Report of the Fuel Cycle Subcommittee

of the

Nuclear Energy Advisory Committee

December 9, 2010

Washington D.C.

Burton Richter (Chairman)

Darleane Hoffman

Raymond Juzaitis

Sekazi Mtingwa

Ron Omberg

Joy Rempe

Dominique Warin

1. Introduction and Summary

The Fuel Cycle Subcommittee (FCSC) of NEAC met in Washington, August 17-19, 2010. DOE's new science-based approach to all matters related to nuclear energy is being implemented. The general approach was outlined to NEAC in the briefing on the NE Roadmap. There are many new directions being considered, and this meeting of the FCSC was to brief the Subcommittee on new directions in nuclear energy that might go beyond our present 4.5% enriched LWRs. The goal is to develop new concepts that have advantages over present systems in some combination of cost, passive safety, proliferation resistance, sustainability, and used fuel disposition.

We note at the outset that there is overlap in the work of the four subcommittees of NEAC: Fuel Cycle, Infrastructure, International, and Reactor. The Fuel Cycle – Reactor coupling is clear. However, the other two subcommittees are critical because the nuclear RD&D infrastructure in the US has decayed badly because of a lack of funds to keep it up, and that will limit what can be done on both fuel cycles and reactors. Likewise, because the U.S. and the international community are interested in the same set of options for the future, there is an opportunity for new kinds of international collaborations to reduce costs and speed progress for all.

Recommendation: NEAC needs to develop a coordination mechanism for its subcommittees.

In this report, we comment on advanced fuels development, uranium resources, proliferation risk reduction, modeling and simulation efforts, international programs, and university programs. Used fuel disposition is, of course, an important part of the fuel cycle, and is now the responsibility of NE with the assistance of the FCSC. Work continues on alternate fuel cycle options that include once-through, modified once-through (a breed and burn concept with no reprocessing), partial recycle, and full recycle. Each has somewhat different requirements and possibilities for used fuel disposal; all need repositories, but the required isolation time for the fuel components differ as do the options for treatment and isolation. However, the DOE's Blue Ribbon Commission on America's Nuclear Future has been charged with reviewing options for disposition and making recommendations on how to proceed. Its preliminary report is expected early next year, and we and NE will need time to review the recommendations and chart an appropriate course. We expect to return to this issue at an appropriate time.

Fuel Cycle: In the fuel cycle arena there are advanced fuel concepts that go with conventional reactors with a once-through fuel cycle, modified once-through cycles, and a variety of reprocessing options. However, the budget and manpower available are insufficient to try all of them. The NE leadership knows this and recognizes that even so an important part of their job is to avoid cutting off promising directions too soon, or to let things that turn out to have less promise go on too long and waste resources. NE has had a team of experts review 21 advanced concept fuel-design papers from the national laboratories and industry, and selected the three most promising for further development. There is a second tier of promising alternates whose pursuit depends upon funding. We have no recommendations at this time since the work is only just beginning.

Fuel Resources: Our Subcommittee has recommended previously that NE do some serious work on uranium availability. We made this recommendation because uranium availability is one of the issues that is important in determining the direction of future reactor development (the others being economics, spent fuel disposal, safety, and proliferation risk). The latest "Red Book" report on natural uranium availability (from the Nuclear Energy Agency and the International Atomic Energy Agency) estimates that there are 16 million tonnes of natural uranium available at no more than $130 per kilogram. This is enough to fuel a fleet of 1300 conventional LWRs for their full 60-year lifetime. There is, of course, much more uranium at lower ore concentrations, and the issue is the cost of extraction. (In-situ leaching using oxygenated water is already being used at scale in Kazakhstan to extract uranium from lower grade ores. Since this process is already commercialized, it does not need DOE support for development.)

