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**Board on Radioactive Waste Management**

November 2, 2000

Dr. Carolyn Huntoon
Assistant Secretary for Environmental Management
U.S. Department of Energy
Washington, D.C. 20585

Dear Dr. Huntoon:

At your request, the National Research Council (NRC) empanelled a Committee[1] to assist the Department in developing a long-range science plan for the management of radioactive high-level waste[2] (HLW) at Department of Energy (DOE) sites.[3] Currently, the Environmental Management Science Program (EMSP) provides DOE's Office of Environmental Management (EM) "with basic research addressing fundamental issues that may be critical to advancing technologies under development, but not yet implemented."[4] The NRC provides you with this interim report to help the EMSP develop a request for proposals (RFP) aimed towards HLW management that will be published in the Federal Register by the end of this year.[5] This report has been reviewed in accordance with the procedures of the NRC[6] and reflects a consensus of the Committee.

In addition to the Committee's expertise in relevant technical disciplines and knowledge of DOE problems, several other sources of information were used to develop this interim report. The Committee reviewed a previous NRC report on the EMSP,[7] as well as three other NRC reports relevant to high-level waste management at DOE sites.[8,9,10] The Committee also held three information-gathering meetings to familiarize itself with the problems at four major HLW sites:

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[1] Committee on Long-Term Research Needs on Radioactive High-Level Waste at Department of Energy Sites. The roster for this Committee is given in Attachment A.

[2] High-level waste is defined by the Nuclear Waste Policy Act (1982) as the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations. This definition does not include DOE's spent nuclear fuel.

[3] The Committee's statement of task is given in Attachment B.

[4] EMSP Program Description (2000). In Environmental Management Science Program. [Online]. Available: http://emsp.em.doe.gov/description.htm [2000, May 31].

[5] Congress has appropriated $37 million to EMSP in fiscal year 2001, including $10 million to fund new research projects. See H.R. 4635 Department of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 2001.

[6] The list of report reviewers is provided in Attachment C.

[7] *Building an Effective Environmental Management Science Program: Final Assessment* (National Research Council, 1997).

[8] *Research Needs in Subsurface Science: U.S. Department of Energy's Environmental Management Science Program* (National Research Council, 1999).

- Hanford, Washington,
- Idaho National Engineering and Environment Laboratory (INEEL),
- Savannah River, South Carolina, and
- West Valley Demonstration Project, New York.

During the first meeting, which was held on March 30-31, 2000 in Washington D.C., DOE gave the Committee an overview of EMSP research activities and HLW management problems at all of its sites. The second meeting was held in Richland, Washington on June 12-14, 2000 to receive briefings from DOE-Richland Operations Office, Pacific Northwest National Laboratory, and INEEL staff. During this meeting the Committee also toured the Hanford Site. A third meeting was held in Augusta, Georgia on August 28-30, 2000 to obtain information about the Savannah River Site and HLW immobilization issues. Presentations from staff of the DOE Savannah River Office, Westinghouse Savannah River Company, and West Valley Demonstration Project were followed by a tour of the site. Thus far, the Committee has received complete cooperation from DOE and has not been constrained in its information gathering efforts.

The Committee also reviewed the portfolio of research projects supported by EMSP since its inception in 1996.[11] The information reviewed included project titles, principal investigator names and affiliations, as well as project abstracts. The purpose of this assessment was to determine the range of research topics and issues being addressed and also to begin the process of identifying potential research gaps. As of fiscal year 2000, there are 306 research projects within the EMSP portfolio. Of these, 76 are categorized by EM under the "HLW problem area."[11] The other EM problem areas are Decontamination and Decommissioning (D&D), Subsurface Contamination, Health/Ecology/Risk, Mixed Waste, Nuclear Materials, and Spent Nuclear Fuels. A complete analysis of the EMSP research portfolio by the Committee showed that there are 92 projects closely related to HLW management problems even though some of them appeared under different EM problem areas. All 92 projects were sorted into six research fields related to HLW management (listed below) or as "other EMSP grants" if they were not directly relevant to any of the research fields. Results are summarized in Appendix D. Some of the projects may appear under more than one field because they affect several phases of the HLW management process. The six research fields relevant to HLW management are the following:

- characterization,
- waste retrieval,
- waste pretreatment,
- waste immobilization,
- tank closure, and
- in situ disposal.

