NRC issuance of Regulatory Guide 1.232 on April 9, 2018, which provides guidance on developing general design criteria for advanced non-LWRs, as well as more specialized criteria for sodium-cooled fast reactors and gas-cooled thermal reactors. Both of these efforts are noteworthy and supportive of a strategy to help commercialize advanced non-LWR reactor technologies.

Recommendations

(1) The DOE-NE regulatory support effort is a reasonable program that has gotten NRC attention and substantial collaboration. However, it is just one piece of a ***broader plan that needs to be better articulated by DOE-NE***. The VTR effort as well as the ART licensing support needs to be part of an overall strategic plan for NE with specific timelines and budgets into later time periods beyond FY19.

(2) Rather than relying solely on a Federal/industrial collaborative strategy to modernize and streamline design and acceptance criteria in the body of Federal regulations, NE should also move expeditiously to promote a ***technical strategy*** developed collaboratively by the National Laboratories and industry to promote R&D priorities and reactor technical design approaches that are aligned and support the Federal regulatory modernization effort. This is one additional facet of a comprehensive plan needed to promote advanced reactor development.

(3) This technical strategy should also address ***integrated computational and experimental efforts*** specifically designed to provide a ***science-based methodology*** to: (a) quantify risk; (b) predictively reduce safety margins; and (c) significantly impact the timeline for the future regulatory cycle attending advanced reactor designs.

(4) The successful ***NEAMS*** computational program and the ***Virtual Test Reactor (VTR)*** design and instrumentation plan could be used to crystallize an NE technical campaign to identify, support, and demonstrate practical outcomes of this strategy. Instituting such a targeted campaign would serve to provide needed technical prioritization guidance to NEAMS and VTR design/operations, as well as promote the national goal of reducing regulatory burden and cycle time faced by industry in commercially deploying advanced non-LWR reactor designs.

(5) A training effort may also be needed to institute (or nurture and accelerate) a program of ***professional internships*** for ***early career*** professionals in the ***NRC***, to spend one to two years with the National Laboratories or industry. During the internship, these personnel will closely participate in the R&D and technology development programs of advanced reactors, giving them greater technical familiarization with the reactor technologies of the 21st century. Clearly such a program could also be reciprocal among National Labs, industry, and NRC.

V. NE-4 Education Activities

Patricia Paviet (NE-43) provided an overview of training activities associated with the GEN-IV International Forum (for which she is Chair of the Education and Training Task Force - ETTF). The Task Force was established in 2015 to share resources and foster collaboration in the development of curricula. A number of Gen-IV systems are expected to be demonstrated or be operational over the next decade. New workers will be required to replace expected attrition. This attrition will come from retirements, based on the demographics of the current nuclear energy workforce (information provided by NEI). The Task Force, comprised of 13 members from 9 countries and the EU, has emphasized identifying and curating web-based training material accessible in an open forum.

The ETTF has created collaborations with other education and training international networks such as ENEN in Europe and ANENT in Asia, and supported training courses and schools. The Task Force has created a social medium platform in order to exchange information on GEN-IV R&D and education and training topics through Linked In. In addition to identifying and advertising already existing training materials, the group has initiated a set of monthly webinars. These are provided live, as well as archived at their website. These webinars, posted by the Department of Homeland Security to the Interagency Network and the GIF website, consist of a one-hour online lecture (on specific Gen-IV systems or cross-cutting topics) by top-level international experts, with free attendance registration at gen-4.org. The Task Force is tracking statistics associated with the viewing of these webinars (numbers), as well as identifying the sites associated with these views (country, organization). The webinars appear to be well received, and feedback is sought from attendees. The Subcommittee applauds the success of the webinars; webinars have been viewed a total of 3387 times (live viewing: 1374; archived viewing: 2013).

Recommendation

The Subcommittee recommends continued support of these activities, including possible discussion within the ETTF of broadening of the scope of the forthcoming webinar presentations. Emphasis should be placed on exploring the value of this material to educational pipelines through engagement with additional stakeholders. For this reason, webinars should include content comprehensible to a non-GIF expert audience. In the longer term, the Subcommittee supports the idea of the elevation of the ETTF task force 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-relates topics.