For many years, the Japanese have been working on extraction of uranium from seawater, which constitutes a huge, but extremely dilute, resource. Current estimates are that it could be done with existing technology for no more than $900 per kilogram. The US has begun a program to develop advanced extraction systems that show promise of being much more efficient and far less costly than those being used today. According to the Nuclear Energy Institute, uranium costs were $115 per kg as of early 2010 and contributed about 0.3¢ per kilowatt-hour (KWh) to the cost of nuclear electricity. Guesstimates are that costs of uranium from seawater might be reduced to $250 per kg or below, effectively making the supply of natural uranium unlimited and increasing the cost of nuclear electricity by no more than another 0.3¢ per KWh. This would certainly impact the thinking about the need for future breeder reactors.

Recommendation: Computer modeling using currently available scientific data on uranium complexes and sorbents under seawater conditions should be used to help select the most promising systems for experimental investigations of extraction of uranium from seawater.

Proliferation and Terrorism Risk Reduction: This is an integral part of NE's R&D program. The Subcommittee heard a presentation about this effort, including a summary of the role of the Materials Protection, Accounting and Control Technology program (MPACT) in extending "Safeguards by Design" to include both sub-national threats and nation-state proliferation at the earliest stages. We commend their approach, which has a strong partnership with NNSA/NA-24 and linkages to International Atomic Energy Agency (IAEA) efforts and industry.

Innovative concepts, technologies and designs to minimize proliferation and terrorism risks will be considered at the earliest possible stages, but NE does not expect, nor promise, a "silver bullet" that will solve the problems of proliferation.

However, MPACT has the potential to further reduce risks. Close coordination with domestic and international partners will be of vital importance. Collaboration and cooperation with NNSA is imperative if any progress is to be made in minimizing proliferation risks.

NE has tried to define metrics that might be useful in quantifying proliferation risks in the fuel cycle. Two reports were produced, but neither was sent for peer review; hence, neither has had any real impact. One, the Waltar report,[1] was produced by an international group of experts who developed a quantitative scheme for evaluating the proliferation risks of various fuel cycles. It concluded that a properly designed recycling system could match the proliferation resistance of the once-through cycle. The second, the Bathke report,[2] was authored by national laboratory personnel and quantified the attractiveness of various materials to both state and non-state potential proliferators.

Recommendation: DOE should convene a group of top scientists, from both inside and outside the Federal system of laboratories and agencies, to begin the process of standardizing a set of metrics by which proliferation potential can be measured. A process for peer review of reports should be formulated, and a path forward charted for addressing the many issues involving proliferation resistance.

Modeling and Simulation: The Subcommittee heard several presentations that identified a key role for Modeling and Simulation in the overall Fuel Cycle R&D Program. The program is in its early days and has high ambitions. In many areas of science and technology, modeling and simulation at various scales show that such

---

[1] A. Walter *et al.*, "*An Evaluation of the Proliferation Resistant Characteristics of Light Water Reactor Fuel with the Potential for Recycle in the United States*," Pacific Northwest National Laboratory Report, November 2004.

[2] C.G. Bathke *et al.*, "*An Assessment of the Attractiveness of Material Associated with a MOX Fuel Cycle from a Safeguards Perspective,*" Publication No. LA-UR-09-03637, Los Alamos National Laboratory.

programs, when well done, can considerably speed the development of advanced technologies and reduce costs. In the DOE, the premier example is the ASCI program of NNSA. This science-based stockpile stewardship program has allowed NNSA to maintain the reliability of its weapons stockpile without testing. This program provides NE with the potential for transformative advances in nuclear energy through science-based predictions, now widely regarded as supporting the traditional scientific method as applied in contemporary technology programs.

Oak Ridge National Laboratory leads the nuclear energy “Hub” effort that will involve other labs, universities, and industry. The program’s goals include modeling an existing reactor, evaluating the effects of off-normal operations, shortening the time for developing acceptable new fuels, etc. The ASCI program runs at the $500 million per year level. The NE program is wisely starting at a much lower level and will build up as more experience is accumulated.

