Report to NEAC

Fuel Cycle Subcommittee

Meeting of November 22, 2103

Washington, DC

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I. Introduction and Summary

The agenda for the November 22, 2013 Fuel Cycle Subcommittee meeting and list of presenters is given below. The meeting focused on providing members an overview of various research efforts funded by the DOE-NE's Fuel Cycle Technologies (FCT) program and related research that is coordinated with the FCT program. A summary for each topic and our recommendations are highlighted in this introduction. More detailed comments are found in subsequent sections of this report.

Agenda

Chair: Dr. Alfred P. Sattelberger

Location: Argonne National Lab Offices, L'Enfant Plaza

9:00	Executive Session	Committee & DOE Mgmt
9:15	High Burn-up Used Fuel Program Overview	William Boyle
10:15	Break	
10:30	Joint Fuel Cycle Study – ROK: Used Fuel Workshop	William Boyle
11:15	High Level Waste and Spent Fuel Inventory Report	Peter Swift
12:15	Lunch	
1:00	Accident Tolerant Fuel Overview Industry, Lab and University progress to date	Andy Griffith/Frank Goldner/Jon Carmack
2:30	NEAMS Update	Steve Hayes
3:15	NRC Proliferation Risk Study Overview	Dan Vega
3:45	Spent Fuel Storage and Transportation R&D	Jeff Williams

The report is organized more or less along the lines of the agenda.

High Burn-up Used Fuel Program - This project is part of the overall efforts to develop options for consolidated storage facilities in response to the recommendations of the Blue Ribbon

Commission (BRC). The “Demo” is also being conducted to confirm the data used to license spent fuel storage casks for high burn-up fuel for transportation and the long term storage.

In order to complete plans for developing a dry storage demonstration project for extended storage of used nuclear fuel, R&D must be conducted to benchmark predictive models of system performance, including observation of used fuel in storage.

Recommendation: The scope of the high burn-up fuels project is complex and consists of many participants. This raises the concern that all *possible* instrumentation options will be explored/employed, rather than *necessary* instrumentation to meet NRC requirements. For this reason, the Subcommittee believes it is appropriate that DOE should work closely with industry and the DOE laboratories to ensure that the scope of the project meets the required programmatic objectives.

Spent Fuel Storage, Transportation and Disposal - In January of 2013, DOE released the “Strategy for the Management and Disposal of Used Nuclear Fuel and High-level Radioactive Waste”. This document provides the framework for moving toward a sustainable program to deploy an integrated system capable of transporting, storing, and disposing of used nuclear fuel and high-level waste in the US. The strategy includes a phased, adaptive, and consent-based approach for siting and implementing a management and disposal system. At its core, the strategy endorses a waste management system containing a pilot interim storage facility, a full-scale interim storage facility, and ultimately a geologic repository.

Recommendations: (1) The Subcommittee is of the opinion that the present scope of the pilot facility may be overly complex for a pilot demonstration. A thorough analysis is recommended to determine what an optimal pilot plant should consist of and how the pilot program can assist in the development of the large-scale storage facility. (2) The high-level waste and spent fuel inventory and disposal options evaluation provides a good framework to understand the problem in hand in a macro sense. We recommend a conceptually similar study on the entire spent fuel inventory in light of storage and transportation requirements evaluations. (3) The Subcommittee recommends that the inventory data be rendered flexible so that it can be sliced in different ways, depending upon the activity under consideration. A study such as this can provide guidance to the design of a pilot interim storage as well as the prioritization of R&D activities.

Accident Tolerant Fuels - The program to develop an Accident Tolerant Fuel (ATF) is an outgrowth of an earlier DOE-NE program to develop innovative LWR fuels with enhanced performance (original scope was high burn-up fuel) and safety. Members of the Subcommittee concurred that the program is well structured with a very impressive array of laboratory, university, and industrial organizations. The objectives of fuel selection in 2016 and the LTA/LRA in 2022 insertion, while undoubtedly correct, may be overly optimistic.

Recommendations: (1) Any reduction in resources for this very ambitious program is likely to place the 2016 and the 2022 milestones at risk. Therefore, the AFC should develop contingency plans in the event that resources and milestones are inconsistent. (2) The current ATF program focus on fuel and cladding does not address other lower cost, reactor enhancements. The Subcommittee strongly recommends that the program become cognizant of the implications of severe accidents on other reactor components, such as control material (control rods) and in the case of BWRs, channel boxes, by performing reactor system response analyses, rather than just focusing on the fuel and cladding.