VI. Materials Qualification and Timeline ASME

Materials qualification for advanced reactors is a challenging task, given the variety of reactor types being addressed (Fast Reactors, FRs; Gas Cooled Reactors, GCRs; and Molten Salt Reactors, MSRs), the challenging environments posed by those reactor designs (high temperatures, corrosive coolants, high-dpa irradiation damage, and/or potentials for other material incompatibilities), the complexity of the requirements for construction and surveillance of in-plant operations, and the long process of developing the code case for any single new material.

The Advanced Reactor Technologies (ART) Program enacted a change in leadership of Materials R&D for Advanced Reactor Concepts since the Subcommittee last heard a discussion in May 2017, in an effort to better coordinate the many materials initiatives with the needs of the three reactor focus areas (FRs, GCRs, MSRs). The presentation at the May 2018 review was at a high level, with little direct connection to the prior presentation. It would have been more helpful if the current presentation explicitly addressed progress made in the year since the ART reorganization, in terms of both technical and organizational progress.

Overall, the program continues to seek to develop ASME Section III, Division 5 Code Case (i.e., Rules for Construction and Design) to assist operators in making the case that a material meets regulatory requirements. This is accomplished through a long-term (10+ years) testing process to characterize mechanical properties (e.g., aging, creep) and coolant compatibility. This data contributes to the development of design procedures and drafting of rules. The NRC does not endorse ASME Section III, Division 5 by reference (i.e., by explicit reference in 10CFR50.55A Codes and Standards), but the NRC is evaluating acceptance of the code as “an acceptable method of meeting the regulations.”

There are NRC materials requirements for reactors beyond the scope of ASME Section III, Division 5, including corrosion and irradiation effects (radiation damage and fission product effects). The program is working to develop the technical bases that will allow an applicant to secure NRC approval of the application of specific materials in specific advanced reactor systems.

The program has historically supported efforts for high temperature materials, graphite, and fast reactor structural materials. The May 2017 presentation stated separation of priorities being pursued in FY17 and after FY17. Providing status updates on such prioritization would have been very helpful. A major shift to focus on moderate temperature material qualifications in the near term, followed by subsequent high temperature qualifications was described. While benefits of this approach are clear as expedient, it was not made clear whether the reactor focus area technology working groups endorsed the new strategy, or how the timeline of the staged approach will fit into the focus area roadmaps.

As we saw in an ART overview last year, MSR systems have more diverse materials issues, given the much greater diversity of designs and somewhat more unique performance requirements (e.g., unusual corrosion considerations). As a result, the strategy is to build on the use of materials for which ASME code cases already exist. The May 2017 presentation indicated that MSR-related efforts would scale-up in FY18, and that scale-up was presented. Like the staged approach for moderate- vs. high-temperature material qualification, two approaches for stage-wise qualification of materials for MSR applications were described. First, cladding of existing materials is being aggressively pursued. Second, *in situ* passive material surveillance addresses service life. Again, coordination of the staged approach with the MSR roadmap was not made clear.

Recommendations

As the Subcommittee noted in May 2017, with limited funding, it is challenging to pursue all the reactor options (and all associated materials applications) effectively. We recommend that the material R&D strategy consider technology readiness as well as industry interest in deployment. Synergies in needs for advanced materials and advanced simulation R&D exist across the distinct Focus Areas (FRs, GCRs, MSRs), and should be carefully coordinated for efficiency and effectiveness. We encourage the program to use Technology Roadmaps in their prioritization strategy and in developing a credible schedule for deployment.

It should also be noted that the Materials R&D presentation was made by teleconference, rather than a face-to-face presentation. This significantly interfered with clarity of the presentation and the ability of the Subcommittee to pursue questions. We strongly recommend that telephonic presentations be avoided at future reviews.

VII. Advanced Manufacturing & 3-D Printing

NE-5 is conducting exploratory work in a range of advanced manufacturing processes, evaluating their potential in reducing the cost and schedule of new plant construction. The effort was initiated in 2012, and funds competitively-selected projects at universities, laboratories, and in industry (this is the first year of a separate industry FOA). Over the past 6 years, the effort has funded $15M of work (plus 10 NSUF projects totaling approximately $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 (to improve modular building methods), advances in manufacturing processes (including hot isostatic pressing, additive manufacturing, and surface modification methods), as well as improved concrete construction, inspection and testing methods. A number of examples were presented of the fabrication of components, from SMR reactor pressure vessel heads to sensors and springs. Surface modification techniques have also been examined for fuel cladding.