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[9] *Alternative High-Level Waste Treatments at the Idaho National Engineering and Environmental Laboratory* (National Research Council, 2000).

[10] *An End State Methodology for Identifying Technology Needs for Environmental Management, with an Example from the Hanford Site Tanks* (National Research Council, 1999).

[11] Environmental Management Science Program (2000). Multiple Criteria Search. In EMSP Projects Database. [Online]. Available: http://emsp.em.doe.gov/portfolio/multisearch.asp [2000, July 31].

This approach follows the DOE baseline approach to HLW management—characterize, retrieve, pretreat, immobilize, and close the tanks—and it includes the option of "in situ" disposal for at least a fraction of the waste. In this context, the Committee's definition of the "characterization research field" covers the characterization of HLW in the tanks and in the near vicinity, characterization of waste during pretreatment and immobilization, and characterization of the remaining HLW left in the tanks after retrieval. Spent nuclear fuel is not considered HLW by DOE (see footnote 2); therefore it was not addressed in the report.

Based on the information gathered to date, the Committee has identified broad research fields that would benefit from a basic science plan. The Committee does not wish to circumscribe the investigators' creativity by giving a detailed list of research projects. It is the role of the EMSP investigators to implement these broad recommendations with proposals addressing specific issues within the research fields outlined in this report. These recommendations are described in the following paragraphs.

It is the judgment of the Committee that some HLW-related problems will require further research and development to minimize risk and program cost and to improve the effectiveness of cleanup. This preliminary analysis of the EMSP portfolio and the review of the information gathered thus far has led the Committee to conclude that the RFP should solicit research projects in the following four fields, in rank order:

1. **Long-term issues related to tank closure and characterization of surrounding areas.** The figure in Attachment D shows that EMSP has awarded 21 projects related to tank closure issues. Specifically, these projects are related to the decontamination of HLW tanks and the characterization of soils around the tanks. However, as noted by a previous National Research Council report,[8] there appears to be only a small number of projects addressing radionuclide and metal contamination problems in the near-field around the tanks, as well as a lack of projects concerning engineered surface or subsurface barriers. Moreover, very few projects are devoted to the characterization of the HLW remaining in the tanks after retrieval. Therefore the Committee reiterates the recommendation in the previous NRC report[8] to strengthen research on these long-term issues. A few examples of research activities to address these issues are: i) innovative subsurface characterization methods to achieve a more effective remediation strategy, for instance using advanced imaging techniques, ii) innovative technologies to remediate small "hot spots" in the ground, and iii) characterization of the HLW remaining in or near the tanks after retrieval to facilitate tank closure.

2. **High-efficiency, high-throughput separation methods that would reduce high-level waste program costs over the next few decades.** The EMSP is supporting a significant number of separation sciences projects in the pretreatment category (Attachment D). These projects are mainly focused on understanding and controlling the speciation of elements under alkaline conditions and developing different radionuclide separation methods. However, there appears to be an insufficient focus on two important goals: high-efficiency separation and the minimization of the volume of secondary waste. The Committee recommends that the EMSP encourage proposals on separation sciences that address these two goals. The projects should directly address all types of separations: solids from liquids from gases, HLW from low-level waste, and

radionuclides from organic compounds. In the Committee's opinion, such research would help to minimize costs and improve the effectiveness of the cleanup effort. One example of a project addressing separation issues could be research on processes that remove multiple radionuclides in a single step.