NEAMS Update - The models being developed by the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program, which is funded by another DOE-NE program office but is coordinated with the AFC program, consider atomistic, meso-scale, and engineering scales with the goal of being capable for use outside the limited range of available engineering scale data. Members of the Subcommittee expressed concerns about validation of these tools that are similar to those expressed previously by the NEAMS NEAC Subcommittee, "An un-validated product is worthless or worse."

Recommendation: Without additional validation data, NEAMS developers should acknowledge the limitations that exist with new Fuel Products Line (FPL) tools, e.g., their applicability may be limited to interpolating between available engineering scale data.

NRC Proliferation Risk Study Overview - The subject report was overwhelmingly written from the perspective of policy utility of these quantitative risk assessments, in keeping with the wording of the study charter. Although alternative nuclear energy system technology research and development was mentioned and referenced, the study mostly focused on the value of potential enhanced R&D aimed at improving the assessment methodologies themselves.

Recommendation: The decision to embark on advanced proliferation-resistant nuclear energy systems cannot depend on "perfect" proliferation risk assessments. As highlighted in the subject Report, these will simply not be available without much more data or more refined definitions of engineered nuclear energy systems. Rather, more fundamental high-level decisions derived from non-proliferation and nuclear material security imperatives must be made in order to promote global nuclear energy development, informed at each step of development by the most accurate proliferation resistance (and risk) assessments consistent with design definition and actual data.

II. High Burn-up Used Fuel Program

The Subcommittee heard from Bill Boyle about the status of the high burn-up cask research and development project. This project is part of the overall efforts to develop options for consolidated storage facilities in response to the recommendations of the Blue Ribbon Commission. In order to complete plans for developing a dry storage demonstration project for extended storage of used nuclear fuel, R&D must be conducted to benchmark predictive models of system performance, including observation of used fuel in storage.

To provide a test platform, an initial demonstration has been planned, involving loading a commercial storage cask with high burn-up fuel in a storage pool, vacuum drying cask contents, and housing the cask at an existing dry storage site. Although the project is only currently resourced for the term of the initial five-year solicitation, the contract is designed so that the project could be extended to permit observation for an additional five-year period. Some aspects of the scope of the project remain to be defined, including determining what specific instrumentation will be introduced to permit monitoring of the system, and how and when the cask might be opened at a future date to permit further evaluation of the fuel/cask. In order to support possible opening of the cask after a period of ten years, the R&D project has specified use of a bolted cask.

A contract has been awarded to a team consisting of EPRI, Dominion Power, and AREVA to conduct the dry storage R&D project, based on the availability of appropriate fuel, cask, and a storage location. A draft test plan has been prepared and published for comments; additional information relating to the monitoring and inspection requirements, once identified, will be included in the License Amendment request to the NRC. The projected timeline for loading the cask is driven by upcoming utility outages. Overall, this project represents a necessary step in the design and performance of systems for extended storage for high burn-up fuel.

Comments and recommendations: The plan for instrumentation of the cask system for monitoring is still in development, and this raises the concern that all *possible* instrumentation options may be employed, rather than *necessary* instrumentation to meet NRC requirements. For this reason, the Subcommittee believes it is appropriate that DOE should work closely with industry and the DOE laboratories to ensure that the scope of the project meets the required programmatic objectives.

Technical requirements may exist outside the scope of the licensing-driven goals of the first five-year contract, however, such as the intent to reopen the cask. We recommend that instrumentation functional requirements to validate the safety and feasibility of this outcome be included.

III. Spent Fuel Storage, Transportation and Disposal

Background

Within the DOE's Office of Nuclear Energy, the Office of Fuel Cycle Technologies has initiated planning projects since 2012 to address many of the recommendations by the BRC. These activities are conducted within the constraints of the Nuclear Waste Policy Act (NWPA) and they will lay the groundwork for the future development of storage and geologic repository facilities, as well as support the transportation infrastructure.

In January of 2013, DOE released the "Strategy for the Management and Disposal of Used Nuclear Fuel and High-level Radioactive Waste". This document provides the framework for moving toward a sustainable program to deploy an integrated system capable of transporting, storing, and disposing of used nuclear fuel and high-level waste in the US. The strategy includes a phased, adaptive, and consent-based approach for siting and implementing a management and disposal system. At its core, the strategy endorses a waste management system containing a pilot interim storage facility, a full-scale interim storage facility, and ultimately a geologic repository.