The projects have made tangible demonstration that components can been produced, although less information was provided regarding the specifications of the materials (dimensionality, materials microstructure, mechanical strength, etc.). It would also be useful to provide some data regarding the assertion that these techniques can help reduce cost and time to make components; this will likely take some analysis of process costs.

Most projects appeared to focus on development of the manufacturing process. Less mention was made of the qualification of the materials for their intended service. Projects listed included one indicating a combination of computational and *in situ* process monitoring for "rapid qualification" without elaboration. The qualification of materials and components produced through advanced manufacturing methods remains a challenge in many areas of manufacturing with more stringent product requirements, and this will likely also be true for nuclear service. This was noted in the presentation, in the suggestion that acceptance criteria, qualification requirements, and inspection methods need to be developed by standards organizations. Whether supported by vendors or standards organizations, qualification approaches may be a necessary precursor to broad adoption of new technologies.

Recommendation

The Subcommittee suggests the program examine its scope and set a strategic direction. Is the purpose of the program to 'seed' innovative techniques, or demonstrate more quantifiable advantage to adoption of one or more methods in particular applications? A compelling value proposition should be identified to motivate specific directions in advanced manufacturing, and an engagement plan must be developed to facilitate the development of appropriate testing and qualification methods before any cost and schedule advantages associated with these methods can be assessed.

VIII. CoDCon & MPACT Engagement

In FY18, a new MPACT campaign R&D study was established within the NE-43 "Office of Materials and Chemical Technologies" entitled "Advanced Processing Modeling and Simulation." The intent is to develop dynamic process models for various chemical and materials processing activities. One application is the use of a dynamic model to predict the performance of the modified PUREX process being used for process control in the CoDCon project, which 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 as applied to used commercial nuclear fuel.

The objectives and the timeline of the co-decontamination project (CoDCon) were presented to the Subcommittee, as it serves to evaluate both process control and material accountability by the combined use of on-line instrumentation and a dynamic process model. Phase 1 of the program (glovebox testing) started with the first CoDCon Test #1 carried out at PNNL in late 2017, using pure chemicals and on-line monitoring by Raman and UV-vis spectroscopy (used to monitor process control). A mathematical "virtual" process model was used to provide guidance for setting process flow rates, temperatures and reagent concentrations (for instance, U(IV) concentration in U-loaded solvent is critical for Pu reduction in modified PUREX) along with predictions of the composition and discharge rates of the various streams.

Results of Test #1 were encouraging, with Pu concentration being 32% plus or minus 3%, even plus or minus 1% during a short period. Nevertheless, some post-test analyses indicated a systematic error in the on-line spectroscopic measurements requiring some experimental adjustments be done for CoDCon Test #2 scheduled in May 2018. LANL and Sandia have also been tasked to prepare a new dynamic process model of the CoDCon separation process and to compare its predictive characteristics with the quantitative values obtained during CoDCon Test #2. CoDCon Test #3, which is scheduled for the late CY2018 time frame, will be performed under more realistic conditions with simulants to approximate the chemical conditions of phase 2 (future hot tests with used commercial nuclear fuel); flowsheet changes will be incorporated, based on the CoDCon Test #2 model results if successful. The Subcommittee considers that it would also be valuable for the study to go beyond only spectroscopy measurements, and in that sense to deploy other analytical measurement technologies in order to improve the needed accuracy of material balances in bulk experimental flow/processing systems and to best understand the precision with which actinides and/or transuranic materials could be accountably tracked.

