Nuclear Energy Research
Advisory Committee

November 30, 2004

Mr. William D. Magwood, IV
Director, Office of Nuclear Energy,
Science and Technology
U.S. Department of Energy
Washington, D.C. 20585

Dear Mr. Magwood:

The Nuclear Energy Research Advisory Committee (NERAC) has addressed the charge in your letter of December 31, 2003 to establish a Subcommittee on Nuclear Laboratory Requirements. The Subcommittee was charged with identifying the "characteristics, capabilities, and attributes a world-class nuclear laboratory would possess". It was also asked "to become familiar with the practices, culture, and facilities of other world-class laboratories - not necessarily confined to the nuclear field - and use this knowledge to recommend what needs to be implemented at Idaho."

In response to your charge letter we are pleased to submit the enclosed report, "Report of the Nuclear Energy Research Advisory Committee Subcommittee on Nuclear Laboratory Requirements", hereafter referred to as the Report. It is hoped that this report will be included as an element of the Department's plans to return the DOE site in eastern Idaho to its historic mission of nuclear technology development.

The Subcommittee has developed 28 recommendations for DOE and the Idaho National Laboratory (INL) in five topical areas: commitment, vision and funding; people; facilities; programs; and governance and metrics. Nine of these recommendations are of the highest priority and are specifically called out in the Report's Executive summary. In the area of governance and metrics, NERAC observes that DOE-NE has the responsibility to provide both contract management and technical oversight of the new INL and that DOE-NE needs to be very careful how they execute both of these responsibilities. The Subcommittee's Recommendation 18 is fully aimed at addressing the contract management responsibility, and Recommendations 21, 25, and 26 address various aspects of the technical oversight of the INL, including the need for DOE-NE to enable the extensive use of outside technical experts to assist them in carrying out their technical oversight responsibility.

The Subcommittee has also determined that a definition for a world-class research and development (R&D) organization (originally developed by the National Research Council and modified by the Subcommittee) serves as a good starting point. This definition states that:

> "A world-class research organization is one that is recognized by peers, customers and competitors as among the best in the field on an international scale."

More to the point for a nuclear technology organization, the Subcommittee believes that:

> "A world-class nuclear technology research laboratory is recognized by peers, customers and competitors as one of the best in a broad range of nuclear technologies and related fields, leads in the discovery of nuclear-related knowledge and in the introduction of new technologies into the marketplace, attracts close interactions with other leading research organizations on a national and international scale, has the respect and admiration of worldwide industry, attracts top students into a career path, and is known and admired in public circles."

Further, the Report has determined that:

> "The capabilities, qualifications, focus, and drive of the scientific, technical and other professional staff of the laboratory are absolutely critical to a laboratory being, and being recognized as, among the best in the world. In addition, strong and steadfast commitment by sponsors and major stakeholders is an essential prerequisite for a world-class laboratory. This commitment requires a sustained allocation of resources – principally funding, people, and facilities – which are needed to ensure the implementation of the laboratory's specific vision, mission, goals and objectives."

The Report also includes the Subcommittee's belief that the vision of the INL and its mission to lead in the development of nuclear technology are such that basic research must be conducted and carried over into applied research and development and then followed through into demonstration. It is clearly the INL's mission to lead in all three. World-class demonstrations demand world-class research as a foundation, and world-class research begets world-class developments and demonstrations.

As concluded in the Report:

> "It is vital that the U.S. reinvigorate its nuclear science and technology base as soon as possible or it will not have the capability to compete economically or to interact effectively in international policy circles on important national security issues involving nuclear technology. The

future of civilian nuclear technology is inextricably linked to the future of international and domestic security.

The next few years are especially critical. What happens during the first years of the INL will determine whether a world-class research laboratory can be achieved. DOE must create an immediate sense of urgency around the formation of the INL and needs to demonstrate its full commitment and focus. Rarely if ever has a laboratory been able to recover and achieve world-class stature, if the tone and commitment are not set right at the beginning. DOE and the INL management team must do this right, the first time."

We are confident that the recommendations contained in the Report will be useful to DOE-NE in developing the people, facilities and programs necessary to make the Idaho National Laboratory a world-class nuclear energy laboratory in ten years.

Sincerely,

William F. Martin
Chairman

cc: Dr. John Ahearne, NERAC
Dr. Andrew Klein, Oregon State University
Mr. Mark Roth, DOE/NE

REPORT

of the

Nuclear Energy Research Advisory Committee

Subcommittee on Nuclear Laboratory Requirements

Andrew C. Klein, Chair
Beverly K. Hartline
Robert L. Long
Robert N. Schock
Michael B. Sellman

September 30, 2004

EXECUTIVE SUMMARY

As an element of its plans to return the U.S. Department of Energy (DOE) site in eastern Idaho to its historic mission of nuclear technology development, the DOE asked its Nuclear Energy Research Advisory Committee (NERAC) to establish a Subcommittee on Nuclear Laboratory Requirements. The Subcommittee was charged with identifying the "characteristics, capabilities, and attributes a world-class nuclear laboratory would possess". It was also asked "to become familiar with the practices, culture, and facilities of other world-class laboratories – not necessarily confined to the nuclear field – and use this knowledge to recommend what needs to be implemented at Idaho."

The definition for a world-class research and development (R&D) organization (originally developed by the National Research Council and modified by the Subcommittee) serves as a good starting point. This definition states that:

> A world-class research organization is one that is recognized by peers, customers and competitors as among the best in the field on an international scale.

More specifically, the Subcommittee believes that:

> A world-class nuclear technology research laboratory is recognized by peers, customers and competitors as one of the best in a broad range of nuclear technologies and related fields, leads in the discovery of nuclear-related knowledge and in the introduction of new technologies into the marketplace, attracts close interactions with other leading research organizations on a national and international scale, has the respect and admiration of worldwide industry, attracts top students into a career path, and is known and admired in public circles.

The capabilities, qualifications, focus, and drive of the scientific, technical and other professional staff of the laboratory are absolutely critical to a laboratory being, and being recognized as, among the best in the world. In addition, strong and steadfast commitment by sponsors and major stakeholders is an essential prerequisite for a world-class laboratory. This commitment requires a sustained allocation of resources – principally funding, people, and facilities – which are needed to ensure the implementation of the laboratory's specific vision, mission, goals and objectives.

World-class performance results from achieving excellence in six key areas: customer focus; resources and capabilities; strategic vision; value creation; quality focus (including safety, security, and management performance); and sound governance. The attributes that all world-class scientific and technical laboratories have in common include:

- A well defined mission
- For applied missions, funding for necessary supporting research programs

- A director and staff with broad experience, outstanding technical judgment and a record of prior success
- A leadership team that has authority and freedom to manage the laboratory while being held accountable
- A sponsoring agency staff that is very knowledgeable and has authority to make decisions for the sponsor
- Substantive interaction with peer technical communities

The Subcommittee believes that the vision of this laboratory and its mission to lead in the development of nuclear technology are such that basic research must be conducted and carried over into applied research and development and then followed through into demonstration. Furthermore, it is clearly this laboratory's mission to lead in all three. World-class demonstrations demand world-class research as a foundation, and world-class research begets world-class developments and demonstrations. Thus, the remainder of this report discusses this continuum as research, development and demonstration (RD&D).

The Subcommittee has developed twenty-eight recommendations for DOE and the Idaho National Laboratory (INL) in five topical areas: commitment, vision and funding; people; facilities; programs; and governance and metrics. Nine of these recommendations are of the highest priority. These priority recommendations are:

Commitment, Vision and Funding

- ***Beginning immediately with the FY 05 Budget the Department of Energy must assign the highest priority to the funding of the Idaho National Laboratory and allocate significant resources to beginning the build-up of facility and staff capabilities. Furthermore, this build-up must recognize and allow for the continuing contributions of the other national laboratories engaged in world-class nuclear technology R&D.***

- ***As soon as possible the DOE and INL need to understand and agree on the vision and mission of the laboratory and develop usable vision and mission statements that inspire the DOE, Congress, and the Public to provide moral and financial support commensurate with the mission, excite scientists and engineers to become involved in the activities of the laboratory, and provide long-term direction and focus for the laboratory.***

People

- ***To attract superb scientists and engineers to become employees, INL must develop policies and practices, including a competitive salary and benefits structure, which encourages the best and brightest scientists and engineers to be and stay involved in the activities of the laboratory. The laboratory also needs to ensure that both its workforce and its users/collaborators comprise a diverse population, in terms of ethnic, gender, cultural, and technical diversity.***

- ***The INL needs to identify and recruit the best and brightest scientists, engineers, and technical managers to be involved as collaborators in the R&D activities of the laboratory. The laboratory should also be creative in developing mechanisms that it can use to involve these high-quality individuals from part-time to full-time employment.***

- ***The INL should create a culture where research and scholarship in the mission areas are encouraged and rewarded.***

Facilities

- ***DOE must fund INL to develop and maintain high quality, state-of-the-art research facilities that will attract the caliber of researchers who will make it a world-class laboratory. Many, if not most, of these facilities must be planned and operated as true user facilities that attract collaboration and encourage both internal and external researchers to propose, conduct, and analyze research of the highest quality and importance.***

Governance and Metrics

- ***DOE must select for INL a managing contractor with superb qualifications, a track record of managing first-class science and technology laboratories, and vision and plans for the science, technology, management, and operational systems required to make INL a world-class laboratory. The plans must include a set of milestones, performance objectives, and incentives that encourage and enable the desired results to be accomplished well, cost effectively, swiftly, safely, and securely. The director and leadership team must combine broad experience, outstanding technical judgment, and prior success in managing research organizations.***

- ***DOE's oversight of INL must focus on managing the contract, not the contractor, consciously enabling the desired world-class technical progress and operational performance, and holding the contractor accountable for managing and operating the laboratory. Consistent with this approach, DOE should reduce to the absolute minimum the number and types of actions, transactions, and processes requiring DOE approval. DOE's oversight approach should concentrate on defining the scope of work and determining whether the contractor is delivering the results (cost, schedule, scope, and quality).***

- ***Selected INL managers and staff should visit and "benchmark" several "world-class" laboratories in nuclear technologies and other fields to experience, identify, and replicate policies, practices, and cultural aspects that contribute to world-class stature.***

It is vital that the U.S. reinvigorate its nuclear science and technology base as soon as possible or it will not have the capability to compete economically or to interact effectively in international policy circles on important national security issues involving nuclear technology. The future of civilian nuclear technology is inextricably linked to the future of international and domestic security.

The next few years are especially critical. What happens during the first years of the INL will determine whether a world-class research laboratory can be achieved. DOE must create an immediate sense of urgency around the formation of the INL and needs to demonstrate its full commitment and focus. Rarely if ever has a laboratory been able to recover and achieve world-class stature, if the tone and commitment are not set right at the beginning. DOE and the INL management team must do this right, the first time.

I. Introduction

BACKGROUND

In 2002, Energy Secretary Spencer Abraham announced plans to return the DOE site in eastern Idaho to its historic mission of nuclear technology development in order to support and advance the Nation's expanding nuclear energy initiatives.

To accomplish this, the Secretary announced on April 30, 2003, that the Department will combine into one organization the research and development activities at that site of Argonne National Laboratory-West and the Idaho National Engineering and Environmental Laboratory, and rename the resulting entity the Idaho National Laboratory (INL). The INL will specialize in developing advanced nuclear energy technologies and perform other research and development (R&D) responding to the Nation's future energy and national security requirements. The Department's Office of Nuclear Energy, Science and Technology will manage the laboratory.

In a letter dated December 31, 2003, the Director of the Office of Nuclear Energy, Science and Technology requested that its advisory committee, the Nuclear Energy Research Advisory Committee (NERAC), establish a Subcommittee on Nuclear Laboratory Requirements.

Subcommittee Membership and Charge

The Subcommittee, chaired by Professor Andrew Klein from Oregon State University, was established by March 2004 with five members: Klein, Dr. Beverly Hartline, Dr. Robert Long, Dr. Robert Schock, and Mr. Michael Sellman. The Subcommittee was charged with identifying the "characteristics, capabilities, and attributes a world-class nuclear laboratory would possess". In addition, the Department expects the "members of this subcommittee to become familiar with the practices, culture, and facilities of other world-class laboratories – not necessarily confined to the nuclear field – and use this knowledge to recommend what needs to be implemented at Idaho." The Department tasked the Subcommittee to report its conclusions and recommendations by the end of fiscal year 2004. The complete charge to the Subcommittee is contained in Appendix A.

