Nuclear Reactor Technology Subcommittee Report to NEAC

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Subcommittee Scope

- *Congress appropriated funds for "an advanced test/demonstration reactor planning study by the national laboratories, industry, and 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."*

- The NEAC NRT subcommittee has reviewed and provided comments on the AT/DR study as it progresses to its final report in April 2016. Since July we have had a number of telecons and a face-to-face meeting on October 6th, 2015 to review progress.

Advanced Reactor Master Plan

- The subcommittee received an update in October on recent developments and how this planning study fits into broader planning for DOE-NE. The AT/DR study is one element of a broader master plan for advanced reactors that is being developed by DOE-NE. Our subcommittee was informed that this is still in the formative stages and that this planning study is a key part of it.

- Our subcommittee recommends that this broader 'Master Plan' be presented to the NEAC for its review and comment. This overall plan can put advanced reactor R&D into its proper perspective with other DOE priorities; e.g., Future energy mix including nuclear, LWR activities, infrastructure needs, modeling and simulation, etc.

Subcommittee Review Activities

- AT/DR study has developed:
  - Annotated Report Outline
  - Gap Analysis for Test Reactor capabilities
  - Evaluation Process; e.g., criteria and metrics

Annotated Report Outline

- The report needs to clearly state the assumptions under which this planning study is being conducted; e.g., future energy mix.
- The report needs to develop the long-term funding needs (capital costs, operational costs, industry cost-share) for advanced test reactor and/or demonstration reactor options.
- The report emphasis of the Technology Readiness (TR) levels as a basis for decisions should be reviewed as study progresses.
- The report should indicate that certain reactor concepts of the Gen-IV technologies can be ruled out now without going through the detailed analysis.
- The report needs to get industry comments; e.g., regarding criteria and metrics
- The report needs to explain how this planning study outcomes fit with other efforts in the US (by industry) and internationally; e.g., there is a parallel effort via the NEI Advanced Reactor Task Force and the report needs to follow and factor into the study.

Test Reactor Gap Analysis

Gap Analysis concludes there is sufficient testing capability for LWR fuels and materials currently. But there is a need for an advanced test reactor with a broader range capabilities. Such a test reactor would provide a wider range of domestic capabilities and provide for accelerated fuels and materials testing for a range of conditions.

While this logic has merit, some issues need to be more clearly addressed in the Gap Analysis.

- The gap analysis concludes that advanced test reactor with just a thermal flux would not significantly speed up LWR fuels and materials qualification. This is likely true but some issues are: Can a larger test volume in a LWR test reactor eliminate the need for lead test assembly in a LWR nuclear plant? Can earlier steps in fuel and materials qualifications be eliminated or accelerated with a larger test volume or multiple test volumes?

- NEAC infrastructure SC has noted that current U.S. test capabilities (including test reactors) suffer from a lack of access (coordination) both domestically and internationally, lack of reliability, lack of funding for adequate staffing and maintenance, lack of well-instrumented standardized test rigs, as well as a lack of fast flux neutrons to accelerate testing. While the gap analysis recommendation addresses this final issue, one needs to emphasize the on-going requirements for current facilities.

- The gap analysis indicates that an advanced test reactor can provide a fast neutron flux to perform accelerated testing of fuels and materials testing in a thermal flux environment. The reverse is not doable nor desirable for a number of reasons. These reasons need further exposition in the report.