Recommendations:

1) Maintain an effective experimental program to run parallel with the modeling and simulations effort in order to verify its predictions. This has not received the attention it deserves, nor do we see a budget line to allow the necessary experiments to be done.
2) Include input from NNSA and the Office of Science from the start.

International Activities: The Subcommittee was briefed on Fuel Cycle international activities. Three action plans are presently in effect with Russia, Japan and China, and, since 2001, there has been a general agreement with France on nuclear technology development. Among other activities, the French agreement allowed fruitful experiments starting in 2005 on innovative materials and fuels under a fast neutron spectrum in the French fast breeder prototype, Phénix. Though Phénix has been shut down, the cooperative program will continue in the coming years with post irradiation examination of these irradiated materials and fuels. This would yield a better understanding of their in-pile behavior under fast neutron irradiation and also would provide experimental nuclear data to test modeling and simulation results.

For the longer term, the US faces a lack of the needed facilities to develop future advanced reactors. As has been mentioned many times before, our R&D infrastructure is far from what is needed for the program that is outlined in the new Roadmap. One of the ways to offset this shortage is increased reliance on international facilities. Other countries have facilities and capabilities that we do not have, while we have things they do not have. This suggests that a program be considered similar to that used in the Office of Science that gives our scientists and foreign scientists access to each other's major experimental facilities. For example, the most advanced high energy particle physics accelerator, the LHC at the CERN laboratory in Europe, has many US scientists and engineers working on experiments there, while the most advanced synchrotron radiation facility in the US, the X-ray laser at SLAC, has many European scientists working there. We need access to a fast spectrum neutron source while others need access to a transient test facility like our TREAT (which needs a considerable investment to restart).

Recommendation: NE should investigate the possibility of new types of international agreements that would allow larger-scale sharing of time on experimental facilities with appropriate financial support either in cash or in kind.

University Programs: NE has responded to the concerns that we and others had expressed recently about the Nuclear Energy University Program (NEUP). It is now organized into three subprograms, Program-Directed, Program-Supporting, and Mission-Supporting, allaying the concern that the entire program would be focused on supporting DOE-led research initiatives conducted at the national laboratories. The peer review process has become more transparent and graduate student support for work in many related areas is now included. We look forward to hearing about results in the expanded 2011 program.

Recommendation: The present program limits fellowship support to three years, which in many cases may not be enough to complete a PhD program. We recommend that NE allow an option for extending the three-year limit on fellowships, with reviews for such extensions to be performed on a case-by-case basis.

Summary of Recommendations

1) NEAC should develop a coordination mechanism for its subcommittees.
2) Computer modeling using currently available scientific data on uranium complexes and sorbents under seawater conditions should be used to help select the most promising systems for experimental investigations of extraction of uranium from seawater. Modelers and experimentalists must work together very closely for the endeavor to be fruitful and not become just a “modeling exercise”.
3) DOE should convene a group of top scientists, from both inside and outside the Federal system of laboratories and agencies, to begin the process of standardizing a set of metrics by which proliferation potential can be measured. A process for peer review of reports should be formulated and a path forward charted for addressing the many issues involving proliferation resistance.
4) Maintain an effective experimental program to run parallel with the modeling and simulations effort in order to verify its predictions. This needs continuous attention and a budget line to allow the necessary experiments to be done.
5) Include input from NNSA and the Office of Science from the start of the Modeling and Simulation program.
6) NE should investigate the possibility of new types of international agreements that would allow larger-scale sharing of time on experimental facilities with appropriate financial support.
7) The present university program limits fellowship support to three years, which in many cases may not be long enough to complete a PhD program. NE should

allow an option for extending the three-year limit on fellowships with peer reviews, with such extensions being performed on a case-by-case basis.