An important part of the INL mission must be the demonstration of nuclear technologies. In addition, working toward demonstrations gives the entire staff of a laboratory a strong sense of mission. Not to be overlooked is the obvious advantage of abundant real estate in Idaho for the INL to carry out demonstrations, something not available at many locations in the world. Thus the Subcommittee will often use the terms research, development and demonstration (RD&D) as well as R&D recognizing that a strong research capability usually begets important demonstrations of technologies and active demonstrations require vibrant research to achieve goals, often in real time.

The Department's plans place INL at the center of its efforts to develop advanced Generation IV nuclear energy systems, nuclear hydrogen production technology, advanced fuel cycle technologies, as well as to assist NASA in the development and testing of space power systems. The Department's stated goal is to have INL emerge within ten years as one of the world's leading nuclear energy research laboratories. As will become clear, the Subcommittee believes that to do this will require excellence in a broad range of nuclear technologies.

What is a world-class laboratory?

The characteristics of a world-class laboratory are discussed in detail in Section II. Very briefly, a world-class nuclear technology research, development and demonstration (RD&D) laboratory is generally considered as one that is recognized by peers, customers and competitors as one of the best in research in a broad range of nuclear technologies and related fields, leads in the introduction of new technologies into the marketplace, attracts close interactions with other leading organizations on a national and international scale, has the respect and admiration of worldwide industry, attracts top students into a career path, and is known and admired in public circles.

The Subcommittee believes that there are a number of requirements that must be met in order to have a "world-class" laboratory and that are represented in all world-class laboratories. These include:

- A well-defined mission of sufficient scientific or applied interest that a funding agency (or corporate entity) has a continuing interest in broad and sustained funding.
- If the mission is applied, as it will be in this case, funding must include the necessary supporting research programs as well as the expertise to assess outside supporting research.
- A director and leadership team that combines broad experience in the field concerned, outstanding scientific and applied judgment, and success in managing research organizations.
- The authority and freedom for the leadership team sufficient to manage the laboratory while being held accountable for the laboratory's performance.
- A staff in the funding agency that is sufficiently knowledgeable to measure the laboratory's performance and that has sufficient authority to make timely decisions for the sponsor.
- Substantive interaction with peer technical communities.

Why is a world-class laboratory in nuclear research and technology needed in the U.S., and why at this time?

To begin, one-third of the population of the world has no access to commercial energy services. Even conservative estimates of future energy needs worldwide indicate 1) that electrical power will likely need to double in the next 30 years, and 2) that some significant fraction of that is likely to come from nuclear power, although more in some regions than in others. The specter of climate change, regional air pollution and other environmental considerations increases the attractiveness of substantial new nuclear power. In addition, there are significant ongoing and developing applications of nuclear technology in medicine, agriculture, space, industry, and in fundamental research in all fields. This prospect raises a number of interconnected issues involving weapons proliferation, homeland security, safety, waste disposal and economic competitiveness, and these responsibilities at least partially and in some cases entirely, fall on the

U.S. government. However, the potential global markets for these technologies are in the trillions of dollars per year and directly involve the competitiveness of U.S. industry. It is important for the U.S. to reinvigorate its nuclear science and technology base in this critical area as soon as possible, or the nation will not have the capability to compete economically or to interact effectively in international policy circles on important national security issues involving nuclear technology. The future of civilian nuclear technology is inextricably linked to the future of international and domestic security.

Report Organization

The remainder of this report is divided into three sections:

- Characteristics of a world-class nuclear technology laboratory;
- Creating a world-class nuclear technology laboratory at INL; and
- Recommendations

Recommendations are printed in bold and italic font in the body of the report and pulled out separately in Section IV. Appendices present the charge letter by DOE to the Subcommittee, a list of the organizations and individuals consulted by the Subcommittee during this study, the list of questions that the Subcommittee used during its visits to the laboratories, and the instrument used to survey experts and organizations by electronic mail.

II. Characteristics of a World-Class Nuclear Technology Laboratory

GENERAL DESCRIPTION

There are many ways of defining a world-class laboratory. A committee of the National Research Council (NRC) has developed a definition that provides a useful starting point for discussion (Reference 1). This definition, which has been modified by the Subcommittee to include recognition by an organization's customers, states that:

> A world-class R&D organization is one that is recognized by peers, customers and competitors as among the best in the field on an international scale.

The NRC Report, which was prepared for a U.S. Army R&D organization, also provides a detailed description of characteristics and metrics that can be used to assess an R&D organization. The relationship between key characteristics is shown conceptually in Figure II-1 with the "characteristic pillars" firmly supported by a demonstrated commitment from the highest levels and throughout the organization to achieve world-class performance. The Subcommittee also found the metrics and processes being developed for DOE by Gretchen Jordan, et al. to be valuable (Reference 2). In the current report the Subcommittee has edited these characteristics so that they apply to a world-class nuclear science and technology laboratory. This section provides a brief description of these characteristics, along with specific examples of one or two laboratories where each characteristic is particularly well developed. In each case, the Subcommittee could have featured other laboratories, including both DOE and non-DOE laboratories. The Subcommittee has chosen to select primarily examples from outside the DOE system, because they are likely to be more educational to the reader.

Recommendation: INL and DOE should adopt a set of metrics to periodically assess progress toward achieving world-class stature for the Idaho Nuclear Laboratory. The concept of a world-class organization should be used for internal self-assessment rather than for external advertising. References 1 and 2 provide a helpful starting point.

Strong and steadfast commitment by sponsors and major stakeholders is an essential prerequisite for a world-class RD&D laboratory. This commitment must be communicated throughout the entire organization from the highest management level to the lowest staff levels. It requires an allocation of resources – principally financial (dollars), people, and facilities - needed to ensure the implementation of the detailed mission, goals and objectives. The Subcommittee believes that this commitment must be strongly demonstrated and would be characterized by sustained allocation of resources - primarily people and dollars - to the systematic achievement of the organization's vision and mission. As stated in Reference 1, "Without this commitment, only lip service can be paid to the concept and goal of world-class performance. Without a demonstrated commitment, reaching or maintaining world-class performance will be doomed."

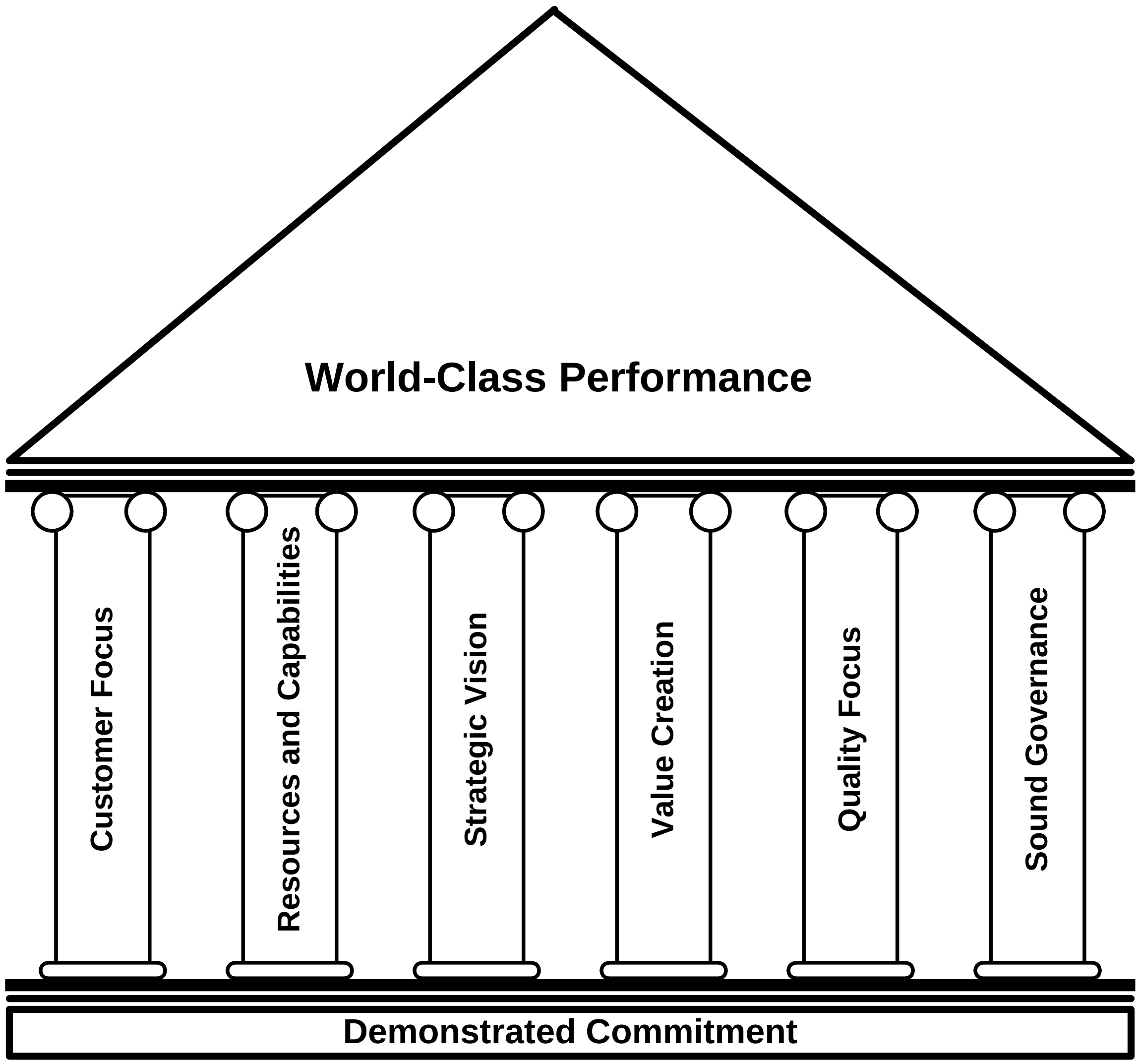

FIGURE II-1. Relationship of the components of world-class R&D organizations (adapted from Reference 1).

This demonstrated commitment was evident in all of the laboratories visited. As an example, the Nuclear Energy Division (NED) of Commissariat à l'Energie Atomique (CEA) in France has committed to the development of the up-to-date research infrastructures needed to sustain nuclear energy in the coming decades. The planned facilities will support:

- Plant life time management (material aging) for Generation II & III
- Long term technological evolution for Generation III (performance improvement, evolution consistent with fuel cycle plants,)
- Fuel performance, safety and economics improvement for Generation II & III
- Fuel behavior validation in incidental and accidental situation
- Fuel optimization for high temperature reactor (HTR)
- Waste management and disposal
- New materials and fuel evaluation and performances optimization for Generation IV

Giving careful consideration to research reactors and facilities around the world, NED has (1) consolidated facilities from their multiple laboratory sites, (2) updated work underway on key existing facilities, and (3) moved forward aggressively on new facilities including the Jules Horowitz Reactor and the new waste management facilities, AGATE (Atelier de gestion avancée et de traitement des effluents) and CEDRA (Conditionnement et entreposage de déchets radioactifs) facilities for the treatment of liquid and solid nuclear wastes respectively. The commitment to the support and continued growth of nuclear energy R&D has been sustained by CEA/NED for decades.

CHARACTERISTICS

As shown in Figure II-1, world-class performance and competitive advantages result from achieving excellence in the six pillars: (1) customer focus, (2) resources and capabilities, (3) strategic vision, (4) value creation, (5) quality focus, and (6) sound governance. Following is a brief discussion of each characteristic and many of the underlined phrases below are further described in more detail in Reference 1.

Customer Focus

Identifying, anticipating and responding to customer needs in a timely and cost effective manner accomplish customer focus. It is composed of:

> Service to the nation – satisfying current and anticipating future national needs.
> Customer satisfaction – customers are satisfied with RD&D results, cost, timeliness and quality.
> Customer involvement – customers feel involved in the RD&D activities and can and do have a major impact on the life-cycle development of the products, service, or program.
> Public relations and outreach – public participation and input is continually sought and is valued.
> Synergistic benefits – laboratory results and programs serve the widest possible range of national needs they could benefit.