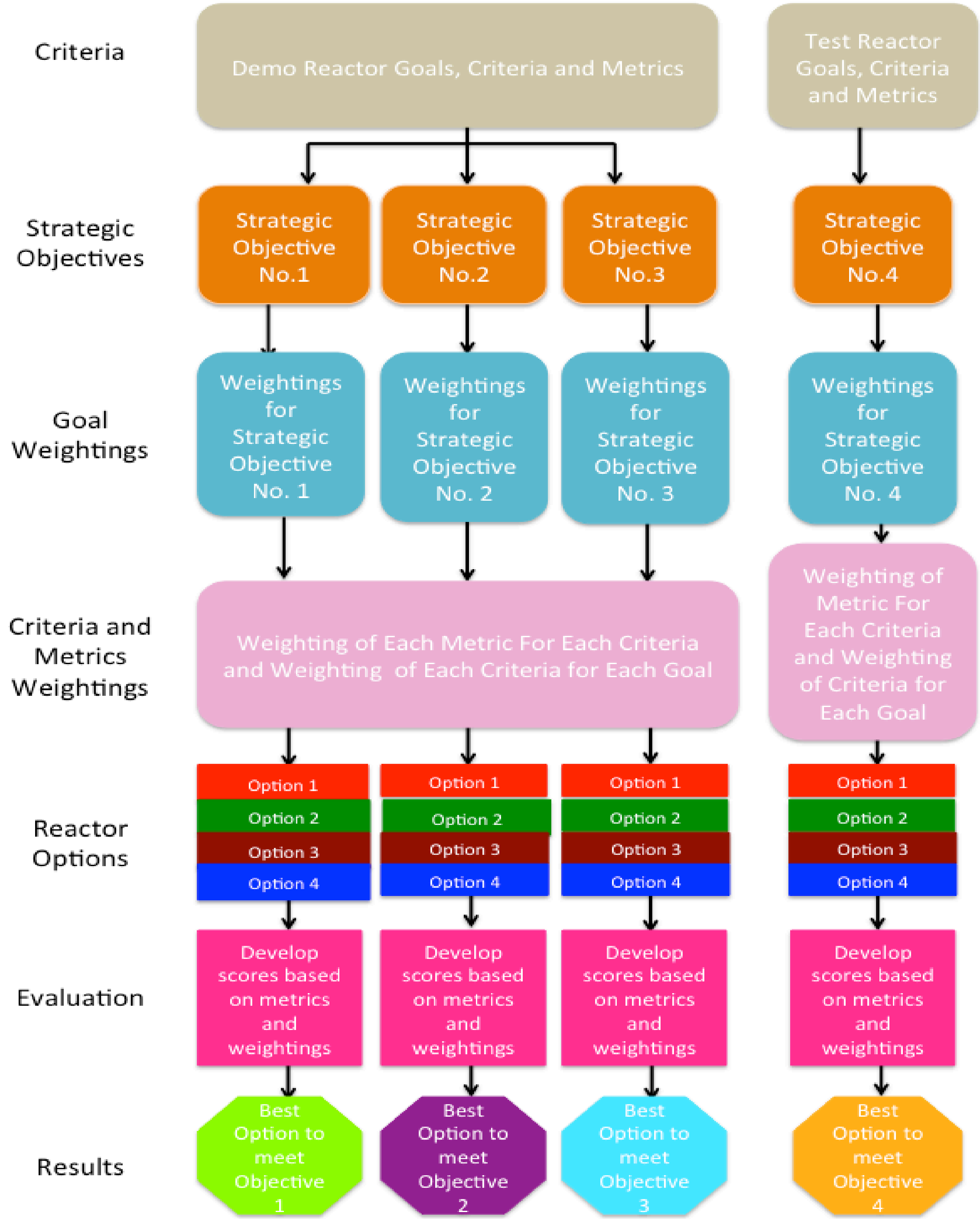
Evaluation Process

Evaluation of conceptual designs for the test reactor is a separate activity from the evaluation of conceptual designs for the demonstration reactor.

There are different goals, criteria and metrics for test reactor concept evaluation than for demonstration reactor concept evaluations.

Our committee concluded this was appropriate and the overall formulation of the goals, criteria and metrics were reasonable.

In order to test the process, we suggested to use the ATR and the EBR-II as real-world examples of a test reactor and demonstration reactor designs to illustrate how the evaluation process would work.



Evaluation Process (cont)

While the general approach to the evaluation method to be reasonable, we had comments, which could improve the evaluation process and/or the exposition of the process to those making use of the results.

