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THE U.S. NUCLEAR CRITICALITY SAFETY EXPERIENCE, NEEDS, AND FUTURE IN A GLOBAL ECONOMY

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THE U.S. NUCLEAR CRITICALITY SAFETY EXPERIENCE, NEEDS, AND FUTURE IN A GLOBAL ECONOMY

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Nuclear criticality safety in the United States of America (U.S.) has experienced recent shifts in administrative, economic, regulatory, and technological demands. These demands are being imposed on the U.S. nuclear criticality safety (NCS) for existing and new production objectives. Most of these objectives are new and place NCS in new "technological space" with regard to the available databases for addressing these objectives. Additionally, there have been growing administrative demands for programmatically justifying research and development for experimental evidence/data to support the use or development of generalized and multipurpose theoretical models, computational techniques, and measurement methods. This growing administrative demand has shifted emphases from historically generalized national support to specific program/project funding. The isolated pursuit of specific information without infrastructure and general support is generally costly and usually not budgeted for by the original project designers. This shift has retarded the maintenance of reliable NCS capabilities in the U.S. to address the evolving technology. Growing global commercial competition provides an increasing economic demand for NCS to accommodate novel productivity improvements resulting in increased production with simultaneous cost-reduction. Such economic demands frequently place NCS in difficult positions.
Key words: criticality, safety, experience, administration, regulation, needs, economy

1. INTRODUCTION

Nuclear criticality safety (NCS) is being tasked with meeting existing and new production objectives to address recent economic, administrative, regulatory, and resulting technological demands. These production objectives include

- the maintenance of historic nuclear capabilities for national electric power and defense purposes;
- the fabrication of new plutonium-uranium mixed oxide (MOX) fuel-blend types;
- the characterization of fissionable-material-process nuclear criticality accidents for emergency preparedness, training, response, and safety documentation;
- storage, transport, and disposal of spent fuel;
- partitioning of major actinides for
  - radioactive thermal-electric generators (RTG)
  - selective actinide production
  - fissionable material waste disposal
  - transmutation;
- disposal and storage of containerized high-level waste in geological repositories;
- disposal and storage of containerized low-level waste and earth-blended waste in geological repositories.

Within the U.S., existing and, most recently, accelerating new economic administrative, regulatory, and technological demands have placed NCS in new technological and regulatory space. The future of nuclear energy in the U.S. is unquestionably influenced by the experiences and needs of our industry to satisfy these demands. Nuclear criticality safety, though seemingly a small expense in the overall scheme of national nuclear energy programs, is a long-term, and nearly always overlooked, expense that impacts nearly all phases of nuclear energy programs using fissionable materials. This is especially true within the U.S. economic, administrative, and regulatory experience, current needs and future participation in the global economy.

2. ECONOMIC DEMANDS

Many NCS economic issues are apparent from the operational, administrative, and technical research and development topics being presented at this NUCEF 2001 Symposium. The U.S. experience with the economic issues of NCS has been highly varied over the past 55 years. Almost no economic consideration was given to the use and potential for nuclear energy during its infancy in the U.S. Some national economic issues were considered during the 1950s "Atoms for Peace" initiative with the growing popularity and evolution of U.S. nuclear research and industry. In the late 1950s and 1960s our power utilities could see the potential of nuclear power and anticipated improved power production efficiencies and cost reduction. Our coordinated and operating research programs and experimental facilities were viewed as a desirable national asset to be maintained as a necessary governmental infrastructure for the new technology. Further, the facilities were judged to assist industry in "boot-strapping" itself into a waiting global opportunity. Existing facilities such as Los Alamos Scientific Laboratory, later renamed Los Alamos National Laboratory (LANL); Oak Ridge National Laboratory (ORNL); and Livermore Radiation Laboratory, later named Lawrence Livermore National Laboratory (LLNL), were joined in their research efforts by numerous follow-on laboratories such as Savannah River and Hanford and commercial facilities such as Pratt and Whitney, Babcock and Wilcox, General Electric, Westinghouse, and numerous others. The economic costs of these laboratories were accepted as prerequisites for obtaining the data, creating the technological and competitive advantages, and educating the personnel to carry forward the "natural" initiatives of a national economic resource, nuclear energy.

Other nations also moved forward into the nuclear energy economy, most out of a recognized need for cost-effective and efficient power generation. In the late 1960s the U.S. moved to develop a commercial breeder reactor which was ultimately thwarted by a national anti-proliferation initiative to ban spent-fuel reprocessing. Shortly thereafter, in 1978, the U.S. experienced its last nuclear criticality accident after 14 years of no accidents. That accident received little national notice and had little economic impact. However, the following year, on March 28, 1979, the U.S. experienced the accident at the Three Mile Island Unit 2 (TMI2) nuclear power plant near Middletown, Pennsylvania. The national reaction had significant repercussions for the nuclear energy industry. The public judged operational and safety risks to be unacceptable irrespective of the actual impact of the event (the best estimates are that the average dose to about 2 million people in the area was about 1 millirem and about 100 millirem to a person who might be and remain at the site boundary).