3. **Robust, high loading, immobilization methods and materials that could provide enhancements or alternatives to current immobilization strategies.** Immobilization strategies involve both the immobilizing matrix and the immobilization technology. DOE currently immobilizes its HLW in a borosilicate glass matrix using slurry-fed electric (Joule) melters. In the Committee's opinion, borosilicate glasses may not be the appropriate immobilization form for all DOE waste streams, in particular for INEEL's calcined HLW and for secondary waste streams, from a risk and/or a cost point of view.[12,13] The Committee encourages research on alternative immobilization matrixes, *tailored for either HLW or low-level waste*, such as cement[14] or crystalline ceramics. Moreover, the use of Joule melters for making borosilicate glasses could limit the processes available for different waste streams leading to less efficient immobilization results. Hence, the Committee also encourages research on alternative melter techniques.[15]

4. **Innovative methods to achieve real-time, and, when practical, in situ characterization data for HLW and process streams that would be useful for all phases of the waste management program.** The Committee is aware of the numerous research projects relevant to the characterization field within the EMSP portfolio (Attachment D). Over two dozen of these projects concern real-time and/or in situ characterization techniques. However, most of the projects focus on the characterization of waste in the tanks. Very few (5 projects have been identified) address the problem of characterization of the waste after retrieval, for instance the characterization of process streams and melter feeds. The Committee recommends research in this area to achieve shorter turn-around times for the analytical results, which would allow better control of HLW processing. An example of such a project is research on fiber-optical interrogation to characterize process streams.

**Desired attributes of the EMSP research portfolio**

In selecting the projects in this proposal cycle, the Committee believes that some attention to the following programmatic recommendations is warranted:

- As noted by previous NRC reports,[7,8] the research projects that are funded should be focused on DOE's significant long-term problems to advance the state-of-

[12] Lutze, W., and R.C. Ewing. 1988. *Radioactive Waste Forms for the Future*. Amsterdam: North-Holland Physics Publishing.

[13] Donald, I.W., B.L. Metcalfe, and R.N.J. Taylor. 1997. The immobilization of high-level radioactive wastes using ceramics and glasses. Journal of Materials Science, vol. 32, 5851-5887.

[14] Cementation was one of the recommended alternatives to immobilize INEEL's calcined waste; see reference 9, chapter 6.

[15] The recommendation of supporting research on alternative melter techniques was also endorsed by two other NRC reports: *Glass as a Waste Form and Vitrification Technology: Summary of an International Workshop*, (National Research Council, 1996) and reference 9.

knowledge well beyond the next decade. One significant issue is the long-term performance of materials used to immobilize HLW.[16,17]

- Because of its mission, the EMSP should promote "needs driven" or "mission-directed" basic science supporting research on fundamental processes and phenomena with potential high-impact results.[18] Such projects should have a sufficient number of single or dual-investigator teams that are exploratory and innovative, and that may use non-conventional approaches possibly borrowed from other disciplines. This recommendation was also endorsed by three previous NRC reports.[19]
- The EMSP should promote underlying science and technology parallel to "baseline" or "programmatic" approaches to enable high-level waste management efforts to be flexible in dealing with any unanticipated difficulties. A recent example of the importance of these "contingency" research activities has been the necessity for rapid identification of alternatives for separating cesium from HLW at the Savannah River Site after the in-tank-precipitation process was abandoned because of technical difficulties.[18] A considerable amount of time and money might have been saved if DOE, as far back as the early 1980's, had invested resources for research and development into alternatives to tetraphenylborate (TPB) precipitation or to better understand the mechanism of TPB decomposition.
- As recommended in two previous NRC reports,[7,8] EMSP investigators should interact with problem holders at the sites to learn about the nature of the problems to be solved. In return, the problem holders might gain a better understanding of the scientific gaps underlying the problems. The Committee therefore recommends that EMSP identifies "liaisons" among the problem holders at the sites to communicate with the investigators. The liaisons "will not only have the greatest knowledge about the sites but will also be able to assist in integrating the results of EMSP into the long-term EM effort."[7]

At the half-way point in this study, the Committee is still debating a number of issues so that it can fully address the statement of task. Although consensus has not been reached on all issues, the Committee wishes to take advantage of this interim report to inform DOE about some of the topics that are being debated. For instance, the Committee recognizes the importance of R&D in contributing to a better understanding and reduction of possible risks to the site workers and the public at large. At this point,

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[16] Weber, W.J., R.C. Ewing, C.A. Angell, G.W. Arnold, A.N. Cormack, J.M. Delaye, D.L. Griscom, L.W. Hobbs, A. Navrotsky, D.L. Price, A.M. Stoneham, and M.C Weinberg. 1997. Radiation effects in glasses used for immobilization of high-level waste and plutonium disposition. Journal of Materials Research 12(8):1946-1978.