This level of customer focus was particularly evident at the MIT Lincoln Laboratory. The fundamental missions of MIT and Lincoln Laboratory are:

- Unfettered transmission of knowledge through educational activities
- Creation of new knowledge through research and other scholarly activities
- Service to the nation
- Service to humanity
- Technology in support of national security

Customer focus and involvement is maintained through advisory committees and frequent technical interchange with government, industry and academia. Top quality staff members are recruited and sustained. Employee performance evaluations focus on identifying and responding to customer needs.

Resources and Capabilities

Resources and capabilities are the assets and talents with which the organization creates value for the customer. They consist of:

Personnel quality – ensures that an irrepressible urge for excellence, accomplishment, customer service, and professional growth is indigenous within the laboratory.
Budget/funding – is provided at levels needed to accomplish the mission and in a timely manner.
Science, engineering, and support capabilities, skills, and talents – make it possible for state-of-the-art techniques and the latest discoveries to be incorporated into the laboratory's activities and for the development of pioneering methods.
External personnel resources – guarantee that organizations and individuals recognized as best in their fields augment 'in-house' efforts and enhance progress, often resulting in leap-ahead and breakthrough advances.
RD&D programs - are anticipatory, scholarly, and results-focused.
Organizational climate – incorporates rewards, recognition, personnel systems, and financial systems that motivate workers, teams, and managers to make excellent contributions and decisions in the greater interest of mission success.
Information technology – is used innovatively, enabling technical breakthroughs, bringing the impossible into reach, and supporting effective business operations, communications, and project management.
Facilities and infrastructure – are exceptional and attract outside users, visitors, and collaborators, who are among the best in their fields.

The CERN laboratory in Geneva, Switzerland and the Fermi National Accelerator Laboratory in Batavia, Illinois, provide extraordinary examples of these resources and capabilities. Scientists, particularly physicists, engineers and technicians from around the world are engaged in the study of the building blocks of matter and the forces that hold them together. Fermilab currently operates the world's highest energy accelerator—the Tevatron, while CERN is currently building the Large Hadron Collider, (LHC), which will take ownership of the energy frontier when it is completed. These two world-leading laboratories share a global user community and collaborate extensively on technology development, while each tries to be first to make the key scientific discoveries. CERN's LHC is being installed in a tunnel 27 km in circumference, which housed a previous facility, the Large Electron Positron Collider (called LEP). The use of contractors, equipment suppliers and researchers from all over the world leads to development of new capabilities, many of which can then be used in other applications. The planning and funding of a new facility begins years in advance of operations. The importance of attracting and fully engaging the best people was emphasized again and again. Because of the incredible amounts of data generated in CERN and Fermilab experiments, information technology is an essential element of their efforts. The World Wide Web was conceived at CERN in order to facilitate communication and data sharing by researchers around the world. Both laboratories also have a major focus on technology transfer.

Strategic Vision

Strategic vision is a clearly stated view of the type of organization that senior management would like the enterprise to become. This view is composed of:

Vision and mission – are aligned to translate the vision into a research strategy that consistently yields superior results and performance and measurable progress toward accomplishing the mission.
Anticipatory yet flexible strategic planning – is in place and invites participation throughout the organization. The planning encompasses research programs, human resources, information technology, budget, travel, facilities, etc., and the planning horizon is sufficient to anticipate major sponsor needs.
Stakeholder buy-in – is so strong that sponsor resources are reprogrammed from other purposes to implement and accelerate the vision.

The Charles Stark Draper Laboratory in Cambridge, MA is an independent, not-for-profit corporation dedicated to applied research, engineering development, education and technology transfer. Its vision is to be a "national center of excellence in the application of technology to the analysis, development, measurement and control of complex dynamic systems". The mission and strategies are demonstrably focused on meeting customer and stakeholder needs. To stay focused and maintain strength Draper has identified four critical technical capabilities:

- Guidance, navigation and control
- Autonomous air, land, sea and space systems
- Reliable, fault-tolerant embedded software
- Miniature, low-power electronic and mechanical systems.

Pioneering in the application of new technology and bridging the gap between academia and industry drive Draper's R&D strategies. They are actively involved with universities and have about 60 grad students a year involved in research. The total staff is about 1100. Their human resources policies attract and retain the very best staff and encourage technology transfer and entrepreneurship through a subsidiary "Venture Company".

Value Creation

Reviews of the breadth of research and technology projects, the performance of products and the benefits of services, and the value of work in progress are all important to assessing value creation. This characteristic includes:

Proper portfolio – features RD&D processes and priorities that lead to programs, products, and services with excellent value, performance, and customer acceptance.
Product/program/service performance – fully meets or exceeds customer requirements and often includes pleasant, unexpected benefits (e.g., reduced maintenance, longer shelf life, longer mean time to failure, or resource savings).
Cycle time, responsiveness, and cost effectiveness – consistently meet or beat the customer's schedule and budget requirements. Technical staff monitor developments by

foreign and domestic industry, academia, and at other laboratories to take advantage of their progress and expedite economical solutions to technical problems.
Value of work in progress – is demonstrated through a complete historical database of projects and through an evaluation methodology. Customers rate programs, products, and services as excellent, with the performance exceeding expectations and anything projected to be available commercially for at least several years.

Value creation is at the heart of the mission of the National Institute of Standards and Technology (NIST). The NIST mission is to develop and promote measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life. NIST research and services focus on enabling innovation, e.g., "Excellence in measurement science, driven by NIST, positions U.S. industry and universities to more quickly solve problems." NIST provides embedded tools essential to commerce and industry, e.g., U.S. automakers and suppliers rely on 350 NIST reference materials. Practical, indispensable technical contributions are provided, such as the performance standards for smoke detectors that are now in 94% of U.S. homes. Critical technical contributions are made to the underpinning of homeland security and public safety, e.g., standards for ballistic resistant armor that have prevented numerous military casualties. NIST consistently seeks to promote innovation by ensuring that advanced measurements, standards, research facilities and services are available in rapidly developing technology areas.

Quality

World-class laboratories have a commitment to all dimensions of quality that is inherent and pervasive, including:

Quality as a top priority – recommendations to improve quality are immediately funded and implemented.
Commitment to environmental protection, safety, health, and security – nationally accepted standards in these areas are followed, and performance is on a par with industry leaders.
Effectively structured processes and best business practices – senior leadership incorporates systematic processes and feedback mechanisms into the organization to improve all systems and processes continuously. Disciplined approaches to problem solving include an extensive network linked to resources within the organization and among partners and collaborators, worldwide.
Learning environment – is adaptive and anticipatory. Personnel are encouraged and rewarded for taking intelligent risks and entrepreneurial initiatives, despite occasional mistakes. Traditional and innovative methodologies are used to measure, evaluate, publicize, and accelerate organizational learning.
Quality of research – research results and technology developments are considered to be among the best in the world. Personnel develop new procedures, processes, and materials, receive numerous patents, present their scientific/technical results to audiences of peers, and publish peer-reviewed reports.

The Korean and Japanese laboratories visited by the Subcommittee demonstrated various elements of a world-class approach to quality. The Korean Atomic Energy Research Institute (KAERI) has taken a structured and systematic approach to quality and continuous improvement as a key strategy toward achieving world-class stature. They have built and developed remarkable nuclear R&D capability in a comparatively short time by following a four–step process: learn from the best in the world, partner with the best in the world, copy from the best in the world, then invent and innovate in certain areas to become world leaders.

The Japan Atomic Energy Research Institute (JAERI) and Japan Nuclear Cycle Development Institute (JNC) both have laboratories in Tokai and Oarai that pay a great deal of attention to both safety and quality and have formal organizations, processes and facilities in place to accomplish both. These laboratories demonstrate a formal and systematic approach to nuclear safety that is careful, yet allows work to be accomplished reasonably effectively. Furthermore these laboratories put considerable effort into R&D that can improve safety and safety instrumentation in their own operations and in the nuclear industry. The government of Japan has decided that these two organizations will merge next year. In anticipation of this merger, and exemplifying another aspect of quality, JAERI and JNC are taking deliberate steps to help the merger go smoothly, such as implementing personnel exchanges in which individuals at various levels, including quite high management, trade positions with their counterparts in the other organization.

The High Energy Accelerator Research Organization of Japan in Tsukuba, which is known as KEK, is a smaller laboratory in the same field as the higher energy CERN and Fermilab facilities described earlier. Despite being at a lower energy, KEK designs, builds, and operates state-of-the-art accelerator facilities for the international scientific community. It has been successfully entrepreneurial by providing reliable “workhorse” user facilities for neutron scattering and synchrotron radiation research, and by identifying and pursuing important areas, such as neutrinos and CP-violation, at the frontiers of high-energy physics where it has significant discovery potential. Currently KEK is partnering with JAERI on a construction project to build a major multipurpose accelerator complex, J-PARC, as a user facility at the Tokai site.

Sound Governance

Without sound governance and oversight, it is impossible for organizations to achieve world-class levels of achievement. Essential to sound governance are advice, independent scrutiny, accountability, and feedback loops that help the organization keep work focused and aid in learning from and recovering from problems. Key elements of sound governance include:

> Director and leadership team – combine broad experience in the field, outstanding scientific and technical judgment, and a record of success in managing other research organizations. Personnel of top-quality will only be attracted to the laboratory if the director and leadership team are of extraordinary high caliber, thus giving personnel confidence that management will lead outstanding efforts.
>
> Board of advisors – populated by distinguished and diverse experts in and beyond the relevant scientific, technical, and managerial areas provides objective and thoughtful advice to guide decisions, set priorities, and helps solve managerial problems.

Standing and independent review committees – regularly assess performance scientifically, technically, managerially, and operationally, in the context of the mission, sponsors' goals, and future research directions. Review committee members include leaders in the appropriate fields and R&D managers from other organizations.
Oversight – emphasizes achievement of science and engineering results (including in safety, health, environmental protection, and security) of the highest quality, and focuses on enabling success, not on preventing mistakes. Sponsors and regulators give the laboratory maximum flexibility to accomplish the mission, goals, programs, and projects in the most effective way it can.
Clear internal roles and responsibilities with checks and balances – ensure understanding of goals, accountability for results, and feedback for coordination and improvement.

The Subcommittee found good governance practices at JAERI and JNC in Japan, at KAERI in Korea, at the CEA in France and at the Jet Propulsion Laboratory (JPL) in the United States. JNC is run by a President with an Advisory Council and a Board of Directors, the latter having considerable authority. JAERI has a similar structure, although without the Advisory Board but with a Board of Executive Directors having line "executive authority". The President of JAERI is appointed by the national government in power and the board by the Cabinet and the Diet.

KAERI uses a matrix organization, with functional "divisions" providing personnel for the projects. Each R&D division has a pool of 10 to 30 technical experts. The division director is responsible for project administration and manpower management. The project manager is responsible for the conduct and management of the project. R&D management is project-centered and formally structured, supported by a management information system. A "Plan, Do, Check" process is followed to set visible and achievable goals in advance, document the agreement with project sponsor, and to check progress against plans. Projects are evaluated and controlled for effectiveness and efficiency. There is a five-step process for selecting and evaluating projects: the research planning department establishes guidance; the project champion/applicant prepares and submits the R&D project planning report; the research subcommittee, containing experts in each R&D area does or oversees a proposal evaluation, including presentation of the proposal to a panel; the R&D council (chaired by the KAERI president, populated by the five vice presidents and three division directors (policy, planning, administration) is KAERI's top internal decision-making committee and makes the final selection and budget allocation. Then the project manager manages the conduct of the project, after reflecting comments or recommendations from the review committee.

For mid- and long-term national nuclear R&D projects in Japan, there are cycles of interaction with MEXT (the Japan Ministry of Education, Culture, Sports, Science and Technology) for government projects or with the industrial sponsor (for industry-sponsored projects). Annual progress summaries and a final report are provided to each sponsor. Japan draws from a pool of experts from university, government institutes, and industry to convene specialized review committees with ten to fifteen members to evaluate each of its national nuclear R&D projects.