2. ADVANCED FUEL DEVELOPMENT

The scope of the fuel development program has expanded beyond ***transmutation*** fuels (those containing minor actinides to be fissioned in order to reduce the long-term burden on the ultimate geologic repository) to what are called advanced ***transformational*** fuels (innovative concepts that are beyond any current program and are not a simple or obvious evolution of any current program). These fuels offer the potential to radically improve overall system performance

The Fuel Development program is to be complimented on the thoughtful and disciplined approach that it took toward seeking the most innovative concepts. The program solicited twenty-one concept papers from nine laboratories; and reviewed these with a panel of well-known fuel experts, using predefined selection criteria and a predefined scoring technique. The panel also heard proposers present their concepts in an open oral review session. All concepts were ranked. Three were selected for immediate development, and seven others were selected for subsequent exploration depending upon funding. The top three were: (1) an advanced metallic fuel with ultra-high burn-up for liquid metal reactors, (2) a vented fuel/getter concept for high burn-up fuels, and (3) uranium-molybdenum metal fuel for Light Water Reactors (LWRs). The net effect of this effort is a broad-based fuels program capable of supporting both traditional and innovative fuel development.

However, the scope of the program has expanded to the point where its funding base may be inadequate. As fuel development relies on in-reactor testing as its *sine qua non* and as in-reactor testing is both expensive and time consuming, the very broad scope presents a potentially difficult dilemma for effective program development. Funding will have to be increased; approaches may have to be evaluated in series rather than in parallel; everything will have to be stretched out; or some things will have to be dropped. At this stage, we have no priority recommendations, but the program will probably have to make some choices.

3. URANIUM RESOURCE ASSESSMENT

The Subcommittee is pleased that NE has chosen to follow up on the Subcommittee's recommendation to perform an assessment on uranium resource availability. The Subcommittee finds the approach being developed by NE is well conceived. The key program elements involve identifying the proper federal role such that the NE program does not attempt to duplicate the work of either private enterprise or of long-standing well-established organizations in this area. To this end, the NE program is not attempting to implement activities in the high-grade extraction area, which is the arena in which private industry currently operates. Nor is NE attempting to perform tasks that well-established international organizations such as the Nuclear Energy Agency (NEA) of the Organization for International Cooperation and Development (OECD), the U. S. Geological Survey (USGS), or the Uranium Institute of London are either currently performing or have performed. Rather, the NE program is attempting to explore the possibility that the price of uranium may have a high-end cap; a price at which an essentially infinite supply exists. This is important because the price at which such a cap exists will determine the cost environment in which reprocessing, plutonium recycle, and fast reactors must ultimately compete.

An example of such a price cap will be found in the cost of extracting uranium from seawater where the supply is essentially infinite but the extraction cost is high because the uranium concentration is exceedingly low. The Japanese are the technological leaders in this area because they have been performing research and development for many years driven by the fact that there is little indigenous uranium in Japan. The Japanese program has proceeded far enough to perform a small-scale engineering demonstration, which provided them with at least a first-cut at the extraction cost. The cost, however, was high (on the order of $900/kg). The NE program is exploring technological approaches that have the possibility of producing a lower cost cap.

The technological breakthrough required and currently being explored in the NE program is the development of high-density polyethylene fibers with smaller diameters and larger surface-to-volume ratios. It is currently projected that the absorbing capability of such fibers can be increased by a factor of 3 to 80 by reducing the 20-micron fiber diameters by factors of 4 to 8, by changing from round to flower shapes or combining both approaches, or by using new materials based on nanotechnology developments which exhibit high surface areas and optimum pore sizes.

The technological developments noted above will, of course, increase the cost of the extractive fiber. Hence, the ultimate cost will be the result of a technological trade-off and will have to be demonstrated with a small-scale engineering demonstration in a marine environment. The NE program office is to be complimented in that they plan to add laboratories with recognized marine experience rather than simply relying on the traditional set of DOE Laboratories known largely for their nuclear experience.

Another proposed approach is to use computer modeling to help select systems of interest for experimental investigations. There is certainly a wealth of fundamental scientific data available on uranium complexes and sorbents under a variety of conditions. If the modeling were constrained to the evaluation of sorption behavior of uranium complexes on various promising materials under known seawater conditions, it could guide the process for selecting approaches and complexing ligands to investigate experimentally.