However, the accident permanently changed the U.S. nuclear industry and significantly broadened the U.S. Nuclear Regulatory Commission's (NRC's) regulations and oversight activities. Until the U.S. nuclear industry was able to accommodate these changes, there were significant cost impacts on power reactor facilities. Those impacts influenced the operations of nuclear fuel fabrication facilities and their nuclear criticality safety programs. While, these changes strengthened public perceptions of the safety of nuclear energy, the commercial power industry had already started to respond to the economic impacts of intervening litigates, increased licensing difficulties, and increased costs of operations. In the U.S., all reactor orders made over the past 20 years have subsequently been cancelled. Between 1972 and 1990, construction of 119 nuclear plants was cancelled by U.S. utilities. The decline in commercial interest in nuclear energy was accompanied by the closure of critical experimental facilities. By the late 1980s, all but one general purpose critical experiments facilitator — the Los Alamos Critical Experiments Facility (LACEF) — were closed within the U.S.

Today, U.S. nuclear fuel fabrication facilities have turned their attention to the global market, selling processes and reactor fuels and participating in joint ventures. Some previously U.S. — owned nuclear fuel processing and fabrication companies have either been sold to international entities or have formed joint ventures to continue the use of the facilities.

What might the future be for NCS as influenced by economics in the U.S.? California's energy crisis this past year and the public's recognition that there will likely be energy shortages as a result of not building power plants over the last decade has renewed interest in the possibilities of nuclear energy in the U.S. The Nuclear Energy Institute reported that a group of utility executives approached them last year to form a task force to determine what would be necessary to deploy a new nuclear plant. The group's idea is to form a consortium of companies that would order several plants, which would be standardized and would benefit from economies of scale of production.

There are mounting concerns which enhance the economic profile of nuclear energy in the U.S. These concerns include

- the CO_2 "greenhouse" effects on global warming;
- the questionable reliability of oil and coal supplies in a highly charged political, emotional, and spiritual world;
- the inability of alternative energy sources to provide reliable energy without environmental impacts;
- the recent unavailability of significant power-producing plants in the U.S.; and
- the problems associated with the U.S. open-ended fuel cycle spent fuel and waste disposition issues.

These concerns serve to accelerate the need for an U.S. national energy policy that is based upon sound economics as supported by sound technology.

International involvement in U.S. fuel fabrication has historically included Siemens Power Corporation and, more recently, British Nuclear Fuels Limited and Framatome Cogema Fuels. Recently, the U.S. nuclear industry has been posturing itself to weather the above mentioned concerns and uncertainties by participating in global exchanges. Currently, there is a joint venture of Duke-Cogema-Stone & Webster in the U.S. to receive excess weapons-grade plutonium, blend it with uranium, and fabricate mixed plutonium-uranium oxide (MOX) commercial fuel elements. General Electric Company (GE) of America; Hitachi, Ltd.; and Toshiba Corp. established Global Nuclear Fuel (GNF), an international nuclear-fuel joint venture, on January 1, 2000. The three companies have integrated their nuclear fuel marketing, design, development, and manufacturing functions into the new company, which established business bases in both Japan and the U.S. These and other joint international business ventures within the U.S. assure a global economic future that will require the continued participation by NCS.

3. ADMINISTRATIVE DEMANDS

For the past 25 years there have been evolving administrative or management mind-sets and perceptions that have created growing fiscal and regulatory demands on U.S. nuclear industries. These mind-sets have changed as the result of the same social and economic events reviewed in Sections 1 and 2 above. Administrative and management mind-sets have shifted from the willingness in the '50s, '60s, and early '70s to generally embrace a promising and lucrative technology with fiscal and intellectual support. From the late 1970s through the mid-1990s there was a desire to separate fiscal responsibilities and administrative accountability from a technology perceived as a liability. Recently, since the late 1990s, the

administrative and management perception is that nuclear energy may be a promising business venture requiring limited, if any, additional intellectual or fiscal support for research and development. It is this last perception that places a substantial technological burden on NCS to address seemingly simple but in actuality complex problems with limited fiscal resources, knowledge, computational tools, and data resources.

The fiscal demands on individual programs or projects are to justify specific needs of research for experimental evidence or data and the development of generalized and multi-purpose theoretical models, computational techniques, and measurement methods. This demand has shifted to the current requirement that individual programs or projects provide their own specific project-related information (e.g., critical experiments, improved cross-section data, improved computational tools) on a limited budget without infrastructure and general support. Therefore, limited fiscal resources are available to acquire needed information. This shift has retarded the development and maintenance of NCS capabilities in the U.S. for addressing the evolving "technological space" imposed by new programs and projects. Maintaining reliable NCS capabilities requires reliable experimental data from critical and/or subcritical systems. Additionally, neutron cross-section measurements and evaluations are needed for the production objectives of concern, which may involve fission products, unusual blends of fissionable materials, geologic materials, and often, unusual neutron energy spectra that may carry the fission chains.

