Report of the Nuclear Reactor Technology Subcommittee

November 18, 2014

Nuclear power competitiveness in the U.S. current electricity market is at risk in several parts of the country. The Department of Energy Office of Nuclear Energy (DOE-NE) has considered the situation and is developing a number of approaches to assist the electric power industry. The Nuclear Reactor Technology Subcommittee and the entire NEAC has already discussed policy issues that should be considered to help retain existing nuclear capacity in the U.S.; e.g., regional power purchase agreements for current LWR's owner/operators; crediting nuclear power as a source of carbon-neutral electricity and baseload reliability, and increased value ascribed to capacity markets in deregulated regions. These actions are not the sole purview of the DOE, but in fact depend on actions taken by other governmental units, such as FERC and state utility commissions.

In addition, at the March 2014 DOE "Big Idea Summit", the Idaho National Laboratory (INL) led the break-out group that discussed more rapid advanced technology deployment in nuclear power plants and more rapid commercialization of advanced nuclear power technology. That group has outlined an approach that takes advantage of scientific advances for nuclear energy applications:

- Develop and maintain small-scale state-of-the-art experimental facilities with easy access through an integrated user-facility approach;
- Develop and maintain up-to-date computational frameworks for the development and use of modeling and simulations in practical but high fidelity applications;
- Establish knowledge-based centers to support access to past and current experimental data and computational results;
- Introduce engineering-scale capabilities to allow for final validation of new innovations under prototypical conditions.

In regard to the final activity, the NEAC Nuclear Reactor Technology Subcommittee is evaluating information and options for new reactor testing and/or demonstration capabilities to serve as a key part of new engineering-scale capabilities if a decision is made to construct such facilities. The NEAC Nuclear Reactor Technology Subcommittee is an appropriate body to provide strategic advice on several aspects in this area, such as the scope and objectives of any new testing/demonstration capabilities and the criteria and the process for selecting an option. Our first subcommittee meeting on this topic was held on September 26, 2014. This report summarizes initial discussions from this meeting and plans for future meetings to assist DOE in this endeavor.

Initial discussions within the subcommittee focused on the following broad types of reactors:

- A demonstration reactor that would be a prototype to evaluate several aspects of a selected advanced reactor technology, e.g., licensing process, safety case, operating characteristics, etc.;

- A test reactor to obtain data to support more rapid RD&D of innovations for the existing fleet of LWRs and/or advanced reactors concepts; e.g., new fuel forms, new cladding or advanced materials.
- A hybrid purpose reactor that employs new technology for the reactor itself, and also enables testing of concepts/materials that might apply to reactors other than the test/demo reactor itself.

The NRT subcommittee is starting to collect input with respect to the benefits of a demonstration versus a test reactor, and the possibility of combining elements of the two. As part of this process, the subcommittee will collect background information on current U.S. test reactors (ATR and HFIR) as well as other key new test reactors worldwide (e.g., JHR in France, MYRRHA in Belgium and MBIR in Russia). Preliminary considerations related to the benefits and needs for each reactor type are discussed below.

The motivation for a demonstration reactor partially stems from the belief that new reactor concepts may be desirable to enable wider deployment of nuclear technology to achieve new missions such as the provision of high temperature heat or the reduction of the nuclear waste burden. Recent DOE-NE interactions with the NRC staff on the Next Generation Nuclear Plant (NGNP) have shown that a demonstration reactor of a particular reactor technology (fast or thermal, gas-cooled or sodium-cooled) could be used to reduce licensing and performance uncertainties associated with subsequent builds of that particular reactor technology. For example, testing could be completed on a prototype reactor design to demonstrate reactor safety performance, benchmark reactor analysis tools, and validate reactor operational characteristics. However, the decision to build a demonstration reactor for a particular reactor technology will primarily limit the benefits from this reactor to that particular technology. Moreover, based on recent experience there is no clear path to move from a demonstration reactor to a new marketable advanced reactor concept, and DOE-NE efforts to accelerate development of first-of-a-kind reactors within the NGNP have proved to be difficult to bring to market.