Recommendation:

Computer modeling using currently available scientific data on uranium complexes and sorbents under seawater conditions should be used to help select the most promising systems for experimental investigations of extraction of uranium from seawater.

4. Proliferation and Terrorism Issues in NE's R&D Program

The Subcommittee heard a presentation about reducing the risks of proliferation and terrorism in NE's R&D program and a summary of the role of materials protection, accounting and control technology (MPACT) in extending "Safeguards by Design" to include both sub-national threats and nation-state proliferation at the earliest stages. We commend their approaches involving strong partnership with NNSA/NA-24 and linkages to International Atomic Energy Agency (IAEA) efforts and industry.

Proliferation and terrorism risk reduction is considered as an integral part of NE's R&D program. Innovative concepts, technologies and designs to minimize proliferation and terrorism risks will be considered at the earliest possible stages, but NE does not expect nor promise a "silver bullet" that will solve the problems of proliferation. However, MPACT has the potential to further reduce risks. Close coordination with domestic and international partners will be of vital importance. Collaboration and cooperation with NNSA is imperative if any progress is to be made in minimizing proliferation risks. NE has tried to define metrics that might be useful in quantifying proliferation risks in the fuel cycle. Two of these are mentioned below. One, the Walter report was produced by an international group of experts and compared the potential of the "once through" fuel cycle with several variants of a fuel cycle that included a MOX phase, or a closed system. The other, the Bathke report, was produced by LLNL, LANL, and PNNL and compared the material attractiveness levels of various reprocessing schemes. Neither was ever peer reviewed nor issued by DOE as a regular report.

Waltar Report:[3] The Advanced Fuel Cycle Initiative (AFCI) of DOE was formulated to perform research leading to advanced fuels and fuel cycles for advanced nuclear power systems. One of its goals was to devise a closed fuel cycle that would not increase proliferation risks. DOE constituted a committee of internationally

[3] Walter *et al.*, op.cit.

recognized professionals in the field to study proliferation risks associated with closing the fuel cycle in the U. S., review alternative fuel forms for LWRs, assess their nonproliferation attributes, compare them to the once-through cycle, and provide input to the ANTT subcommittee of NERAC. The committee included experts from France, Japan, UK, and the US, and was chaired by Dr. Alan Waltar (PNNL).

The final report was posted in November 2004, but was not peer reviewed. Therefore, no final official report was issued. However, it is worth noting the main conclusion of the Committee (p. 2 of the Executive Summary): *"The research and development being conducted on advanced fuels in the AFCI program on the UREX process has the potential for a major nonproliferation advance and can raise the bar with respect to proliferation resistance; The time integrated proliferation resistance measure of a fuel cycle intended to transmute minor actinides, if properly designed, has the potential to be roughly equal to that of the Spent Fuel Standard…"*

Tables and diagrams addressing metrics to be used in assessment and quantification of proliferation risks are given, and Appendix C of the Waltar report is devoted to a study of time-dependent proliferation resistance of seven commercial fuel cycles. Increases in proliferation resistance were noted due to both safeguards levels and characteristics of the material in process in each cycle. Dramatic increases in proliferation resistance were noted for enrichment plants when safeguards were implemented. Incremental increases in proliferation resistance were noted at other points in the cycles due to degradation in plutonium quality and decreases in plutonium quantity/concentration; however, none of the cycles considered demonstrated any ability to completely eliminate a proliferation risk due to the use of nuclear fuel for the production of electricity.

Bathke Report:[4] More recently, in LA-UR-09-03636, Bathke et al. (including personnel from LANL, LLNL, and PNNL) have extended earlier studies examining the attractiveness of materials mixtures containing special nuclear materials (SNM) and

[4] C.G. Bathke *et al.*, op. cit.

alternate nuclear materials (ANM) associated with a wide variety of reprocessing schemes. This study extends the figure of merit (FOM) for evaluating attractiveness to cover proliferant State and sub-national group capabilities.