Good examples of external and independent review and oversight were observed at both CEA in France and at JPL. At CEA/NED there is a top-level "Scientific Committee" that consists of twenty-one external members; nine of these members come from within France and twelve members are from foreign countries. This panel meets in plenary session every 6 months to assign review tasks to ad-hoc thematic working groups, review the summary reports of the reviews conducted recently, and nominates outside experts to participate in the review process. Members of the Scientific Committee and other experts with appropriate backgrounds to review the research themes conduct the “Thematic Reviews” in every research area every three years. This process provides excellent and timely information to the CEA/NED and its laboratories to utilize in research planning and budget preparation.

Oversight of the operations at JPL is the responsibility of the Caltech Board of Trustees Committee on JPL and the twenty members of this committee are Presidents, CEOs and other leaders of major US corporations and research organizations. This committee is supplemented by “Consulting Members” from industry and academia and “Standing Attendees” from the Caltech community. Additionally, JPL uses a “JPL Advisory Council” consisting of twenty-five members of the university and industry communities for guidance, review, and oversight. Furthermore, JPL involves a series of discipline and/or mission specific advisory groups in consultation on particular research programs. The sum of these advisory and oversight committees provides JPL with a regular flow of external information that it uses to tailor and improve its operations and programs.

The complete set of characteristics is summarized in Table II.1.

Table II.1 Features of the Six Pillars (adapted from Reference 1).

Pillars	**Characteristics**
Customer Focus	Service to the Nation
	Customer Satisfaction
	Customer Involvement
	Public Relations and Outreach
	Synergistic Benefits
Resources And Capabilities	Personnel Quality
	Budget/Funding
	Science, Engineering and Support Capabilities, Skills, and Talents
	External Personnel Resources
	RD&D Programs
	Organizational Climate
	Information Technology
	Facilities and Infrastructure
Strategic Vision	Vision and Mission
	Anticipatory Yet Flexible Strategic Planning
	Stakeholder Buy-In
Value Creation	Proper Portfolio
	Product/Program/Service Performance
	Cycle Time, Responsiveness, and Cost Effectiveness
	Value of Work in Progress
Quality Focus	Quality as a Top Priority
	Commitment to Environmental Protection, Safety, Health, and Security
	Effectively Structured Processes and Best Business Practices
	Learning Environment
	Quality of Research
Sound Governance	Director and Leadership Team
	Board of Advisors
	Standing and Independent Review Committees
	Oversight
	Clear Internal Roles and Responsibilities with Checks and Balances

III. Creating a World-Class Nuclear Technology Laboratory at the INL

VISION AND MISSION

One of the pillars of a world-class RD&D organization is having a clear and compelling vision and mission. Understanding the vision and mission and translating them into a set of statements and research strategies will be singularly important activities at the initiation of the INL. This vision and mission will then enable enthusiastic stakeholder buy-in and support so the sponsors of the organization can focus their efforts on providing the resources needed for it to be successful. The goal of creating a world-class nuclear energy RD&D laboratory cannot be achieved without such support.

Recommendation: As soon as possible the DOE and INL need to understand and agree on the vision and mission of the laboratory and develop usable vision and mission statements that inspire the DOE, Congress, and the Public to provide moral and financial support commensurate with the mission, excite scientists and engineers to become involved in the activities of the laboratory, and provide long-term direction and focus for the laboratory.

The Subcommittee drafted examples of vision and mission statements for a hypothetical world-class nuclear energy research, development and demonstration laboratory to guide our analysis and to elucidate our thinking on what INL should be. Both of these statements are based on some of the best practices that we observed during our study.

An example vision statement for a world-class nuclear technology RD&D laboratory is:

"Advancing the United States to the forefront of nuclear technology research and applications"

An example mission statement for a world-class nuclear technology RD&D laboratory is:

Be a national resource to develop and demonstrate the science and technology needed to enable a broad range of civilian nuclear technology applications to gain public acceptance and provide a significant portion of the energy needed by the world in a safe, secure, environmentally sound, and economically competitive manner.

We note that world-class laboratories, in fulfilling their missions, consistently:

- Produce the science, research, technology and engineering demonstration support needed to advance their missions;
- Excel in operations and the timely development of cost-effective solutions to both fundamental and advanced challenges;
- Provide leadership to focus and strengthen the nation's overall program in their mission areas by prioritizing objectives and setting and achieving challenging goals;
- Partner and actively collaborate with universities, colleges, industry, and other government laboratories, both domestically and internationally;

- Maintain an outstanding record in safety, security, health, human resources, project management, environmental stewardship, and business practices; and
- Are a good neighbor and exemplary public citizen.

With respect to this vision and mission, we note that it will be vital to include the laboratory's customers and stakeholders in the development of these statements in order to obtain their buy-in. We also observe that a U.S. world-class nuclear science and technology laboratory's customers and stakeholders would include

- The U.S. government and its agency-sponsors of projects and programs at INL
- The national and global nuclear energy industry
- National and homeland security organizations
- University faculty and students
- Medical researchers and clinicians
- Agriculture and environmental protection concerns
- American taxpayers
- The global nuclear RD&D community
- International entities, foreign governments and their nuclear energy agencies

COMMITMENT

As emphasized in Section II, a demonstrated commitment by the sponsoring agency to achieving excellence in all the desirable characteristics will be required if INL is to become a world-class nuclear science and technology laboratory. Without exception the world-class laboratories visited by the Subcommittee have had the unstinting financial and human resources support of their sponsors and customers. State-of-the-art facilities, laboratories and computing capabilities were repeatedly identified as the key to attracting the best people in the world. Very close ties with the best university researchers, both faculty and students, was also a recurring theme.

Since the announcement in July 2002 by the Secretary of Energy that the combination of INEEL and ANL-W was intended to become the lead DOE laboratory for nuclear technology RD&D, there has been little to no evidence that the Department is truly committed to creating a world-class laboratory at the newly-designated Idaho National Laboratory. In their January 2003 Report (Reference 3) the NERAC Infrastructure Task Force (ITF) stated that, "For the Administration to go forward with 'nuclear energy beyond 2010' the lead lab site at Idaho requires an immediate and significant increase in funding to, e.g., clear up maintenance backlog and make key facilities mission ready." The FY 04 and FY 05 DOE budget requests for INL do not recognize this need for a major increase in INL funding.

The ITF Report also stated that, "New facilities will probably be needed for the purposes of 'nuclear energy beyond 2010'. We believe this might include a source of fast neutrons, among others. In this regard ITF recommends a specific study on the need for steady and transient fast neutron facilities in the U.S. This study should consider accessibility of existing support facilities." To the Subcommittee's knowledge there has been no effort to initiate this study. As noted in Section II, the CEA Nuclear Energy Division has already completed assessments of the need for new facilities and computational capabilities, and construction has been completed or is underway. For the effort to make INL a world-class laboratory to be successful, DOE must examine its total budget and allocate the necessary funds to move INL forward.

Recommendation: Beginning immediately with the FY 05 Budget the Department of Energy must assign the highest priority to the funding of the Idaho National Laboratory and allocate significant resources to beginning the build-up of facility and staff capabilities. Furthermore, this build-up must recognize and allow for the continuing contributions of the other national laboratories engaged in world-class nuclear technology R&D.

CHALLENGES AND OPPORTUNITIES

The definition of the characteristics associated with a world-class nuclear energy research, development and demonstration national laboratory given above sets an aggressive target for the INL. There are a number of challenges and opportunities that the DOE and the leadership of the INL will encounter as they strive toward reaching this vision. The Subcommittee has observed some of these. They fall into ten general categories including creating and maintaining scientific and technical excellence; facilities; significant and sustained funding; governance and oversight; operational excellence; interfaces and partnerships; public relations, outreach, and education; culture; transitions; and a sense of urgency.

Creating and Maintaining Scientific and Technical Excellence

Beyond the obvious need to have a significant challenge (or a few significant challenges) with clear goals and timelines, as well as major facilities to help meet the challenge, there are other characteristics that world-class laboratories possess that are crucial to creating and maintaining a top-notch scientific and technical staff.

The single, most important component of building a world-class national laboratory is to attract, develop, and retain the very best staff for the laboratory. A nuclear-energy-focused laboratory must attract the best and brightest scientists and engineers from many different technical disciplines in order to be successful. It will require more than just nuclear engineers to make the INL a world-class laboratory. Skilled scientists and engineers of many types, including computational scientists, mechanical engineers, materials scientists, chemical engineers, physicists, chemists, social scientists, economists, electrical engineers, and a range of other technical specialists will be needed to build the base for a world-class laboratory.

World-class laboratories typically have uncharacteristically high ratios of PhD-level scientists and engineers to lower degreed professionals and to the remaining staff. At Sandia PhDs outnumber BS-level professionals by a ratio of almost 2 to 1 (1.9). While this ratio is never a reliable figure of merit when comparing individuals, in total it is indicative of the scientific and technical capacity of a laboratory. Comparable ratios at other national laboratories include the Oak Ridge National Laboratory where it is 1.3, the Pacific Northwest National Laboratory where it is 1.3, the Army Research Laboratory where it is 1.1, and the Princeton Plasma Physics Laboratory where it is 1.6. Thirty percent of the entire professional staff members at Lawrence Livermore National Laboratory have PhD degrees and a majority of the remaining staff members have Master’s degrees. At the Korean Atomic Energy Research Institute (KAERI) the PhD/BS ratio is 1.7. At INEEL, this ratio is currently significantly less than 0.5, because INEEL has had primarily a role in demonstrations and more recently environmental cleanup, rather than research. At ANL-W it is 0.5, for what is an engineering demonstration group, but one which has traditionally been closely associated with the research group at ANL-E, which has a larger fraction of PhDs. Thus, a challenge in establishing INL as a world-class laboratory will be to institute policies that attract a scientific and technical staff that is among the best educated in the world in a variety of disciplines and levels of research and development.

A diverse population of women and men from varied ethnic and cultural backgrounds must provide the required mix of technical disciplines needed at the INL. This aspect of diversity will be important to the success of the laboratory because the brightest scientists and engineers, both now and even more so in the future, will come from diverse ethnicities and nationalities. It will be crucial for the laboratory and its neighboring communities in Eastern Idaho to embrace this cultural diversity and welcome foreign nationals to the maximum extent possible, in order to make it a compelling and welcoming environment to work and live.

With respect to recruiting a high-quality staff, special efforts need to be made to maintain first-class personnel benefits (salary, pensions, vacation policy, time reporting flexibility, reasonable progress reporting requirements, leave policies, and university teaching possibilities). Attention also needs to be paid at INL and in the nearby communities to provide employment opportunities that can attract and fulfill the career aspirations of the spouses/living-partners of its current and prospective employees. Additional efforts and programs will be needed to ensure that staff members remain committed to the success of the laboratory (continuing education, challenging assignments, associated faculty appointments at nearby universities, promotion, and competitive salary scales for example). Leadership by management at all levels is critical to the success of recruiting and maintaining the highest quality professional staff.

Recommendation: To attract superb scientists and engineers to become employees, INL must develop policies and practices, including a competitive salary and benefits structure, which encourages the best and brightest scientists and engineers to be and stay involved in the activities of the laboratory. The laboratory also needs to ensure that both its workforce and its users/collaborators comprise a diverse population, in terms of ethnic, gender, cultural, and technical diversity.

Attracting and retaining high caliber researchers to work on the challenges of developing the nuclear energy systems of the future will be demanding and it is critical that the INL take a flexible approach to get these people involved in the work of the laboratory. The community of researchers and scholars who are and will be involved in nuclear-energy-related research is an international one and the INL must develop close interactions with many of these researchers in order to get the best input and ideas.

Since it will be impossible to lure all of these individuals to come together permanently in Idaho Falls, the INL must find creative and innovative ways to engage the most important individuals and research groups to work closely with them. These individuals and groups currently reside in national laboratories, industry, and universities around the globe. Some of them are currently students in our nation's K-12 school systems. Finding creative ways to involve all of these people in research aimed at the development and demonstration of new nuclear energy systems will be among the important success criteria for the laboratory. The leadership of the INL will need to include a wide range of appointment types and opportunities ranging from full-time employment to part-time appointments or consulting arrangements to be able to include the needed people in this enterprise.

Recommendation: The INL needs to identify and recruit the best and brightest scientists, engineers, and technical managers to be involved as collaborators in the R&D activities of the laboratory. The laboratory should also be creative in developing mechanisms that it can use to involve these high-quality individuals from part-time to full-time employment.