Three presentations under the scope of used fuel storage, transportation and disposal were reviewed:

- Spent Fuel Storage and Transportation R&D
- High-Level Waste and Spent Fuel Inventory Report
- Joint Fuel Cycle Study – Republic of Korea: Used Fuel Workshop

Spent Fuel Storage and Transportation R&D

Many activities have been completed during FY 2013 including a ten-year project plan, building a siting database, investigating public preferences related to consent-based siting, initial design concepts for interim storage, preliminary evaluation of removing fuels from shut-down sites, a draft national transportation plan, feasibility studies for standardized transportation, aging, and disposal canisters, establishing integrated waste management systems analysis capabilities, establishing unified used fuel database and analysis capabilities, and establishing a centralized used fuel resource for information exchange.

Due to the legislative and court actions, the initial focus of the project should be slowed down until a clear path forward is understood. The project currently has been transitioned from "planning and implement" to "laying the groundwork". Near future activities are focused on generic, foundational information and capabilities to support future actions and decision.

High-Level Waste and Spent Fuel Inventory and Disposal Options Evaluation

The goal of this activity is to catalog the inventory of US spent fuel and high-level waste and group them into categories based on similar disposal characteristics to identify potential disposal options for each group. Four disposal concepts – mined repositories in clay/shale, mined repositories in crystalline rock, mined repositories in salt, and deep boreholes in crystalline rock – are evaluated. DOE identified 43 waste types and grouped them into 10 waste groups, based upon their disposal characteristics, with some types mapping to more than one group. The 10 waste groups were evaluated against the four disposal concepts.

The preliminary conclusions from this study indicated that all wastes could go to one mined geologic repository and there is no compelling basis for choosing one rock medium over others. Finally, the study suggests that deep borehole disposal should work well for some small and low-volume waste types such as Cs/Sr capsules.

US-ROK Joint Fuel Cycle Study Fuel Cycle Alternatives Working Group

A Fuel Cycle Alternatives Working Group (FCAWG) was established between the US and the Republic of Korea to collaborate and exchange information of interest to both countries. The presentation provided the recent history of meetings between the two countries and the evolution of topics identified.

The FCAWG includes the disposition subgroup and the storage and transportation subgroup. After several meetings it became apparent that some of the topics only have "one-way" flow of information and would not constitute good collaboration topics that benefit both countries. As a result, only portions of the storage and transportation subgroup tasks will be continued and the disposition subgroup activities are put on hold.

Comments and Recommendations: Members of the Subcommittee concurred that without new legislation replacing the NWPA and with the shortfall of funding, the best strategy for the used fuel management program is to focus on foundational information and capabilities that will support future decisions. We congratulate all the accomplishments of the program in spite of the uncertainties and difficulties. Based on the long history of the program, one of the most important lessons learned is that the spent fuel management system has never been well analyzed and integrated. The pause in the program can provide excellent opportunities to look at the "big pictures" of the program, ask fundamental questions and re-assess assumptions, and thus provide guidance to the program.

The Subcommittee agrees that the near-term objectives of the Nuclear Fuel Storage and Transportation Planning project (NFST) are to emphasize the integration of storage into the waste management system and to establish a foundational, unified storage, transportation, and disposal database and analysis system. However, the Subcommittee has not been convinced that the development of a pilot interim storage facility should be focused only on shut-down reactor sites. As it stands, the Subcommittee is of the opinion that the present scope of the pilot facility may be overly complex for a pilot demonstration. Thus, a thorough analysis is recommended to determine what an optimal pilot plant should consist of and how the pilot program can assist in the development of the large-scale storage facility (see below).

The high-level waste and spent fuel inventory and disposal options evaluation is a good example of the "big picture" assessment of the program. This work provides a good framework to understand the problem in hand in a macro sense. We recommend a conceptually similar study on the entire spent fuel inventory in light of storage and transportation requirements evaluations. Specifically, existing spent fuel storage system/canister and their current transportation-readiness status can be analyzed for the operational requirements for an interim storage. Each spent fuel type may be grouped by similar characteristics that are important to the planning option. The Subcommittee recommends that the inventory data be rendered flexible so that it can be sliced in different ways, depending upon the activity under consideration. A study such as this can provide guidance to the design of a pilot interim storage as well as the prioritization of R&D activities.

Work is already underway in establishing a foundational, unified UNF storage, transportation, and disposal database and analysis system. We believe this database and analysis system needs to be carefully structured so the information will be truly useful for future decisions. The Subcommittee would like to learn more about this particular task in the near future.