This report is an excellent example of the use of metrics to attempt to "quantify" attractiveness of materials to a broader range of would-be proliferators ranging from sophisticated nation states to terrorists or suicide bombers who just want to create a nuclear explosion, not enhance their supply of nuclear weapons.

The study has also not been peer reviewed outside the participating weapons laboratories.

Recommendation

DOE should convene a workshop of top scientists, from both inside and outside the Federal system of laboratories and agencies, to begin the process of standardizing a set of metrics by which proliferation potential can be measured. During the workshop, a process for peer review of reports should be formulated and a path forward charted for addressing the many issues involving proliferation resistance.

5. Modeling and Simulation

The Subcommittee heard several presentations that identified a key role for "Modeling and Simulation" in the overall Fuel Cycle R&D Program. A presentation from Alex Larzelere on the last day presented an integrated structure for the management of multiple activities spread across a wide overall NE program scope. This clarified some of the issues that had arisen earlier in a discussion of the Nuclear Energy Enabling Technologies (NEET) Program (which introduced the Modeling and Simulation "Hub"). This overall structure is organizationally captured in the responsibilities of NE-71: Advanced Modeling and Simulation Office (AMSO). It includes key program sub-elements in (a) CASL- Energy Innovation Hub, budgeted at $12.5M in FY11; (b) NEAMS (Nuclear Energy Advanced Modeling and Simulation) at $30M; and (c) CESAR

(Center for Simulation of Advanced Reactors) at $4M. The program also identified the following general “Delivered Simulation Capabilities”: ***Integrated Performance & Safety Codes*** to be delivered by NEAMS for various program elements, including Advanced Fuels, Safeguarded Separations, and Waste Repositories; ***Virtual Reactor of a Westinghouse PWR*** to be delivered by the CASL Hub for industry customers; and ***Exa-Scale Computing Designs/Exa-Scale Applications for Advanced Reactors*** to be delivered to the Office of Science and the Reactor Concepts program element of NE.

This program provides NE with the potential for transformative advances in nuclear energy through science-based predictions, now widely regarded as supporting the traditional scientific method as applied in contemporary technology programs. Key potential benefits include:

- ***Reduced cycle times*** for developing *validated* computer models of complex physical and chemical processes undergirding nuclear reactor performance and safety, as well as the efficiency of separation processes, reduction of proliferation risk, and characterization of material properties of fuels and structural materials subjected to radiation and high temperatures over long periods of operational life. It remains to be seen if modeling & simulation can also reduce timescales that stretch from fundamental R&D through prototype development/demonstration. Realizing the latter would help to cement support for the NE R&D program across multiple Administrations.

- ***Shortened regulatory timelines*** or ***reduced conservatism in safety margins*** that would result from a more fundamental understanding of safety (or security) risks in advanced nuclear technologies, as well as a science-based quantification of uncertainties in key design parameters that underlie the safety and security of nuclear systems. These outcomes would conceivably result in significant benefits by lowering decision thresholds that prevent the private sector from more aggressive commercial deployment of nuclear energy or used-fuel recycling in alternative energy scenarios.

Addressing fundamental commercial risk factors associated with the deployment of nuclear technologies would create tangible economic value beyond the more esoteric value associated with raising the nuclear enterprise from a primarily expensive trial-and-error activity to an activity that would successfully compete with other contemporary technology fields in attracting the imagination and creative engagement of a new generation of scientists and engineers (e.g., the "nano-info-bio" fields).