Recommendation

The Subcommittee is pleased with the progress made to date on the CoDCon process demonstration; however, some aspects of the integrated timeline are possibly too optimistic: can Phase 1 (glove box testing) and Phase 2 (hot cell testing) both be accomplished in the FY18-19 timeframe to serve the 2020 long-term milestone? The Subcommittee feels also that there is more laboratory-scale research to be done before moving on to engineering-scale studies. For instance, after the modified PUREX solvent extraction process studied with CoDCon, the capability for the following co-conversion step of the U/Pu nitrate stream to a mixed oxide powder material, suitable for pellet fabrication, has to be demonstrated while determining the uncertainty of maintaining the 70/30 target all along the co-conversion process.

It will be important for the MPACT campaign to develop comparable studies, similar to the ones presently devoted to aqueous processes, for other chemical and materials processing activities, including those associated with metallic fuels (the reference case for VTR) or advanced molten salt reactors. Success in such a measure/model approach applied to other systems may be required before it is used in the future as a basis for licensing a U.S. commercial separations plant.

IX. SiC and ATF

The Subcommittee continues to monitor progress of the Accident Tolerant Fuel (ATF) program, which has been tasked by Congress to pursue the development and qualification of accident tolerant nuclear fuels that would enhance the safety of present and future generation Light Water Reactors (LWRs). Vendors are pursuing a strategy which relies on the ability of ATFs to significantly extend the time before initiation of the exothermic oxidation reaction associated with hydrogen generation from the zircaloy-based cladding in current LWR fuel. Table 1 summarizes the current schedule for ATF lead test assembly (LTA) irradiations in commercial plants. As indicated in Table 1, transportation issues led to unfueled samples of cladding material being inserted into Hatch (rather than pins with fuel contained with the new ATF cladding materials).

Table 1: Near-term Accident Tolerant Fuel LTA Irradiations

Vendor	**Description**	**LTR/LTA Irradiation**	
		Date	**Plant**
GE	Iron-Chromium-Aluminum (FeCrAl) Alloy Cladding [IronClad] and Coated Cladding [ARMOR] on Uranium Dioxide (UO_2) Fuel*	Spring 2018	Hatch Unit 1 BWR
		Spring 2019	Clinton BWR

Framatome	Chromium-Coated M5® Cladding [eATF] on Chromia-doped UO_2 Fuel	Spring 2019	Vogtle Unit 2 PWR
	SiC cladding on Chromia-doped UO_2 Fuel	2022	TBD
Westinghouse	Chromium-coated Zirlo Cladding on Uranium Disilicide (U_3Si_2) Fuel [EnCore™]	Spring 2019	Byron Unit 2 PWR
	SiC Cladding on Uranium Disilicide (U_3Si_2) Fuel	2022	TBD

*Hatch Insertion did not include fuel in "ATF rods". The ARMOR coated cladding was developed outside of the DOE program.

As noted in our December 2017 report, the Technology Readiness Level (TRL) differs for these fuels and the associated qualification approach proposed by each vendor varies. Ultimately, all three vendors will need to qualify the fuels for high burnups (e.g., greater than 62 GWD/MtU). Significant U.S. resources have been allocated to support ATF deployment. These resources support fabrication of some fuel pellets and coated clad variants; irradiation testing of fuel exposed to nominal PWR and BWR conditions; and transient fuel testing. In addition, DOE has developed infrastructure to support Loss of Coolant Accident (LOCA) testing of irradiated fuel at ORNL and irradiated fuel material characterization and thermal property testing at INL. In 2017, DOE signed a Memorandum of Understanding with the U.S. 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.

During our May 2018 review, we learned of several difficulties associated with ATF fabrication, transport, and irradiation testing. These difficulties resulted in "unfueled GE ATF rods" (i.e., clad samples rather than lead test rods) being deployed at Hatch (due to the program not being able to transport the GE ATF fuel to the plant). In addition, these program difficulties will result in most of the ATF concepts listed in Table 1 NOT being available for the upcoming ATR ATF-2 irradiation (primarily attributed by DOE to mis-communication and fabrication issues), and all ATR instrumentation will be removed from the ATF-2 irradiation. experiment. Table 2 documents the ATF-2 changes described between our December 2017 and May 2018 reviews.

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

	SiC cladding on Chromia-doped UO_2 Fuel	Yes	Withdrawn
Westinghouse	Chromium-coated Zirlo Cladding on Uranium Disilicide (U_3Si_2) Fuel (EnCore^{TM})	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

*The ARMOR coated cladding was developed outside of the DOE program.