In contrast, a test reactor could offer the potential to obtain data for multiple types of reactor technologies—from the existing LWR reactor fleet to advanced reactor designs. Among the possible research goals for the test reactor are:

- Improving LWR risk tolerance (fuel, methods of providing auxiliary power upon emergencies, etc.) to reduce the need for complicated regulatory responses (Beyond design basis accidents, security, external/internal events, etc.)
- Demonstrating methods for cost reduction of O&M, including on-line inspection and maintenance, and application of information technology to monitor the plant health
- Performing accelerated testing of materials to prove the possibility of increasing the useful life of existing and future LWRs beyond 60 years and thus enhance the return on capital investment.
- Performing accelerated testing on new fuel and cladding materials that might enable very long core life-time, thus improving the fuel cycle cost due to reduced demand for enrichment and for waste handling, and reducing the proliferation risk of misuse of the enrichment facilities. (This requires very long life under irradiation through microstructural configurations or accelerated self-annealing)

Specific capabilities, not fully provided in current DOE test reactors, that could be incorporated into a new test reactor include:

- Large test volumes allowing real-time data to be obtained from lead test assemblies or substantial portions thereof;
- Well-instrumented standardized test rigs for fuel, cladding and materials irradiations;
- An ability to have multiple spectra, in specific regions or with differing core configurations;
- Loops containing a variety of coolants, such as boiling water, helium, molten salt, or sodium; allowing fuels and materials to be tested in prototypic coolant conditions under normal and to the extent possible, under accident conditions;
- Ability to act as a magnet for talent among the university research community by involving them in design of test rigs, instrumentation and associated computational modeling of test protocols and test results; and
- Ability to incorporate new test reactor design innovations with LEU fuel as a desirable upgrade.

Whether the demonstration of new technology can be attained simultaneously with provisions for allowing the testing of other technologies remains to be demonstrated. But, in principle this could help achieve two objectives at once. However, it is likely that such combined objectives will be difficult and costly to achieve.

The siting of any new reactor was also discussed. There are likely to be security considerations if the reactor is sited away from a government reservation where a DOE national laboratory is sited. Thus, it may be desirable to consider siting at a DOE national laboratory.

Additionally, licensing of this reactor must be carefully considered. If the reactor is built on a non-DOE site, it must be licensed by NRC. Furthermore, the Atomic Energy Act requires that a prototype or demonstration reactor be licensed by NRC (even if it is built on a DOE site). If a test reactor were built on a DOE site, there is the potential for it to be licensed by NRC by obtaining a 10 CFR50 Class 104 license or its operation to be authorized by DOE orders. Although the Subcommittee is still collecting information, preliminary investigations suggest that an NRC licensing option for the test reactor would be preferred for the following reasons:

- The DOE orders for authorizing startup of a new reactor would require careful review as the current orders, which were written to cover a broad range of nuclear facilities, have not been applied to large new facilities of this type for a long time.
- The NRC is better staffed, and more current than DOE to conduct new reactor licensing and operations; and
- More detailed guidance, requirements, and experience exists for reactors licensed using NRC Class 104 license process;
- The NRC licensing process, as opposed to DOE using a self-regulatory process, would offer additional benefits with respect to public acceptance.

In our next meetings, we plan to learn more about the requirements and process for obtaining a Class 104 license from NRC and implications for applying this process to a reactor built on a DOE site.

NEAC-NRT is also considering guidance related to the selection process and the evaluation criteria for engineering scale capabilities. As part of our discussions, our subcommittee heard an overview of the Generation IV Roadmap program (2000-2002) as well as lessons learned from this process. Because the development of new capabilities might be solely funded by the DOE, our impression is that a simpler, less expensive process is more appropriate for selecting whatever is needed. However, we recognize that our guidance should consider lessons learned from the Generation IV process, such as the need for early definition of evaluation criteria and a focus on building consensus within the US nuclear research community and industry.

As noted above, our first meeting was held on September 26, and we are beginning to collect the information needed to form a strong basis for our recommendations. We plan to hold additional meetings in December 2014 and January 2015. Before the June 2015 NEAC meeting, we expect to have finalized our recommendations related to needed U.S. test/demonstration reactor capabilities.