Along with supporting the potential programmatic benefits of adopting a strong modeling & simulation program focus, however, the Subcommittee also voices a strong cautionary note. This concern arises from two key considerations:

(1) True predictive capability that results from scientific modeling and simulation will only emerge if a ***program of experimentation*** is conducted in parallel with computing. This would allow for generating critical data that serve to validate any conceivable computationally-based set of results. It is presently not clear whether the budgeted program scope of NE R&D accommodates a commensurately strong ***and carefully aligned*** experimental program that supports such an objective. Such a set of activities would involve not just basic exploratory experiments normally associated with a basic R&D program, but also a carefully designed set of more integrated experiments that allow for the interaction and feedback of multiple physical and/or chemical processes across multiple length and time scales. ***It is highly recommended that program plans be integrated to align the modeling/simulation programs with experimental efforts at multiple facilities.***

This alignment will allow review bodies to carefully assess the correct "balance" in the R&D program. The budget levels that have been allocated to the NE R&D program are arguably modest when compared to other national technical programs (e.g., NNSA weapons program) that have undertaken to develop predictive capabilities. It is essential that DOE-NE carefully develop, implement, and execute an R&D plan that maintains the right balance between theoretical/computational elements and experimental elements. For example, the energy innovation HUB highlights a technical vision to create a “virtual reactor of a Westinghouse PWR”. Indeed, this is a monumental undertaking that seems to dwarf the resource levels currently being discussed ($12-16M). Industry can help significantly by providing a properly documented and attributed set of operating data that will support the HUB technical objectives. However, the program must be careful not to articulate expectations that cannot be met. Developing computer codes that meet the requirements of the regulators is a monumental job. Clearly, the program is in its early stages and will have to grow if it is to meet its goals.

(2) In the August briefings, the Subcommittee was not presented with program integration plans that illustrated the scope-schedule-budget balancing necessary for gauging how tightly the cross-cutting modeling & simulation effort is integrated with the individual plans of the supported NE program elements (including Fuel Cycle R&D and joint effort with NNSA and The Office of Science). This was perhaps beyond the scope of this Subcommittee’s charter, certainly beyond the time available for this particular review. Nevertheless, given the fairly complex R&D program structure, which includes separate activities identified by the crosscutting efforts embodied in NEET and the AMSO, program integration will demand special consideration.

Recommendations:

1 Maintain an effective experimental program to run parallel with the modeling and simulations effort in order to verify its predictions. This has not received the attention it deserves, nor do we see a budget line to allow the necessary experiments to be done.

2 Include input from NNSA and the Office of Science from the start.

6. International

The Subcommittee was briefed on the international activities linked to the Fuel Cycle R&D Program. Three action plans are presently effective with Russia, Japan and China on these collaborative activities; DOE also has had a general agreement with France on nuclear technology development since 2001. Among other activities, this last agreement allowed the sharing of fruitful experiments starting in 2005 on innovative materials and fuels under a fast neutron spectrum in the French fast breeder prototype Phénix. While the Phénix reactor has been shut down, the cooperative program should continue in the coming years with post irradiation examination activities on these irradiated materials and fuels. This would yield a better understanding of their in-pile behavior under fast neutron irradiation and in addition provide experimental nuclear data in parallel with the modeling and simulation program.

More generally, there is no Fast Spectrum Test Reactor (FSTR) for materials and fuel development in the US, and very few in operations in the world. Since testing in a FSTR will be required to license any fast spectrum system, the US has to look elsewhere, or build a new facility of its own. Phénix was shut down in 2009 after 35 years of activity, and first steps of its dismantling have started. Joyo in Japan is currently shut down, and a decision is awaited about repairs needed to restart. On May 6, 2010, Japan reactivated the Monju breeder reactor prototype (280 MWe) whose operation has been suspended for 14 years. However, a new temporary shutdown of one year has been again recently announced, and it is to be hoped that the long-term US-Japan-France Global Actinide Cycle International Demonstration (GACID) based on irradiation experimentations in this reactor will go forward without too much delay. Russia has two operating fast reactors, the BN-600 fast breeder near Beloyarsk and the old experimental BOR-60 at Dimitrovgrad, and the Russian government is pushing forward with sodium-cooled fast breeder units of about 800 MWe, but these reactors are not designed to accommodate efficiently irradiations of materials and fuels. There seems to be no real opportunity for experiments in a fast neutron spectrum reactor to advance U.S. R&D goals.