World-class laboratories also have a significant portion of their budgets set aside for discretionary research aligned with their mission. These resources allow researchers to pursue a developing strategic area or innovative, exploratory idea quickly, on the basis of an in-house competitive proposal process, without having to wait the several months or more typically involved in seeking external funding. At the DOE national laboratories this 'funding' is called Laboratory Directed Research and Development (LDRD). LDRD is part of the laboratory's approved overhead budget, and it can be as high as 6 percent of operating funds. The best laboratories set aside this amount or an amount very close to it. A challenge for the INL will be to ensure that the negotiated contract has such a provision in it from the beginning and that it is maintained at a sufficient level. Once established, a competitive, quality-based review process for determining how these funds will be spent must be put in place and made transparent to the staff. Additionally, that process must ensure that only the highest quality proposals and strategic initiatives are chosen and pursued.

Recommendation: The INL and DOE need to ensure that the contract to manage and operate INL allows an adequate level of LDRD, with 6 percent being considered a desirable lower bound, during the first years of establishing the laboratory. INL must develop and implement an LDRD review and selection process that is transparent to the staff, and results in the most innovative and meritorious R&D proposals being funded.

Another aspect of world-class laboratories is a commitment to maintaining sustained interaction with comparable international organizations and personnel. This interaction ensures that the laboratory has not only the benefit of ideas from outside, but that its ideas and projects receive full vetting, that the best, most enthusiastic personnel work on the ideas, and that optimum use of resources (people, funds, and facilities) is achieved. A major challenge is to ensure that foreign national access is facilitated, while at the same time making sure that security is not compromised. The DOE science and weapons laboratories have had considerable experience in these matters and their examples will be of some help in this regard.

Recommendation: The DOE and INL should set up international cooperation agreements and joint programs that emphasize collaboration on research and take advantage of expensive facilities, wherever they are. This approach will allow INL facility investments to complement existing and planned facilities elsewhere in the world, and allow available funds for facilities at INL to be used maximally for building truly new, innovative, important, and world-class facilities.

Close contacts with universities (including, but not limited to, summer programs and joint research), with professional societies, with industry and with Congress and the Administration are crucial to being recognized as a world-class laboratory, maintaining this position and ensuring that its technologies are effectively implemented. Setting up and running a series of workshops on critical topics is an example. Publishing papers in reviewed technical journals as well as in volumes that translate technical work into policy implications is also important.

Finally, the INL will also need to be a leader in utilizing new and expanding electronic technologies to draw people in from other geographic areas for open collaborations to enable the best ideas to be brought to the problems that INL will be tackling.

Recommendation: The INL should run workshops and other programs to inform and involve the entire technical and policy community to discuss issues and results in the broad fields of energy and nuclear technology. These workshops and other programs should attract university students at an early stage in their careers, and closely involve university faculty.

Recommendation: The INL needs to utilize electronic communication technologies effectively and systematically to enable individuals from around the world to be intimately involved in the scientific and engineering activities of the laboratory and to inform policymakers continuously of progress toward the goals of INL.

Recommendation: Selected INL managers and staff should visit and "benchmark" several "world-class" laboratories in nuclear technologies and other fields to experience, identify, and replicate policies, practices, and cultural aspects that contribute to world-class stature.

Facilities

Having facilities and infrastructure that are exceptional is essential to attracting staff and outside users, visitors, and collaborators, who are themselves among the best in their fields. At laboratory after laboratory, Subcommittee members saw examples of research facilities that used the latest technologies and provided experimental capabilities that offered unique opportunities to perform advanced RD&D.

In support of the preparation of the NERAC Infrastructure Task Report (Reference 3), INEEL and ANL-W provided updated facility descriptions that were included in the *Nuclear Science and Technology Infrastructure Roadmap* maintained by the DOE Office of Nuclear Energy, Science, and Technology. The first draft of the *Nuclear Science and Technology Infrastructure Roadmap* was completed in December 1998. The *Roadmap* documented a detailed analysis of the Nation's nuclear research and development (R&D) infrastructure in which likely science and technology requirements through the year 2020 were compared to existing facility capabilities. A subsequent revision, issued in March 2000, added additional analyses that considered such factors as facility staffing requirements, evolving missions, schedules, costs, and facility capacities.

Both the new facility descriptions and the needs/facilities assessment were provided to DOE for inclusion in the next revision of the *Infrastructure Roadmap*. The ITF recommended that a broader revision of the *Roadmap* be undertaken to bring it up to date. There have been numerous changes to the DOE facilities and missions in recent years that should be included in the *Roadmap*. To the Subcommittee's knowledge this update has not been undertaken.

The INL Ten-Year Comprehensive Site Plan, dated October 2003 (Reference 4), purports to establish the framework for current and future infrastructure needs. However it only looks at the facilities at INL. In testimony before the House of Representatives Subcommittee on Energy, the Director of the Office of Nuclear Energy, Science, and Technology stated:

> "We [the DOE] expect that, as a command center for nuclear energy, the INL will form close and productive relationships with other national laboratories, particularly those where important, irreplaceable expertise and capabilities exist today. We fully expect the labs, such as Argonne, Oak Ridge, Los Alamos, and Sandia will remain important contributors to the Department's nuclear energy R&D efforts. We do not anticipate the consolidation of all programs into the Idaho laboratory. What we do anticipate is that Idaho will be at the leading edge of new programs that we develop."

Thus, to optimize the use of national resources, use of facilities beyond the Idaho site but in the U.S. (e.g. ANL-E, Oak Ridge, and Savannah River) and at international sites should be included in a long-range site plan for INL. The CEA Nuclear Energy Division approach to consolidating facilities and capabilities within their numerous laboratories could serve as a model for DOE. Additionally, DOE should take advantage of the information and processes developed by DOE's Office of Science to identify and prioritize future facility needs in its mission areas (Reference 5).

Recommendation: At the earliest possible date, DOE should work with key stakeholders to update the Nuclear Science and Technology Infrastructure Roadmap. The Infrastructure Roadmap should include all relevant existing and planned facilities in the U.S and abroad. With the updated Infrastructure Roadmap and a clearly defined vision and mission for INL as inputs, INL and DOE should revise the INL Ten-Year Site Plan, consistent with the DOE's stated expectations that other national and international laboratories "…will remain important contributors to the Department's nuclear energy R&D efforts."

Drawing the very best people to come to work with the INL will require establishing a series of highly respected and unique user facilities. One aim here is to get researchers from universities, industry and other national laboratories to want to work with the people and facilities sited at the INL. It is clear that the best people are attracted to working closely with other top people in outstanding, state-of-the-art, one-of-a-kind, facilities. University faculty who are involved on research projects with the INL will bring their ideas, and more importantly their best graduate students to make good use of the facilities and infrastructure that will be located at INL. Some of those students will be attracted to stay after their graduation, become INL researchers themselves, and further build the INL to world-class status.

Recommendation: DOE must fund INL to develop and maintain high quality, state-of-the-art research facilities that will attract the caliber of researchers who will make it a world-class laboratory. Many, if not most, of these facilities must be planned and operated as true user facilities that attract collaboration and encourage both internal and external researchers to propose, conduct, and analyze research of the highest quality and importance.

Significant and Sustained Funding

In order to support a clear, compelling vision, a world class laboratory focused on nuclear energy must have sustained, significant funding. We found the clearest examples in France and Japan, where nuclear energy research and development laboratories received more than $2B annually. For the INL, most major projects (e.g., the Next Generation Nuclear Plant, or NGNP) would take at least several years to complete and would be jeopardized by ramp-ups and ramp-downs due to annual budget variations.

The research done at INL can lead to the deployment of cost-effective, passively safe base load electric power plants with very low proliferation risk and no greenhouse gas emissions. In addition, research that reduces the toxicity and radioactive lifetime of high-level nuclear waste can provide huge potential benefits in the form of cost avoidance. For example, research on nuclear waste treatment to eliminate the actinides could minimize the number of expensive nuclear waste repositories, like Yucca Mountain, which is expected to cost $40 B to $60 B. Moreover, the resultant reduction in radioactive decay time would lower the isolation time requirement from more than tens of thousands of years to hundreds of years. When one also considers the potential benefits of the efficient utilization of fissile material in spent fuel through recycling of spent fuel, the benefit could be even higher. Obviously, the French and Japanese recognize this huge potential benefit for their countries and fund their nuclear technology laboratories at a level commensurate to the benefit. We should do likewise.

Recommendation: A very high priority for the INL RD&D portfolio is to advance the knowledge and technologies needed to close the nuclear fuel cycle in a way that minimizes the number and maximizes the safety of radioactive waste repositories. Technologies, such as fuel recycling, chemical separations, pyroprocessing, and actinide burning, all hold great promise in this regard.

Governance and Oversight to Enable World-Class Performance

Oversight. Oversight of INL by DOE and the contractor must be aligned and coordinated to enable and facilitate the laboratory achieving and sustaining world-class performance. This alignment requires giving the selected contractor the authority and responsibility to direct and manage the RD&D, facilities, site, and operations consistent with its best judgment, excellent practice, and accepted national and international norms and standards. Any contractor lacking the requisite qualifications—including the ability to establish and sustain world-class scientific/technical performance and culture—should not be selected.

Oversight should emphasize the achievement of results (including in safety, health, environmental protection, and security) and science and engineering of the highest quality, and focus on enabling success, not primarily on preventing mistakes. Multiple layers of oversight and multiple sources and levels of direction are confusing, inefficient, ineffective, unnecessarily costly, and incompatible with world-class performance. The DOE's oversight system will be most effective if it includes the fewest people necessary to accomplish the government's responsibility, their roles and responsibilities are clear, and each one is well qualified for his or her duties and rewarded for accomplishing them in a way that supports world-class performance.

For a world-class laboratory, where creativity and innovation are essential to success and scientific knowledge and technology advance rapidly, it is vital for governance and oversight to promote flexibility, nimbleness, initiative, responsiveness, and collaboration, as well as an environment where creative people can do their best work. Incentives should be implemented that reward the contractor's progress in improving the reputation of the laboratory; recruiting and retaining superb staff; partnering; taking initiative, and being flexible; along with achieving specific scientific, technical, and operational goals and milestones. Performance objectives should focus on results rather than process.

Recommendation: DOE must select for INL a managing contractor with superb qualifications, a track record of managing first-class science and technology laboratories, and vision and plans for the science, technology, management, and operational systems required to make INL a world-class laboratory. The plans must include a set of milestones, performance objectives, and incentives that encourage and enable the desired results to be accomplished well, cost effectively, swiftly, safely, and securely. The director and leadership team must combine broad experience, outstanding technical judgment, and prior success in managing research organizations.

Recommendation: DOE's oversight of INL must focus on managing the contract, not the contractor, consciously enabling the desired world-class technical progress and operational performance, and holding the contractor accountable for managing and operating the laboratory. Consistent with this approach, DOE should reduce to the absolute minimum the number and types of actions, transactions, and processes requiring DOE approval. DOE's oversight approach should concentrate on defining the scope of work and determining whether the contractor is delivering the results (cost, schedule, scope, and quality).

Scientific and Technical Direction and Planning. The scientific priorities and technical directions of world-class laboratories in many fields in the U.S. and abroad are defined with significant advice and input from their scientific/technical communities and stakeholders. In June 2000 the NERAC Subcommittee on Long-Term Planning for Nuclear Energy Research worked extensively with the national community to develop a long-term nuclear technology research and development plan (Reference 6). However there is little evidence that this plan has been used by DOE-NE, and it does not appear to have been closely incorporated into the planning activities of DOE-NE.

One DOE example of planning that is incorporated into programmatic priority setting is the strategic plan prepared by the DOE Office of Science in February 2004 (Reference 7). For nuclear energy, the letter written to Secretary of Energy Spencer Abraham by six national laboratory directors in April 2003 (Reference 8) and the follow-on report prepared by scientists and engineers from these laboratories in May 2003 (Reference 9) appear to be a reasonably current starting point, though they lack the credibility of a plan endorsed by the national nuclear science and technology community and other key stakeholders.