Need for a Roadmap and Schedule: There are a number of phases to the projects (AT or DR) and those using this planning study need to understand these phases and the schedule that this implies. A high-level exposition of this would be useful for the decision-maker.

Identify Constraints: There are many constraints for the deployment of advanced reactor technology including availability of performance data to support licensing, significant time to construction and questions related to siting, and de facto policy issues, e.g., use of high uranium enrichment in the fuel cycle. The study should make these constraints clear to both the investor community and the congressional sponsors as a discriminator between technologies. Many of the people supporting advanced reactor initiatives are new to the field and have yet to encounter these 'realities'.

Consistency in Explaining the Point Designs being Evaluated: It is quite important that a description of each conceptual point design being evaluated (for either test reactor or demonstration reactor) have a consistent set of information. Such consistency in the design description and engineering detail is crucial to get a clear and unbiased view of the various designs being evaluated.

Licensing: Any AT or DR will be licensed by USNRC. This also supports the long-term mission of commercialization. The licensing process is not a discriminator in the decision-making process. But there was discussion about the need for revisions to the licensing review process; e.g., regarding the siting of facilities near man-made hazards. Such issues will need to be examined as the planning study proceeds with more details.

Path Forward

- AT/DR study began in spring 2015 and substantive results are expected in early 2016.
- NRT will schedule telecons and meetings to view results as appropriate to meet the spring 2016 targer

Extra Slides

Test Reactor Goals, Criteria, and Metrics

Test Reactor Goals, Criteria and Metrics		
Goal	**Criteria**	**Metrics**
1. Test Reactor provides irradiation services for a variety of reactor and fuel technology options	1.1 Irradiation Conditions	1.1.1 Flux Conditions (Fast and Thermal)
		1.1.2 Irradiation Volume and Length
		1.1.3 Maximum sustainable time at power, to provide a time-at-power for a single irradiation (i.e. cycle length)
		1.1.4 Provisions for testing prototypic and bounding conditions (Temperature, Coolant, Chemistry)
	1.2 Support diverse irradiation testing configurations concurrently (accommodate various sizes and tailor irradiation parameters to wide group of simultaneous users)	1.2 1 Number of Test Zones
		1.2.2 Number and type of irradiation test loops with cooling systems independent of the primary reactor coolant
		1.2.3 Ability to insert/retrieve of irradiation specimen while staying at power
2. Test Reactor will be built and operated reliably and in a sustainable cost-effective manner. (Need to be able to justify initial and long-term expense)	2.1 Project Costs and Schedule (including contingency that reflects technical maturity of the concept)	2.1.1 Project Cost
		2.1.2 Schedule
	2.2 Operational Costs and Schedule (including contingency that reflects technical maturity of the concept)	2.2.1 Annual Operating Costs
	2.3 Reliability of Operations	2.3.1 Availability Factor
3. Capability to accommodate secondary missions (e.g., electricity, isotope production, etc.) without compromising primary mission of testing fuels and materials for advanced reactor technologies	3.1 Identification of Secondary Missions	3.1.1 Number of Secondary Missions