[17] Weber, W.J., R.C. Ewing, C.R.A. Catlow, T. Diaz de la Rubia, L.W. Hobbs, C. Kinoshita, Hj. Matzke, A.T. Motta, M. Nastasi, E.K.H. Salje, E.R. Vance, and S.J. Zinkle. 1998. Radiation effects in crystalline ceramics for the immobilization of high-level nuclear waste and plutonium. Journal of Materials Research 13(6): 1434-1484.

[18] In the Committee's view, basic science is defined as research that creates new generic knowledge and is focused on long-term, rather than short-term, problems. See also reference 8, page 13.

[19] See reference 7, page 3; reference 8, page 117; and *Allocating Federal Funds For Science and Technology*, pages 76-79 (National Research Council, 1995).

[20] More details are available in the NRC report *Alternatives for High-Level Waste Salt Processing at the Savannah River Site* (National Research Council, 2000).

however, the Committee has not yet converged on the specific risk-related tasks that are consistent with its understanding of the basic research element in the statement of task.

The Committee is cognizant of the fact that the RFP planned for the end of this calendar year cannot immediately fulfill all of these essential attributes, but the EMSP should continue its endeavors to develop a portfolio having the attributes discussed in this letter. The Committee will hold two more meetings to discuss further the issues identified in this report and will develop more detailed findings and recommendations. The Committee hopes to issue its final report by June 2001.

Sincerely yours,

Michael Corradini
Chair

Attachment A: Committee Roster
Attachment B: Statement of Task
Attachment C: List of Reviewers
Attachment D: Committee's Analysis of the EMSP Portfolio

ATTACHMENT A
COMMITTEE ROSTER

COMMITTEE ON LONG-TERM RESEARCH NEEDS FOR HIGH-LEVEL WASTE AT DEPARTMENT OF ENERGY SITES

MICHAEL CORRADINI, *Chair*, University of Wisconsin, Madison
DAVID CAMPBELL, Oak Ridge National Laboratory (retired), Oak Ridge, Tennessee
MICHELINE DRAYE, Ecole Nationale Superieure de Chimie de Paris, Paris, France
CHARLES DRUMMOND, III, Ohio State University, Columbus
PETER HAYWARD, Eutechnics Consulting, Inc., Pinawa, Manitoba, Canada
LINN HOBBS, Massachusetts Institute of Technology, Cambridge
EDWARD LAHODA, Westinghouse Science and Technology Department, Pittsburgh, Pennsylvania
ROBIN ROGERS, The University of Alabama, Tuscaloosa
BEN STERNBERG, University of Arizona, Tucson
EDWIN ZEBROSKI, Elgis Consutling, Inc., Los Altos, California

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ROBERT M. BERNERO, U.S. Nuclear Regulatory Commission (retired), Gaithersburg, Maryland

***Staff***

BARBARA PASTINA, Study Director
LAURA LLANOS, Senior Project Assistant
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Dr. Carolyn Huntoon
November 2, 2000
Attachment B

ATTACHMENT B
STATEMENT OF TASK

COMMITTEE ON LONG-TERM RESEARCH NEEDS FOR HIGH-LEVEL WASTE AT DEPARTMENT OF ENERGY SITES

The objective of this study is to provide recommendations to the U.S. Department of Energy's Environmental Management Science Program on the development of a long-term basic research agenda to address high-level waste problems at Department of Energy sites. The study will accomplish the following:

- Identify significant high-level waste problems that cannot be addressed effectively with current technologies.
- Recommend areas of research where the Environmental Management Science Program can make significant contributions to solving these problems and adding to scientific knowledge generally.