Another proven planning model is to use a regular, independent, expert, open, and inclusive process for developing, and building consensus around plans and priorities for the mid- and long-term. In the United States, many agencies have tapped the National Research Council to prepare topical "Decadal Surveys," which identify priorities and directions for specific fields, for example astronomy or particle physics (Reference 10). When the survey is published, it is used by the appropriate agencies, congressional committees, world-class laboratories in that field, and others to develop, approve, and implement budgets, projects, and program plans during the following several years. Every 10 years, a new "Decadal Survey" is prepared for the field.

For nuclear science, technology, energy, and applications the Department of Energy is the dominant Federal agency. However, within DOE, it is not only NE, but also several other program offices that have purview over and invest in important elements and fields related to civilian nuclear technology development. These additional program offices include notably RW for spent fuel disposition and nuclear waste disposal, and NNSA for non-proliferation and materials disposition. In addition, SC sponsors relevant basic research, and some nuclear power research is sponsored by Naval Reactors. To advance and demonstrate nuclear science and technology, issues of waste, proliferation, economics, and safety must be addressed, and leadership within DOE for each of these issues is found within a different program office. In other fields where there are multiple Federal agencies involved (e.g. high energy physics and nuclear physics), one advisory committee advises both or all affected program offices.

Recommendation: The DOE should adopt the "Decadal Survey" as an important mechanism for long-range planning and priority setting for nuclear science, technology, energy, and applications. Building on the past work of NERAC, DOE should commission the National Research Council to prepare the first of several decadal surveys and use the survey to guide program, project, and facility prioritization. This planning process could include the Infrastructure Roadmap.

Recommendation: To improve coordination and integration of nuclear-related RD&D, DOE's advisory committee (NERAC) should be explicitly chartered to advise NE, along with the R&D programs of NN, and RW, at the least. Any program office with a significant nuclear portfolio that the advisory committee is not formally advising should designate a liaison with this advisory committee.

Laboratory Governance. Each world-class laboratory typically has a top-caliber director and a talented board of independent directors, populated by distinguished and diverse members collectively expert in and beyond the relevant scientific, technical, and managerial areas. This board provides objective and thoughtful advice to the laboratory director and contractor to guide the highest-level decisions, set priorities, and solve managerial problems. The board is independent of the sponsors and is a valued resource for the laboratory director.

Recommendation: The INL contractor should establish a Board of Directors to provide high-level, independent advice to its highest level official and to the director of INL.

Independent Review. At world-class laboratories, a standing and independent review committee regularly assesses laboratory performance scientifically, technically, managerially, and operationally, in the context of the mission, sponsors' goals, and future research directions. Every program area is reviewed by this committee (or topical subcommittees reporting to this committee) every few years regarding the quality of the science and engineering. The review committee is typically chartered to answer the key questions: is the laboratory doing the right things? Is it doing them right and well? The reviews tend to sample, rather than being exhaustive, and they involve intense interaction by reviewers with individual investigators who are doing the work. Review committee members include leaders in the appropriate fields and RD&D managers from other organizations. The review reports are factually accurate, timely, candid, complimentary (where deserved) and constructively critical (where appropriate), to help drive the laboratory toward ever improving performance.

Recommendation: The INL contractor should establish an independent review structure to regularly assess the extent to which the laboratory is doing the right things and doing them well.

Policy and Funding. For world-class enterprises, there is effective communication, clear roles and responsibilities, good coordination, and alignment among the various entities setting priorities, allocating funding, and implementing programs. For nuclear matters at all levels, the organizational interfaces and responsibilities are fractionated and stove-piped, both within DOE as well as within the Congress. There are multiple Congressional committees, agencies, DOE offices, and OMB offices with some purview. Coordinated communication is so challenging that many organizations focus simply on doing their part, ignoring or bemoaning the choices of others.

Recommendation: Coordination among the various government entities with nuclear portfolios and energy portfolios should be improved. Possible mechanisms include providing Congressional oversight via a "Joint Committee," establishing an interagency working group with appropriate representation, and establishing an independent advisory board that hears from and advises all agencies with nuclear and energy portfolios.

Operational Excellence

A commitment to environmental protection, safety, health (ES&H), and security is inherent and pervasive throughout a world-class laboratory. The laboratory strives to identify and incorporate the best management processes and business practices into the organization and to improve all systems and processes continuously. Traditional and innovative methodologies are used to measure, evaluate, publicize, and accelerate organizational learning.

The “Request for Proposal – Idaho National Laboratory”, issued May 2004 appears to appropriately emphasize the many aspects needed to achieve operational excellence (Reference 11). It requires that the contractor, e.g., shall:

1. "Develop and implement innovative approaches and adopt practices that foster continuous improvement and efficiency in accomplishing INL missions.

2. Identify national or commercial standards and best business practices that can be used in place of DOE requirements and implement those approved by DOE.

3. Work in a manner that is safe to workers, the public, and the environment."

Section 2.4 of the RFP is devoted to more detailed environmental, safety and health (ES&H) requirements. It is vitally important that these ES&H requirements be implemented in a performance rather than a compliance mode and that the INL performance in ES&H becomes recognized as a model for the nation. Too often in the past, poor business and ES&H performance at DOE laboratories has been a major impediment to accomplishment of their missions, e.g., the recent stand down of the entire Los Alamos National Laboratory over security and safety issues. It should be remembered that the public would not differentiate between adverse events at INL and those associated with the environmental cleanup of the site. The October 2003 report issued by the DOE's Laboratory Operations Board provides an excellent reference for all national laboratories (Reference 12).

Recommendation: From the very beginning of the new contracts, DOE and the contractors should ensure that exemplary ES&H, security and management practices are integrated with, support, and enable world-class RD&D and high productivity in both the INL and Environmental Management activities of the Idaho site.

<u>Interfaces and Partnerships</u>

The INL is being created within an established collection of organizations and institutions that have considerable expertise in nuclear energy research and technology development. Within the US, these organizations include the other national laboratories in the U.S. Department of Energy complex, universities with nuclear engineering, health physics and other related education and research programs, and industry which ranges from the companies that design and construct nuclear power systems and engineering firms to utilities and operating companies. There is also a large group of international organizations that have considerable interest and expertise in nuclear science and engineering developments. The INL must find acceptable ways to work and interface with all of these entities if it will be able to take a leadership role in the creation of a new nuclear energy system that is acceptable to government, the public, and private businesses that will finally implement the ideas and strategies that are developed. The national laboratories, universities and industry all have important roles to play in the development of the technology related to this energy source and in the development of the people needed to design and operate these facilities safely and efficiently. In its overall role as investor, program manager, and steward of taxpayer resources, DOE-NE should ensure that taxpayer funds are invested in a manner that makes significant progress toward the goals and priorities established through the open planning process described earlier. Furthermore, a major criterion for selecting specific institutional and individual performers should be to choose those who are best qualified and best prepared to accomplish the work at a world-class level.

Recommendation: The INL needs to develop close interactions and partnerships with the many individuals and institutions that have expertise in nuclear energy and technology and broader energy issues. These partnerships include the other national laboratories in the U.S. Department of Energy complex, universities with nuclear engineering, health physics and other related education and research programs, and the varied industrial firms with interests in developing nuclear and other energy applications, both domestically and internationally.

Nuclear technology researchers and developers globally have often been viewed in recent decades as being outside of the mainstream of energy R&D activities in the U.S. The energy community overall has seemed divisive and fractionated into different supply groups and use groups who fight among each other. Sometimes it seems that the nuclear technology community has become rather insular and, when viewed from the outside, defensive. Instead of finding opportunities to work with others who are also working on solving energy problems, the U.S. nuclear technology community tends to debate these general issues within its own group. The global discussion of energy issues need the wisdom and experience that the nuclear technology community brings, and the nuclear technology community can benefit from the wisdom, perspectives, and experience of the others. Solutions to global energy problems are too important to be blocked by infighting in the energy communities. In health care there are different disease advocacy groups, but one rarely (if ever) sees the advocates of a cure for one disease battling against the advocates of a cure for another.

Recommendation: The INL should aggressively pursue re-connecting the laboratory to the other energy R&D communities to help break down the barriers and distrust that have developed between nuclear energy technology developers and those who advocate and develop alternatives, particularly in the area of energy supply technologies. The creation of INL provides a timely opportunity to lead the nuclear energy community to greater involvement in the discussions surrounding energy production and distribution and the full environmental impact of energy technologies.

To help develop staff with the professional capabilities and credentials needed to make the INL a world-class laboratory, the INL will need to both develop the people already in Idaho, and also attract advanced-degreed individuals. For the employees of the INL there should be opportunities for employees to pursue advanced degrees and also to take appointments (tenured or adjunct) at universities to teach the subjects of expertise relevant to them and INL. These should include release time and other flexible scheduling techniques to take or teach classes in Idaho Falls, across the Internet, and at other universities away from Idaho. Within the programs that are developed by the new management and operations (M&O) contractor that involve universities and other educational institutions, both in Idaho and nationally, there needs to be close attention to providing stability of funding for graduate students and post-doctoral researchers, who are supported by these programs. INL's involvement with educating the next generation of nuclear researchers must be sufficiently strong that its management recognizes its relationships with students as a commitment that must endure through to the degree, despite possible funding fluctuations (even termination) of programs paying the student's stipend. In the past certain organizations were established to provide the national laboratories with management and contractual services that enabled the easy involvement of students and faculty. The

Associated Western Universities (AWU) and the Northwest Colleges and Universities (NORCUS) are two that were successful in allowing the laboratories to delegate these functions and provided straightforward access for students and faculty in the activities of the laboratories, for minimal overhead charges. Alternatively, the INL should look into policies and practices that will enable easy connections to be made with individual faculty and students that are outside of the normal contracting pathways for working with universities.

Recommendation: The INL needs to develop policies and practices that will enable easy partnerships to be made with university faculty and students, including mechanisms that are more flexible than the normal contracting pathways for working with universities.

<u>Public Relations, Outreach, and Education</u>

Idaho National Laboratory must become recognized as a solid citizen and a trusted and valued neighbor in its communities and region, and it must contribute to improving the "literacy" and comfort of students and the public with science, technology, energy issues, radiation, and nuclear matters. In addition, it must become a key player in improving the public view and trust of nuclear energy and related technologies throughout the United States.

Proactive openness, candor, and trustworthiness will be necessary to overcome the image of secrecy, untrustworthiness, and unacceptable risk that many members of the public associate with the nuclear enterprise. Laboratory leaders must respect the public and ensure that it is informed promptly and candidly about mission, progress, proposed changes, and any potential problems or programs that could affect it. Establishing formal and informal mechanisms for public input that go beyond the formal requirements of the National Environmental Policy Act (NEPA) would be very advantageous. The risks and benefits of new plant designs must be disclosed up front in ways that people who are not technical experts can understand. Realistic assessments and projections of safety, economics, environmental benefits and impacts (including waste disposal), proliferation risks, and homeland security should be shared with the public in ways that are easy to understand. Public participation and input should be sought and valued continually and proactively, via many means. Staff members should be encouraged to consider themselves emissaries and ambassadors of the laboratory, representing it with pride 24 hours a day, and giving talks to community groups and civic organizations (throughout the country). The laboratory must develop positive visibility and name recognition with taxpayers throughout the nation. With respect to informing and educating the public, the laboratory and its partners should be creative to identify and use numerous mechanisms, such as shopping malls, movie theatres, museums, schools, sports venues, and highway rest areas, for example.

Additional connections will be required with the local community in Idaho Falls and the neighboring areas to enhance the community’s attractiveness to prospective researchers and their families. The compelling nature of the activities being conducted by the INL will bring excitement to the lives of those working directly on the projects at the laboratory. The cultural and recreational opportunities of the local area must be sufficiently vibrant and diverse to sustain these individuals and their families over the long run. Working with the State of Idaho, the City of Idaho Falls and its surrounding areas, the INL needs to cultivate a broad set of local cultural, industrial and recreational capabilities that will attract people with the appropriate nuclear and other technical skills and their families. These can include technology spin-off companies and other companies that bring the specialized capabilities needed to complement the activities and capabilities to be assembled within the INL. These other locally based entities will be important to the development of the diversity of the knowledge and talent bases at the INL.