The Subcommittee members commend the ongoing work of a standardized canister concept. We encourage that this work be considered and evaluated as part of the entire system.

Although a consent-based siting process cannot be actively pursued at this point due to legislative constraints, there are several international examples of this process that can be used in the future work. With the recent significant progress in Canada using the consent-based siting, we recommend that the program examine the lessons learned from the Canadian process.

Improving the assessment of proliferation risks during transportation, storage and disposal of used nuclear fuel is of continuing concern. The Subcommittee encourages continued attempts to quantify proliferation risks, as done recently.[1] However, the Subcommittee recognizes that the policy decisions surrounding issues of proliferation are only guided by such studies, and thus are more difficult to assess.

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[1] 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. See other references cited in that publication.

IV. Accident Tolerant Fuels

The program to develop an Accident Tolerant Fuel (ATF) is an outgrowth of an earlier DOE/NE program to development innovative LWR fuels with enhanced performance (original scope high burn-up fuel) and safety. The program was initiated by DOE/NE in January 2010, well before the Fukushima events starting on March 11-12, 2011 and likewise well before the Senate language on developing an accident tolerant fuel (December 2012). The program has subsequently evolved with a strong focus on accident tolerance and particularly the response of cladding in the presence of high temperature steam caused by a loss of active cooling.

A key tenant of this program is that the current UO_2-Zircaloy fuel system has been optimized as far as possible and is supported by a well-established infrastructure. A key corollary is that any replacement to this fuel system must offer more than marginal improvements.

ATF-Specific Background

The current ATF program is oriented around a ten-year timeline with a fuel selection to be made in 2016 and a Lead Test Assembly (LTA) or Lead Test Rod (LTR) ready for insertion in 2022. To achieve this goal, the ATF program has collected an impressive array of organizational talent. Six national laboratories are involved as well as six universities, and most impressively, three of the major fuel suppliers. The Funding Opportunity Announcement (FOA) which brought in the fuel suppliers indicated that their activity and progress will be evaluated after two years, and that the decision to continue will be made based on progress toward objectives and available funding.

The ATF program is focused on cladding, in particular upon cladding materials that will limit the high-temperature steam reaction. Examples of this under investigation in the program are:

- Advanced steels such as FeCrAl,
- Refractory materials such as molybdenum alloys,
- Ceramic cladding such as SiC,
- Zircaloy with a coating.

In addition, higher density fuels with a higher thermal conductivity such as metal, nitride, and silicide are being examined.

Each of the above concepts has its advantages and disadvantages across the spectrum of operating and transient conditions under which the current LWR must necessarily operate. To guide development, a systematic analytical and ex-reactor experimental evaluation is being performed, in addition to in-reactor tests in ATR.

Comments and Recommendations: Members of the Subcommittee concurred that the program is well structured with a very impressive array of laboratory, university, and industrial organizations. The objectives of fuel selection in 2016 and the LTA/LRA in 2022 insertion, while undoubtedly correct, may be overly optimistic. This is particularly true because the program is attempting to develop an entirely new fuel system for which the most desirable accident tolerant characteristics are not yet completely defined. Achieving this level of knowledge will require completion of the ex-reactor tests, the ATR tests, and also the feasibility study. Nonetheless, the program management has laid out an aggressive program which is consistent with the magnitude of the problem that they are trying to resolve, e.g. obtaining a superior performance in a Fukushima-type event.

There are two items of concern to the Subcommittee. The first is that any reduction in resources is very likely to place the 2016 and the 2022 milestones at risk. Therefore, it would be prudent to develop contingency plans in the event that resources and milestones are not consistent. This may include either delaying the milestones, or it could include the more drastic measure of reducing the scope of the industrial participants. The latter would be less than desirable as they are the end users of the products of this program. Moreover, the three industrial fuel suppliers are all experimenters in the ATR tests, and reducing the industrial scope in these tests would reduce the value and meaning of same.

The second concern of the Subcommittee is that the ATF program is focused on cladding to the extent that it does not address other problems. Of principal concern here is the response of other replaceable components in the reactor core (e.g., controls rods). Lacking an adequate response of the Emergency Core Cooling System (ECCS), the other core components will overheat, undergo serious oxidization, potentially lose their integrity, and fail to perform their function. An example of this concern is the failure of control rods and control rod drives, with subsequent loss of reactivity control. In addition, failures of channel boxes and core support structures are also of concern. The Subcommittee strongly recommends that the program become cognizant of the implications of a Fukushima type event on other reactor components and the reactor system response, rather than just focusing on the fuel and cladding.