Furthermore, we learned that all planned irradiations at the Halden Boiling Water Reactor (HBWR) are at high risk of being canceled (due to likely shutdown of the HBWR prior to 2020 license renewal). Presentations made to the Subcommittee again stressed claims of enhanced safety associated with the use of ATFs, but without a description of the data collection plan that will validate these claims. Without high fidelity data, similar to the data that could have been obtained from the well-instrumented HBWR test rigs, it is unlikely that industry will be able to provide data required for regulatory decision-making or to develop the quantified business case required to offset higher ATF fabrication and material costs.

In response to the many challenges that have significantly reduced the data that will be generated by the near-term ATF tests, we strongly recommend that DOE-NE pause on-going efforts and revise their ATF deployment strategy. The revised strategy should include a focus on desired objectives of each irradiation with careful evaluations prior to proceeding with partial tests. These objectives should be developed with input from the regulator regarding the data required for regulatory decisions. If it is determined that the required data should be obtained from existing U.S. irradiation facilities (e.g., ATR, MITR, TREAT, etc., rather than Halden), then the revised strategy should describe upgrades required at the facilities or their instrumented-experimental capabilities. As we emphasized in our December 2017 report, early NRC input regarding the information needed to license ATF concepts could significantly reduce testing costs and expedite regulatory reviews. Lack of NRC input poses a significant risk that gaps will remain after the planned ATF irradiations.

A revised strategy, if it includes well-instrumented standardized test rigs for use in U.S. MTRs, will offer benefits that extend beyond the ATF program. Such test rigs would provide the U.S. industry and regulator, as well as the international community, a sorely-needed capability to address issues that periodically emerge regarding currently-used and evolutionary LWR fuels. In addition, it would provide DOE-NE a test-bed for demonstrating well-instrumented standardized test rigs that will be required for efficient use of TREAT and the proposed VTR.

If the time and resources are wisely allocated, delays associated with developing this revised strategy could lead to significant DOE cost-savings. Personnel involved with ATF development could gain additional experience with 'first-of-a-kind' processes and then progress through more of the required fuel design steps (as concepts go from DOE laboratory bench scale fabrication, through industrial pilot line deployment, to scaled industrial deployment). It is important to recognize that licensing will require that some key data be demonstrated by qualification irradiations of rods fabricated by scaled, deployed systems rather than by bench-scale samples. Early irradiations of a limited number of samples without any instrumentation in a high flux reactor and deployment of 'unfueled' ATF rods in a commercial reactor may not be a prudent use of U.S. resources.

We continue to emphasize the need to provide analyses that demonstrate the safety benefit of ATF concepts during severe accidents using systems analysis codes, such as MELCOR and MAAP. Presentations highlighted the need for data to characterize ATF thermal and structural properties for conditions expected during normal operation, design basis accident, and beyond-design-basis conditions. If plant owners/operators desire a reduction in regulatory requirements (such as maintenance and test frequency of other plant components and systems) to offset the additional costs associated with fabrication of ATF, then system evaluations must consider the impact of ATF on overall plant risk. Any postulated benefit of delayed production of hydrogen must consider other factors, such as the ability to ensure that the core remains subcritical when control rod components liquefy at elevated temperatures, and the total amount of combustible gas produced when ATF cladding materials are exposed to high pressure/high temperature steam during severe accidents. DOE-NE may find it prudent to accelerate efforts to complete these tests prior to investing in irradiation testing of these materials.

Recommendations

(1) In summary, the Subcommittee **strongly recommends that DOE-NE pause on-going efforts and re-evaluate the current strategy for ATF deployment**. The revised strategy should include input from the regulator to ascertain what data are required for rendering regulatory decisions. If it is determined that the required data should be obtained from existing U.S. irradiation facilities (e.g., ATR, MITR, TREAT, etc., rather than Halden), then the revised strategy should describe upgrades required at the facilities or their instrumented-experimental capabilities. It is unlikely that ATF can be commercialized without implementing this revised strategy.

(2) The Subcommittee further recommends that efforts to develop the business case be expedited to provide confidence that ATF efforts will yield a product that can be commercialized.