Recommendation: Working with other laboratories, universities, and industry, INL should lead the development of a public communications and outreach plan and strategy to accompany the technology roadmap for nuclear energy, with clear timetables, goals, and objectives. To get its outreach activities off to a strong start, INL should, as soon as possible, (a) create, start communicating with, and listen to a "public citizen" advisory group, which has members from across the nation, and includes several skeptical about or opposed to nuclear power; and (b) create, start communicating with, and listen to a group of community-selected representatives from the communities in its region. "Open" meetings are recommended. These groups may be helpful in developing and vetting the public communications and outreach plan and strategy.

Because of its ongoing need for a diverse cadre of skilled technical workers, the laboratory must engage actively to support and improve quality pre-college and higher education, especially in math, science, engineering, and technology, locally, regionally, and beyond. It should encourage managers and staff to volunteer in schools. The laboratory should develop educational programs targeting pre-college teachers and students, and pursue partnerships with institutions of higher education and professional educational organizations, such as the National Science Teachers Association. It will also be important to increase the number of students from high school through graduate school who come to the laboratory for meaningful summer and longer research experiences, and in addition to provide research opportunities to teachers and faculty from middle school through university. A particular emphasis should be placed on interesting, inspiring, recruiting, and engaging bright female and male students from all ethnic and demographic groups. These opportunities must not be limited to U.S. nationals and permanent residents.

Recommendation: INL should "benchmark" RD&D organizations that are "best in class" in education and public outreach, and develop and implement with its academic, industrial, and laboratory partners an education and outreach program that inspires and educates Americans of all ages.

Culture of a World-Class National Laboratory

One of the observations made during the visits to the varied laboratories was the importance for a world-class laboratory to maintain a culture of scholarship, even if it also had a product-driven mission. This is distinctly different from a “product” or “sales” oriented research and development culture that places greater emphasis on products and output of saleable results than on scholarship and scholarly activities. This culture is evident in the activities of the laboratory as well as in the terms used by the researchers to describe their work.

While it is important to bring successful business practices to application on a national laboratory’s activities, it must be remembered that a national laboratory should not be operated as an industrial laboratory that must generate products that must contribute to the corporate bottom line. It must be a place where ideas and knowledge are generated, just to enhance the relevant knowledge base. A true national laboratory will develop a balance between product-driven research and development and research simply for greater understanding of our world.

Examples of this balance exist at the Naval Research Laboratory, at JPL, at the Chalk River Laboratory (CRL) in Canada and at the four CEA laboratories that were visited in France, among others. CANDU reactors are the focus at CRL and advanced pressurized water reactors and fuel cycles are concentrated on in France. All of these laboratories have a product focus, yet still maintain a sizable fraction of their research on fundamental topics, albeit closely related to the general nature of the products. Another excellent example of this balance between scholarship and products exists at the Jet Propulsion Laboratory where the "product" of developing and deploying hardware for very challenging space missions drives a culture of excellence. The manifestation of this culture appears in the application of scientific discoveries to the development of practical and usable equipment to be used on flight hardware for the collection and transmission of data from extremely harsh environments. In all examples, world-class fundamental research in materials, actinide science, separations, and other areas are conducted with the general research direction provided by the laboratory focus.

General research areas should be identified and the scientists and engineers turned loose to create, identify and develop research ideas that are publishable as new and innovative knowledge that may or may not directly lead to a realizable product at the end of their particular activity. Too much emphasis on obtaining a product stifles research creativity; too little emphasis leads to wandering and unfocused research activity.

A true world-class national laboratory develops a healthy balance between product focus and scholarship. Too much emphasis on product and the financial bottom line is unhealthy for the development or maintenance of a world-class laboratory.

Recommendation: The INL should create a culture where research and scholarship in the mission areas are encouraged and rewarded.

Transitions

There are a series of transitions that will take place over the next few years with respect to the formation of the INL. It will be important for all parties involved to acknowledge that these transitions will take place and to do everything possible to make these transitions as smooth as possible. Up-front planning to determine desired results (including cultural ones) and identify barriers, challenges, risks, and metrics will pay significant dividends.

The first major transition to take place will be the change of the laboratory to a new management and operations contractor. Proposals have already been submitted and are currently under review by DOE. A decision by DOE is expected in mid-November 2004 and is greatly anticipated by all parties with even a remote interest in the development of nuclear energy resources in the U.S. and around the world. The selection by DOE of an M&O contractor for the INL will set the tone and direction toward (or away from) world-class stature. This contractor will be charged with making the INL a world-class laboratory and DOE and the broad nuclear industry must be willing to support fully and work closely with the chosen contractor to create this reality.

A second important transition is the splitting of the responsibilities at the current INEEL into a cleanup mission still managed by DOE-EM and the new nuclear energy mission managed by DOE-NE. The INEEL, as managed by DOE-EM, has had a vastly different focus than it needs to have under the RD&D focus needed by DOE-NE. It is encouraging to see signs that this change has begun to take place over the past year, but much more needs to be done to build research and scholarship fully into the culture at the INL. It is also very important that the establishment of the INL not be delayed by any contracting or other holdups in establishing the separate Idaho Cleanup Project (ICP). In particular, it will not be effective to delay full funding of the RD&D mission until after clean-up funding decreases.

As emphasized in earlier recommendations, DOE-NE needs to fully establish the INL and give it the focus and support that it will need to become a world-class RD&D laboratory within 10 years. DOE-NE needs to structure and fund the contract with the new M&O contractor with this paramount objective in mind and provide the continued commitment and support needed. That said, INL management and staff cannot see funding as an "entitlement." They must earn significant taxpayer investment in themselves and INL facilities on the basis of their ideas and plans and their ability to execute successfully, safely, securely, and cost effectively.

A third transition is the merger of the cultures and operational backgrounds of the INEEL and the ANL-W. These organizations have evolved from distinctly different pathways and cultures. The INEEL culture of a distinct focus on sales and products plus the regular turnover of their M&O contractor over the past 15 years is contrasted with the academic culture at ANL-W that is a result of the long-standing management by the University of Chicago and ties to ANL-E. For example, there is already a strong culture of research and scholarship at ANL-W. In our meetings with both staff and administrators in both organizations, one thing is very clear – merging the INEEL and ANL-W cultures will take considerable patience and planning and the current leadership and staff in both organizations should not wait until a new M&O contractor is named to initiate and shape this cultural merger.

Recommendation: The management and staff at both INEEL and ANL-W should immediately begin to facilitate the merger of the two distinctly different cultures that currently exist in these two organizations. Taking steps now to start the close connection of these two organizations before the new M&O contractor is announced in November 2004 will enhance a smooth and effective transition to the new organization of the INL.

Sense of Urgency

A world-class laboratory requires not only a clear compelling mission but also a sense of urgency. The best example is the Manhattan Project. People knew what they had to do and how fast they had to do it. Another example was NASA's mission to put a man on the moon before the end of the decade, in response to President Kennedy's vision. The people involved worked carefully. They worked hard. They had to do research to break new intellectual ground. As these projects proceeded, decisions were made and implemented, always with the goal in mind.

On the opposite end of the spectrum is pre-college science and math education in the United States. This area was recognized as a crisis in the 1980's by "A Nation At Risk," yet is in as bad, if not worse shape, today. Directly relevant to the future of nuclear power, are the construction of a high-level-waste repository and the closure of the fuel cycle. Despite the passage of a few decades and the government's collection for this purpose of roughly $20 billion from American electricity consumers, the solution is not in hand.

In numerous public lectures around the country, Nobel Laureate Richard Smalley of Rice University identifies energy as the keystone for solving most of the world's major problems, including clean water and disease. Given the broadly recognized serious climate impacts of fossil fuel use (the back end of the fossil fuel cycle), and developments in nuclear technology in the rest of the world, nuclear power will continue as a major, nearly carbon-free, and possibly growing part of the global energy mix. The creation of INL comes at an opportune time to reinvigorate nuclear energy in the United States and further US leadership in worldwide nuclear matters.

DOE has an opportunity NOW to create a sense of urgency around the formation of the INL. The vision for the INL must be clear and compelling. Its goals must be important. If its progress becomes mired in a bureaucratic morass, then its ability to attract the best and brightest researchers will be undermined, and the INL will not become world class.

The next few years are especially critical. What happens during the first five years of the INL will strongly determine the path that it takes to world-class status. It must be done the right way, the first time. DOE needs to demonstrate its full commitment and focus to enable the laboratory to meet its world-class vision.

IV. Recommendations

This concluding section captures all of the recommendations made previously in this report. The recommendations are grouped into five general categories: commitment; vision and funding; people; facilities; programs; and governance and metrics. The recommendations are further prioritized by the Subcommittee within each of these categories below.

The recommendations of the NERAC Subcommittee on Nuclear Laboratory Requirements are:

Commitment, Vision and Funding

1. ***Recommendation (see page 20): Beginning immediately with the FY 05 Budget the Department of Energy must assign the highest priority to the funding of the Idaho National Laboratory and allocate significant resources to beginning the build-up of facility and staff capabilities. Furthermore, this build-up must recognize and allow for the continuing contributions of the other national laboratories engaged in world-class nuclear technology R&D.***

2. ***Recommendation (see page 18): As soon as possible the DOE and INL need to understand and agree on the vision and mission of the laboratory and develop usable vision and mission statements that inspire the DOE, Congress, and the Public to provide moral and financial support commensurate with the mission, excite scientists and engineers to become involved in the activities of the laboratory, and provide long-term direction and focus for the laboratory.***

3. ***Recommendation (see page 22): The INL and DOE need to ensure that the contract to manage and operate INL allows an adequate level of LDRD, with 6 percent being considered a desirable lower bound, during the first years of establishing the laboratory. INL must develop and implement an LDRD review and selection process that is transparent to the staff, and results in the most innovative and meritorious R&D proposals being funded.***

People

4. ***Recommendation (see page 21): To attract superb scientists and engineers to become employees, INL must develop policies and practices, including a competitive salary and benefits structure, which encourages the best and brightest scientists and engineers to be and stay involved in the activities of the laboratory. The laboratory also needs to ensure that both its workforce and its users/collaborators comprise a diverse population, in terms of ethnic, gender, cultural, and technical diversity.***

5. ***Recommendation (see page 22): The INL needs to identify and recruit the best and brightest scientists, engineers, and technical managers to be involved as collaborators in the R&D activities of the laboratory. The laboratory should also be creative in***

developing mechanisms that it can use to involve these high-quality individuals from part-time to full-time employment.

6. ***Recommendation (see page 33): The INL should create a culture where research and scholarship in the mission areas are encouraged and rewarded.***

7. ***Recommendation (see page 30): The INL needs to develop close interactions and partnerships with the many individuals and institutions that have expertise in nuclear energy and technology and broader energy issues. These partnerships include the other national laboratories in the U.S. Department of Energy complex, universities with nuclear engineering, health physics and other related education and research programs, and the varied industrial firms with interests in developing nuclear and other energy applications, both domestically and internationally.***

8. ***Recommendation (see page 31): The INL needs to develop policies and practices that will enable easy partnerships to be made with university faculty and students, including mechanisms that are more flexible than the normal contracting pathways for working with universities.***

9. ***Recommendation (see page 34): The management and staff at both INEEL and ANL-W should immediately begin to facilitate the merger of the two distinctly different cultures that currently exist in these two organizations. Taking steps now to start the close connection of these two organizations before the new M&O contractor is announced in November 2004 will enhance a smooth and effective transition to the new organization of the INL.***

<u>Facilities</u>

10. ***Recommendation (see page 25): DOE must fund INL to develop and maintain high quality, state-of-the-art research facilities that will attract the caliber of researchers who will make it a world-class laboratory. Many, if not most, of these facilities must be planned and operated as true user facilities that attract collaboration and encourage both internal and external researchers to propose, conduct, and analyze research of the highest quality and importance.***

11. ***Recommendation (see page 22): The DOE and INL should set up international cooperation agreements and joint programs that emphasize collaboration on research and take advantage of expensive facilities, wherever they are. This approach will allow INL facility investments to complement existing and planned facilities elsewhere in the world, and allow available funds for facilities at INL to be used maximally for building truly new, innovative, important, and world-class facilities.***

12. ***Recommendation (see page 23): The INL needs to utilize electronic communication technologies effectively and systematically to enable individuals from around the world to be intimately involved in the scientific and engineering activities of the laboratory and to inform policymakers continuously of progress toward the goals of INL.***