V. NEAMS Update

General Background

The current suite of fuel performance models is semi-empirical in nature as they are validated against separate effects and integral data at the engineering scale. As such, they are limited to the range and domain over which the validation data exist. In contrast, the models being developed by the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program consider atomistic, meso, and engineering scales with the goal of being capable for use outside the limited range of available engineering scale data. To achieve this goal, it would be best to validate such models first against meso-scale data and subsequently against engineering-scale data. Absent this validation, employment of this new suite of codes may involve some risk.

NEAMS-Specific Background

The goal of NEAMS is to develop improved, mechanistic, and predictive material models for fuel performance using hierarchical multi-scale modeling. The NEAMS Toolkit strives to obtain a "Pellet-to-Plant" simulation capability useful for predicting performance and safety for a broad range of nuclear reactor power systems. The Toolkit is modular in design with components organized under a Fuel Products Line (FPL) and a Reactor Products Line (RPL). Individual components represent key physical phenomena (e.g., neutronics; structural, thermal, and fluid mechanics; and materials science). To ensure that the Toolkit provides the desired physical representation, components must simulate:

- Multi-physics (coupled phenomenology),
- Multi-scale (considering the atomic-, meso- and engineering-scales),
- Multi-resolution (more-detailed resolution phenomena informing less-detailed phenomena

The FPL Toolkit development focuses on delivering an integrated set of mechanistic-based computational tools for fuel performance analysis and design. It uses the Multi-physics Object-Oriented Simulation Environment (*MOOSE*) computational framework. Fuel performance simulations with the engineering-scale *BISON* code are informed by material property and irradiation performance models developed from meso-scale *MARMOT* code simulations of microstructure evolution under irradiation. *BISON* simulations are informed by inputs from fundamental materials parameters obtained from atomistic scale simulations using stand-alone codes. *MOOSE* is able to run both *BISON* and *MARMOT* simultaneously to create a three-dimensional simulation that displays microscopic radiation effects evolving into fuel or cladding failures at the macroscopic scale. These new FPL tools are being used by several universities, and are being reviewed and assessed by several industry organizations.

By predicting fuel behavior based on mechanistic models, the developers hope to achieve an unprecedented degree of predictability in the nuclear fuel performance arena, allowing them to extrapolate to other materials and operating conditions. This is in contrast the current and widely-used set of models which are semi-empirical in nature and rely on empirical fits to existing data

Comments and Recommendations: Members of the Subcommittee concurred that the combined physics capabilities of these new tools (e.g., coupled structural deformation, thermal response, and fission gas release) are not possible with existing tools. However, Subcommittee members expressed concerns similar to those expressed previously by the NEAMS NEAC Subcommittee,[2] on the need to validate these new FPL tools. The NEAMS development team stated that funding limitations will preclude them from obtaining all of the data required for input to their models. Hence, the program is focused on validating tools using available engineering scale data and by comparisons with validated fuel performance codes, such as *FRAPCON*. These codes in turn rely on models that are semi-empirical fits to available engineering-scale data. The developers have indicated that this approach has led to the need to 'calibrate' their NEAMS tools (because it is not possible to obtain all of the lower scale data required for their mechanistic models). In light of existing funding constraints, the Subcommittee concurs that the proposed approach for assessing the FPL tools is reasonable, but quite limited in nature. Verification against existing models and validation against the same data as used by the current suite of models used has real limitations. The principal limitation is the lack of data for justifying the extrapolation of NEAMS models beyond range of the current and existing set of models with assurance. The Subcommittee recommends that without additional validation data and validation/assessment activities, the developers should acknowledge that there are limitations that exist with these new FPL tools, e.g., their applicability could very well be limited to interpolating between available engineering scale data, albeit with a superior scientific base.

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[2] Juzaitis, Ray, Chair, "NEAC Review: NEAMS, Summary of Subcommittee Report" (December 6, 2012).

VI. NRC Proliferation Risk Study Overview

The Subcommittee was briefed by Daniel Vega (NE) on a recently-concluded study conducted by a committee of the National Research Council: ***"Improving the Assessment of Proliferation Risk in Nuclear Fuel Cycles."*** DOE/NE and NNSA/NA-24 co-funded this study in response to challenges identified in the NE R&D Roadmap (Objective 4, April 2010), as well as to provide a basis for consensus between NE and NA-20 on issues related to mission, technologies, and policy. The five-element charter for the study addressed *inter alia* key non-proliferation policy questions presumably informed by such risk assessments, along with an assessment of the utility provided by them.