Given this situation and the cost of a new FSTR, it is worth considering models for international support of construction and operation of major facilities used in high energy physics (the LHC at CERN, for example), synchrotron radiation (the European Synchrotron Radiation Facility at Grenoble), or fusion energy (the ITER project in the south of France). Constructions of new or restart of existing FSTRs are taking place in a number of countries. Based upon existing models of international collaborations, a partnership for sharing the construction and operating costs of an international FSTR could be considered, and the experimentation program of such a FSTR would be determined by an international committee of the participating nations.

The US does have at least one facility that could be shared in a model with distributed R&D facilities. The modified open cycle or the closed cycle are based on reactors which could be operated in much more severe conditions than for the existing nuclear power plants, given the objectives of improved uranium utilization and very high burn-up. In parallel with a fast test reactor, a thermal reactor capable of studying the response of materials and fuels to these severe or transient reactor conditions is needed. The use of the Transient Reactor Test Facility (TREAT) could be the US contribution to the set of international user facilities; but the Subcommittee cautions, as already mentioned in a previous report, that it must be demonstrated that restarting TREAT is the most effective way for getting a state-of-the art facility for transient testing.

Regarding separations and waste forms R&D, consideration is given to develop aqueous, dry and innovative separations and waste management technologies that enable a sustainable fuel cycle, with minimal processing, waste generation and potential for material diversion. Depending upon what could be still done in US hot lab facilities, the NE might explore possible joint work with foreign teams using their existing hot laboratories, such as the Recycle Equipment Test Facility (RETF) in Japan, the Atalante Facility in France or the Institute for TransUranium Elements in Karlsruhe Germany. Common research areas should include science-based rather than process-oriented programs in order to tackle grand challenges such as a single-step separation process for Am or TRU, or near-zero radioactive off-gas emissions (an order of magnitude lower than risk-based regulations).

The issues discussed in this section are clearly also in the domain of other NEAC subcommittees.

Recommendation: NE should investigate the possibility of new types of international agreements that would allow larger-scale sharing of time on experimental facilities with appropriate financial support either in cash or in kind.

7. University Programs

The Subcommittee was pleased to learn that the FY11 DOE-NE Nuclear Energy University Program (NEUP) will be organized into three major components (Program-Directed, Program- Supporting, and Mission-Supporting) and that substantial funding (i.e., 20% of NE's research budget) will be allocated to this reorganized NEUP effort. We commend NE for rapidly responding to recommendations from our Subcommittee and other stakeholders concerning this program. In particular, we were pleased to observe that NEUP is providing substantial funding for upgrades to university research reactor and laboratory equipment, multi-year fellowships, and one-year scholarships to top students studying nuclear engineering and related fields, such as nuclear chemistry, radiochemistry, health physics, mechanical engineering, and materials science.

The Subcommittee applauds NE for modifying the NEUP peer-review process so that it is more transparent and for offering funding opportunities that enable university professors to support graduate students wishing to earn Ph.D.s in a wide range of fields, including nuclear chemistry/radiochemistry (e.g. actinide chemistry) and physics to conduct fundamental science-based research.

We also commend NE for organizing a Student Awards program and for including opportunities for FY10 NEUP fellowship recipients to interact with NE, NRC, and laboratory research staff. We encourage NE to continue such activities in the larger, reorganized FY11 program. In addition, we recommend that NE consider an option for extending the three-year limit fellowships with reviews for such extensions being performed on a case-by-case basis. The Subcommittee will continue to follow NE's efforts to improve this key activity, to make it known to a larger community of relevant scientists, and to continue attempts to ensure appropriate peer review of proposals.

Recommendation: The present program limits fellowship support to three years, which in many cases may not be enough to complete a PhD program. We recommend that NE allow an option for extending the three-year limit on fellowships, with reviews for such extensions to be performed on a case-by-case basis.