Demonstration Reactor Goals, Criteria, and Metrics

Demonstration Reactor Goals, Criteria and Metrics		
Goal	**Criteria**	**Metrics**
1. Demonstration Reactor significantly advances the technology toward a potential FOAK plant	1.1 Capability to demonstrate safety behavior of commercial system	1.1.1 Does the demonstration system have safety characteristics and systems/components expected in the commercial plant?
	1.2 Detailed instrumentation and data for code validation tests	1.2 1 Does the design have adequate instrumentation and will it gather appropriate data for code validation tests?
	1.3 Scalable technology choices	1.3.1 Does the design implement technology selections that are prototypic or scalable to commercial unit?
	1.4 Scalable maintenance techniques and schedules	1.4.1 Does the design have maintenance approaches that are prototypic or scalable to commercial unit?
	1.5 Scalable fabrication options	1.5.1 Does the design use prototypic of scalable technologies in the fabrication of important systems and components?
2. Demonstration Reactor operations help resolve technical barriers (e.g. predictability) to advanced reactor economics and reliability	2.1 Construction Costs and Schedule	2.1.1 Project Cost
		2.1.2 Schedule
	2.2 Operational Costs and Schedule	2.2.1 Annual Operating Costs
	2.3 Reliability of Operations	2.3.1 Availability Factor
3. Demonstration Reactor has a robust Safety Design Basis for	3.1 Licensed by NRC	3.1.1 Ability to address key licensing issues for follow-on commercial units
4. Demonstration Reactor Supports demonstration of technology and system integration (enhancing immediate, intermediate and long term value of the project)	4.1 Facilitate component demonstration	4.1.1 Does the system facilitate component demonstration of that expected in follow-on commercial units?
	4.2 Demonstrate alternate core configurations and fuel types	4.2.1 Number of alternative core configurations
		4.2.2 Number of alternative fuel types
	4.3 Demonstrate integration with various energy conversion systems or industrial applications (hybrid energy systems)	4.3.1 Number of energy conversion systems or industrial applications
	4.4 R&D required before demonstration reactor construction/operation	4.4.1 R&D Time
		4.4.2 R&D Cost
	4.5 Provide ability to conduct irradiations of materials and fuels under prototypical conditions	4.5.1 Flux Conditions (Fast and Thermal)
		4.5.2 Irradiation Volume and Length
5. Demonstration Fuel Cycle of Advanced Reactor	5.1 Prototypic fuel fabrication	5.1.1 Is the fuel fabrication approach prototypic or scalable to commercial unit?
	5.2 Prototypic fuel performance	5.1.2 Is anticipated fuel performance prototypic or scalable to commercial unit?
	5.3 Spent fuel handling	5.1.3 Is the spent fuel handling prototypic or scalable to commercial unit?

Example of Metric - #1

Metric 1.1.1. Flux conditions (fast and thermal)

Note: Test reactors usually have a range of flux conditions within their testing environment to allow flexibility to meet a wide range of needs. In addition, the physical volume over which that flux exists also can vary (and is captured in Metric 1.1.2) For simplicity here, the fast and thermal flux conditions do not necessarily have to occur in the same location within the test reactor. Nor will a specific volume be required. The fast and thermal flux levels will be evaluated individually and the scores averaged to obtain a final numerical value.

Metric	>5 x 10^{15} n/cm^2-s fast (>0.1 MeV) >5x10^{14} n/cm^2-s thermal	5x10^{14} to 5 x 10^{15} n/cm^2-s fast (>0.1 Mev) 1 to 5x10^{14} n/cm^2-s thermal	<5 x10^{14} fast (>0.1 MeV) <1x10^{14} thermal
Score	3	2	1

- Defined, quantifiable performance feature
- Grouped from best (3) to least (1) performance

Example of Metric - #2

Rationale: Advanced reactors have both inherent and passive design features that should enable a demonstrable benefit for public acceptance. However, the size of the demonstration reactor or other constraints may limit the ability of the system to demonstrate the safety behavior of the ultimate commercial system because of lack of prototypicality and/or scalability.

Metric 1.1.1. Does the demonstration system have safety characteristics and systems/components expected in the commercial plant?

Metric	Demo replicates the safety characteristics and has prototypic systems/components	Safety behavior of Demo can be confidently scaled to the commercial system	Safety behavior of Demo has important non-prototypic aspects
Score	3	2	1

- Rationale also provided for each metric
- Qualitative performance feature
- Grouped from best (3) to least (1) performance

Weighting Factor Exercise

- The weight factors reflect different strategic objectives of the decision-maker
  - Also called value functions in other evaluation studies
- To assess the evaluation approach, four potential strategic objectives were considered
  - Do the metrics distinguish between these objectives?
  - Are the priority/emphasize weightings clear?
- All four objectives evaluated independently by Lab teams at Argonne, Idaho, and Oak Ridge
  - Metric priorities do change between the different objectives
  - Weighting functions were consistent between the three teams
  - Metrics were refined, based on specific issues identified