The subject report was overwhelmingly written from the perspective of policy utility of these quantitative risk assessments, in keeping with the wording of the study charter. Although alternative nuclear energy system technology research and development was mentioned and referenced, the study mostly focused on the value of potential enhanced R&D aimed at improving the assessment methodologies themselves.

A key emphasis of the Report was to draw a clear distinction between "proliferation resistance" and "proliferation risk". Proliferation ***resistance*** is defined as "***the characteristics of a nuclear energy system*** that ***impede the diversion*** of undeclared production of nuclear material or misuse of (nuclear) technology by states in order to acquire nuclear weapons or other nuclear explosive devices". On the other hand, Proliferation ***risk*** includes, in addition, a host of other subjective elements and country-specific issues that together influence a state's proclivity to proliferate. The latter assessments are inherently more difficult to quantify objectively.

Of available assessment methodologies, "predefined framework" methodologies proceed by first deconstructing the nuclear fuel cycle into discrete processing steps. For each of these steps, intrinsic and extrinsic attributes are assigned specific values related to diversion or misuse; such values are properly weighted and then integrated to provide an overall value/metric of proliferation resistance assigned to the entire fuel cycle. Another class of "case-by-case" assessments involves more *ad hoc*, subjective evaluations involving multidisciplinary teams of experts, involving sometimes close collaboration with the intelligence community. Owing to the number of subjective factors requiring subject matter experts' judgment in predefined frameworks, as well as an absence of uncertainty and sensitivity analysis, the Report concludes that such analyses (six methodologies were studied) have limited utility. In fact, the Report finds that policy and decision makers find little utility in these assessments of proliferation resistance; moreover, potential improvements in these methodologies will be limited owing to a fundamental paucity of actual proliferation data or a verified ability to model adaptive "adversaries". The Report does not support new or expanded R&D in the methodologies themselves.

Nevertheless, the Report recommends that proliferation resistance (vs. *risk*) assessments do have value in informing fuel cycle R&D decisions, as long as data-driven limitations are acknowledged. Further, it encourages NE and NNSA **to jointly formulate high-level questions to compare the proliferation resistance of alternative fuel cycles to the *de facto* once-through fuel cycle**.

Comments:

In quantifying assessment of proliferation resistance (and risk), it is imperative that the nuclear weapons technology community maintain an appropriate and adequate interface with the nuclear energy development community. Ultimately, judgments regarding "use" of different materials/approaches for the initiation and characterization of nuclear explosions must be made by the nuclear weapons designers and engineers. While protecting design information, such judgments must be passed over to the non-proliferation and nuclear energy technologists for use in proliferation resistance assessments. The NNSA has, in fact, proposed an approach for the general characterization of material that may be employed for proliferation or terror purposes. This approach involves quantification of a Figure of Merit (FOM) for materials which embody material type, its quantity, and how readily it can be used to create a nuclear explosive device. The subject report references this approach. **If such information is to be useful, then a critical review must be made to ensure that FOM formulations objectively, adequately and consistently represent the potential "risk" associated with diversion of such material.** Such a review has, presumably, not yet been completed. The FOM formulations would properly synch with proliferation resistance assessments, as well as assessments of physical security associated with transportation and storage of such materials. Only in this way will more extensive, consistent, and precise assessments of cost/benefit be enabled for proliferation risk assessments.

Given the global danger posed by diverted special nuclear materials, especially separated plutonium and HEU, it is imperative that such materials be eliminated or adequately protected on a global scale. These priorities have been highlighted in the last few Nuclear Security Summits. Correspondingly, the nuclear energy community should respond, arguably, with designs for civilian nuclear energy systems (reactors and fuel cycle) driven by the same imperatives. Sustainability issues (including safety, nuclear waste management, proliferation resistance and cost) will guide development decisions for 21st century nuclear energy systems. To support such a mission and to enable non-proliferation policies of the United States (including potential fuel supply and "take-back" guarantees), it is important that proliferation resistance and risk assessments be developed in tandem with R&D decisions. However, the decision to embark on advanced proliferation-resistant nuclear energy systems cannot depend on "perfect" proliferation risk assessments: as highlighted in the subject Report, these will simply not be available without much more data or more refined definitions of engineered nuclear energy systems. Rather, more fundamental high-level decisions derived from non-proliferation and nuclear material security imperatives must be made in order to promote global nuclear energy development, informed at each step of development by the most accurate proliferation resistance (and risk) assessments consistent with design definition and actual data.