4. REGULATORY DEMANDS

Regulatory demands on NCS parallel the temporal changes in the economic and administrative demands imposed by the social and economic changes in the U.S. The means of addressing regulatory demands on NCS have varied over the decades, ranging from

- relatively informal (by today's standards) memos by eminent scientists who were participating in the emerging studies of the 1940s; to
- structured analytical and safety analysis protocols used by scientific apprentices and technical engineering graduates and accepted by regulatory bodies during the 1950s, 1960s, and early 1970s; to
- increasingly complex and voluminous safety evaluation and safety analysis reports prepared by formally educated nuclear engineers and reviewed by facility management staff and regulatory personnel during the late 1970s to the late 1990s; to
- guidance that may develop from the U.S. Department of Energy (DOE) to include detailed safety analysis report criticality safety controls for DOE central review and approval.

Additionally, the U.S. American Nuclear Society (ANS) has proposed an initiative to develop standard guidance for the performance of probabilistic risk analysis for nuclear facility criticality safety analyses.

The International Organization for Standardization (ISO) has a relatively active working group on nuclear criticality safety within the ISO Technical Committee 85 (TC 85), *Nuclear energy*, Subcommittee 5 (SC 5), *Nuclear fuel technology*, Working Group 8 (WG 8), *Standardization of calculations, procedures and practices related to criticality safety*. Existing NCS ISO standards include; ISO 1709, *Principles of criticality safety in storing, handing and processing*, and ISO 7753, *Performance and testing requirements for criticality detection*. Those standards are being supplemented with developing standards on *Administrative criteria related to criticality safety* and *Nuclear criticality control and safety of plutonium-uranium oxide fuel mixtures outside of reactors*. A standard on *the Estimation of nuclear criticality accident yields* has been suggested but has not yet been initiated. These

existing and developing ISO standards on NCS are likely to play a prominent role in the future in collaborative international ventures involving fissionable materials.

5. TECHNOLOGICAL DEMANDS

The growing global commercial competition provides an increasing economic demand for NCS to accommodate novel process improvements that may result in increased production with simultaneous cost reduction. The changing administrative or management demands challenge NCS staffs to provide their administrators and managers with information and insights to recognize the trade-offs associated with the lack of technical resources for addressing the technical issues. The shifting regulatory expectations in the U.S., and seemingly throughout the world, demand greater levels of elementary justifications and demonstrations of subcriticality for safety with increasingly greater levels of statistical confidence and vanishingly small probabilities of failure.

Those demands, coupled with some existing and mostly new production objectives, place new, unusual, and sometimes conflicting demands on NCS to accommodate programmatic needs. Within the U.S. we are working on approaches and methods to address these demands.

The NRC has considered various evolving issues that are being generated from these typically new processes and technological demands. It has supported

- the acquisition of critical experimental data from intermediate enriched uranium experiments for consideration in the evaluation of fabrication processes for extended-life reactor fuels in combination with the development of a prototypic sensitivity and uncertainty method for examining ranges of the applicability of experimental data to safety evaluations;[1]
- studies to evaluate the influences of fissionable material waste matrixes[2] on subcriticality as it could be affected by reconcentrating hydrogeochemical mechanisms;[3, 4, 5, 6, 7] and
- examination of spent nuclear fuel issues.[8, 9, 10, 11]

Following the Recommendation 97-2 of U.S. Defense Nuclear Facility Safety Board,[12] DOE, with senior U.S. NCS personnel assistance, designed a comprehensive DOE Implementation Plan for a high-level national DOE Nuclear Criticality Safety Program (NCSP) to assist DOE NCS programs and engineers in meeting some of the above-mentioned demands. The NCSP provides support for the

- acquisition of data (e.g., subcritical and critical experiments measurements[13, 14] neutron cross-section measurements and evaluations[15, 16]);
- maintenance and expansion of computational methods (e.g., MCNP[17] and other codes[18, 19, 20]);
- training and guidance of NCS and facility personnel (e.g., issuance of training modules and assistance in the development of regulations/guides and the conduct of classes); and
- sharing and communicating of information (e.g., workshops, conferences, OECD Handbook of Criticality Safety benchmark evaluations[21] and the dissemination of handbook and logbook information[22]).

Much of the information and some of the computational tools that have evolved from the U.S. NRC research support and DOE NCSP have been used to address some of the demands on NCS.[23]

6. U.S. NCS IN A GLOBAL ECONOMY

The NUCEF 2001 Symposium has numerous presentations that address national and global production objectives and their associated demands on NCS programs and engineers to function in the new "technological space." Clearly, innovative applications of science and technology are needed to accommodate these demands in a competitive and growing global economic markets. Through joint international ventures and the sharing of innovative solutions and information at symposiums such as this, the U.S. is likely to remain a partner in the global economy for the success of nuclear energy. This participation is needed and is inevitable for the benefit of the environment that includes us humans.

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