In recommending specific areas of research, the Committee should take into account, where possible, the agendas of other high-level waste-related research programs.

The Committee may also consider and make recommendations, as appropriate, on the processes by which (1) future research needs can be identified and (2) successful research results can be applied to the Department of Energy's high-level waste problems.

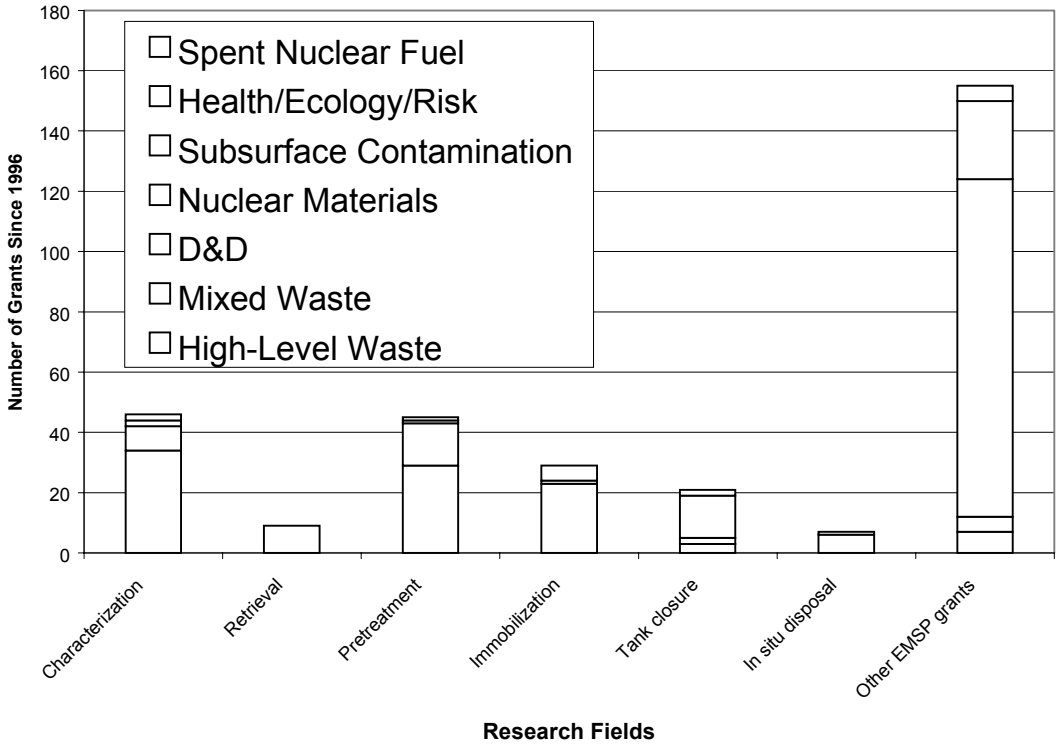
# ATTACHMENT C
# LIST OF REVIEWERS

This letter report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

Dr. John F. Ahearne, Sigma Xi and Duke University
Mr. Philip Clark, GPU Nuclear Corporation (retired)
Dr. Rodney C. Ewing, University of Michigan
Dr. Jane C.S. Long, University of Nevada
Dr. Juan Carlos Santamarina, Georgia Institute of Technology
Dr. Alfred P. Sattelberger, Los Alamos National Laboratory
Dr. D. William Tedder, Georgia Institute of Technology

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by George Hornberger, appointed by the Commission on Geosciences, Environment, and Resources, who was responsible for making certain that an independent examination of this report was carried out in accordance with NRC procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the NRC.

ATTACHMENT D
COMMITTEE'S ANALYSIS OF THE EMSP PORTFOLIO




Number of projects awarded by EMSP since 1996 sorted into HLW-related research fields. The column "Other EMSP grants" includes grants that are not directly related to the management of HLW. Some projects may appear in more than one research field. The legend refers to the seven EM problem areas. Source: EMSP Online (see reference 11).