Programs

13. ***Recommendation (see page 32): Working with other laboratories, universities, and industry, INL should lead the development of a public communications and outreach plan and strategy to accompany the technology roadmap for nuclear energy, with clear timetables, goals, and objectives. To get its outreach activities off to a strong start, INL should, as soon as possible, (a) create, start communicating with, and listen to a "public citizen" advisory group, which has members from across the nation, and includes several skeptical about or opposed to nuclear power; and (b) create, start communicating with, and listen to a group of community-selected representatives from the communities in its region. "Open" meetings are recommended. These groups may be helpful in developing and vetting the public communications and outreach plan and strategy.***

14. ***Recommendation (see page 25): A very high priority for the INL RD&D portfolio is to advance the knowledge and technologies needed to close the nuclear fuel cycle in a way that minimizes the number and maximizes the safety of radioactive waste repositories. Technologies, such as fuel recycling, chemical separations, pyroprocessing, and actinide burning, all hold great promise in this regard.***

15. ***Recommendation (see page 23): The INL should run workshops and other programs to inform and involve the entire technical and policy community to discuss issues and results in the broad fields of energy and nuclear technology. These workshops and other programs should attract university students at an early stage in their careers, and closely involve university faculty.***

16. ***Recommendation (see page 30): The INL should aggressively pursue re-connecting the laboratory to the other energy R&D communities to help break down the barriers and distrust that have developed between nuclear energy technology developers and those who advocate and develop alternatives, particularly in the area of energy supply technologies. The creation of INL provides a timely opportunity to lead the nuclear energy community to greater involvement in the discussions surrounding energy production and distribution and the full environmental impact of energy technologies.***

Governance and Metrics

17. ***Recommendation (see page 26): DOE must select for INL a managing contractor with superb qualifications, a track record of managing first-class science and technology laboratories, and vision and plans for the science, technology, management, and operational systems required to make INL a world-class laboratory. The plans must include a set of milestones, performance objectives, and incentives that encourage and enable the desired results to be accomplished well, cost effectively, swiftly, safely, and securely. The director and leadership team must combine broad experience, outstanding technical judgment, and prior success in managing research organizations.***

18. ***Recommendation (see page 26): DOE's oversight of INL must focus on managing the contract, not the contractor, consciously enabling the desired world-class technical progress and operational performance, and holding the contractor accountable for managing and operating the laboratory. Consistent with this approach, DOE should reduce to the absolute minimum the number and types of actions, transactions, and processes requiring DOE approval. DOE's oversight approach should concentrate on defining the scope of work and determining whether the contractor is delivering the results (cost, schedule, scope, and quality).***

19. ***Recommendation (see page 23): Selected INL managers and staff should visit and "benchmark" several "world-class" laboratories in nuclear technologies and other fields to experience, identify, and replicate policies, practices, and cultural aspects that contribute to world-class stature.***

20. ***Recommendation (see page 28): Coordination among the various government entities with nuclear portfolios and energy portfolios should be improved. Possible mechanisms include providing Congressional oversight via a "Joint Committee," establishing an interagency working group with appropriate representation, and establishing an independent advisory board that hears from and advises all agencies with nuclear and energy portfolios.***

21. ***Recommendation (see page 8): INL and DOE should adopt a set of metrics to periodically assess progress toward achieving world-class stature for the Idaho Nuclear Laboratory. The concept of a world-class organization should be used for internal self-assessment rather than for external advertising. References 1 and 2 provide a helpful starting point.***

22. ***Recommendation (see page 24): At the earliest possible date, DOE should work with key stakeholders to update the Nuclear Science and Technology Infrastructure Roadmap. The Infrastructure Roadmap should include all relevant existing and planned facilities in the U.S. and abroad. With the updated Infrastructure Roadmap and a clearly defined vision and mission for INL as inputs, INL and DOE should revise the INL Ten-Year Site Plan, consistent with the DOE's stated expectations that other national and international laboratories "…will remain important contributors to the Department's nuclear energy R&D efforts."***

23. ***Recommendation (see page 27): The DOE should adopt the "Decadal Survey" as an important mechanism for long-range planning and priority setting for nuclear science, technology, energy, and applications. Building on the past work of NERAC, DOE should commission the National Research Council to prepare the first of several decadal surveys and use the survey to guide program, project, and facility prioritization. This planning process could include the Infrastructure Roadmap.***

24. ***Recommendation (see page 27): To improve coordination and integration of nuclear technology RD&D, DOE's advisory committee (NERAC) should be explicitly chartered***

to advise NE, along with the RD&D programs of NN, and RW, at the least. Any program office with a significant nuclear portfolio that the advisory committee is not formally advising should designate a liaison with this advisory committee.

25. ***Recommendation (see page 28): The INL contractor should establish a Board of Directors to provide high-level, independent advice to its highest level official and to the director of INL.***

26. ***Recommendation (see page 28): The INL contractor should establish an independent review structure to regularly assess the extent to which the laboratory is doing the right things and doing them well.***

27. ***Recommendation (see page 29): From the very beginning of the new contracts, DOE and the contractors should ensure that exemplary ES&H, security and management practices are integrated with, support, and enable world-class RD&D and high productivity in both the INL and Environmental Management activities of the Idaho site.***

28. ***Recommendation (see page 32): INL should "benchmark" RD&D organizations that are "best in class" in education and public outreach, and develop and implement with its academic, industrial, and laboratory partners an education and outreach program that inspires and educates Americans of all ages.***

V. References

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Two individuals were especially helpful in making our European and Asian visits extremely successful. The Subcommittee members are especially grateful for the assistance provided us by Jacques Bouchard in France and Atsuyuki Suzuki in Japan. Without their help it would have been very difficult for the Subcommittee members to identify and meet the right people in Europe and Asia.

The Subcommittee also wishes to thank Linda McCoy, Chief Scientist for DOE-Idaho and Matea McCray, Engineer for DOE-Idaho for their logistical support for the Subcommittee. Their helpful discussions and assistance were also invaluable to our completing this report.

Finally, the Subcommittee wants to express our thanks to Nancy Carder of the Medical University of South Carolina for her help and assistance in making our travels go smoothly and for processing our travel reimbursements expeditiously.

Appendix A

<u>Charge to the Nuclear Energy Research Advisory Committee to Create a Subcommittee on Nuclear Laboratory Requirements, December 31, 2003.</u>

"A key Department of Energy objective is to make Idaho National Laboratory the leading nuclear energy research laboratory in the world in ten years from its inception. To this end, Nuclear Energy requests NERAC's assistance in identifying what characteristics, capabilities, and attributes a world-class nuclear laboratory would possess. The staring point of this analysis should be the January 16, 2003 report of NERAC's Infrastructure Task Force. Nuclear Energy would expect members of this subcommittee to become familiar with the practices, culture, and facilities of other world-class laboratories – not necessarily confined to the nuclear field – and use this knowledge to recommend what needs to be implemented at Idaho. The subcommittee should submit its report by the end of fiscal year 2004."

Appendix B

Laboratories Visited, Questionnaire Respondents, and Individuals Consulted

Domestic Laboratories Visited

Argonne National Laboratory, Argonne, IL
Argonne National Laboratory-West, Idaho Falls, ID
Charles Stark Draper Laboratory, Cambridge, MA
Fermi National Accelerator Laboratory, Batavia, IL
Idaho National Engineering and Environment Laboratory, Idaho Falls, ID
Jet Propulsion Laboratory, Pasadena, CA
Lincoln Laboratory, Cambridge, MA
Los Alamos National Laboratory, Los Alamos, NM
National Center for Atmospheric Research, Boulder, CO
National Institute of Standards and Technology, Gaithersburg, MD
Oak Ridge National Laboratory, Oak Ridge, TN
U.S. Army Research Laboratory, Adelphi, MD
U.S. Naval Research Laboratory, Washington, DC

International Laboratories Visited

Atomic Energy of Canada Limited Chalk River Laboratory, Chalk River, Canada
Commissariat à l'Energie Atomique (CEA)/Cadarache, Cadarache, France
Commissariat à l'Energie Atomique (CEA)/Grenoble, Grenoble France
Commissariat à l'Energie Atomique (CEA)/Marcoule, Marcoule, France
Commissariat à l'Energie Atomique (CEA)/Saclay, Saclay, France
European Organization for Nuclear Research (CERN), Geneva, Switzerland
European Synchrotron Radiation Facility, Grenoble, France
High Energy Accelerator Research Organization (KEK), Tsukuba, Japan
Japan Atomic Energy Research Institute (JAERI), Oarai, Japan
Japan Atomic Energy Research Institute (JAERI), Tokai, Japan
Japan Nuclear Cycle Development Institute (JNC), Oarai, Japan
Japan Nuclear Cycle Development Institute (JNC), Tokai, Japan
Korean Atomic Energy Research Institute (KAERI), Daejeon, Republic of Korea

Organizations Responding to the Survey

Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID
Exelon Nuclear, Chicago, IL
Oak Ridge National Laboratory, Oak Ridge, TN
University of Florida, Gainesville, FL
American Nuclear Society, La Grange Park, IL
South Carolina Electric and Gas Co., Jenkinville, SC
University of Michigan, Ann Arbor, MI
Pacific Northwest National Laboratory, Richland, WA

Sandia National Laboratories, Albuquerque, NM
Thomas Jefferson National Accelerator Facility, Newport News, VA
University of Wisconsin-Madison, Madison, WI
Princeton Plasma Physics Laboratory, Princeton, NJ

Individuals who Responded to the Survey
(Including current and former NERAC members)

Allen Croff, Oak Ridge, TN
Gail P. Gary, St. Louis, MO
Bill Kastenberg, Berkeley, CA
Warren F. "Pete" Miller, Los Alamos, NM
Joy Rempe, Idaho Falls, ID
Bruce Tarter, Livermore, CA
Neil Todreas, Massachusetts Institute of Technology

Individuals Consulted or Who Provided Written Input

John F. Ahearne, Sigma Xi and Vice Chair of NERAC
John C. Browne, former Director, Los Alamos National Laboratory
Dana Christensen, Los Alamos National Laboratory
Kathryn Clay, U.S. House of Representatives Science Committee, Energy Subcommittee
Michael Corradini, University of Wisconsin, Madison
Jose Luis M. Cortez, University of Texas-Pan American
U.S. Senator Larry E. Craig, Idaho
Paul Doucette, Office of U.S. Representative Judy Biggert, Illinois
Michael Holland, Office of Science and Technology Policy
Leslie Huddleston, Office of U.S. Senator Mike Crapo, Idaho
Gretchen Jordan, Sandia National Laboratories
Patrick Looney, Office of Science and Technology Policy
Pete Lyons, Office of U.S. Senator Pete Domenici, New Mexico
Michael M. May, former Director, Lawrence Livermore National Laboratory and Center for International Security and Cooperation, Stanford University
Raymond L. Orbach, Director, Office of Science, U.S. DOE
Per Peterson, University of California, Berkeley
John Pfeiffer, Office of Management and Budget
Allen Sessoms, President, Delaware State University
U.S. Representative Mike Simpson, 2nd Congressional District, Idaho
Ashok Thadani, Office of Commissioner N.J. Diaz, U.S. NRC
Alvin Trivelpiece, former Director, Office of Science, U.S. DOE and former Director, Oak Ridge National Laboratory
Paul Turinsky, North Carolina State University

Appendix C

Discussion Areas for Laboratory Visits

1. **VISION.** What is the mission and strategic vision of the Laboratory, and how do they relate to your R&D portfolio and research strategy?

2. **RESOURCES AND CAPABILITIES.** What are the characteristics, capabilities, and attributes of the Laboratory that cause it to be a world-class R&D organization?

3. **BUDGETS.** What is your budget? How is funding obtained, allocated, and accounted for?

4. **HUMAN RESOURCES.** How do you ensure the quality of R&D personnel? How do you attract, select, retain, develop, evaluate, motivate, reward, and recognize your research personnel? Support personnel?

5. **R&D FACILITIES & INFRASTRUCTURE.** What are the most important R&D facilities at your laboratory, why were they developed, and how are they funded, maintained, and operated effectively?

6. **R&D COLLABORATION.** What is the nature and extent of the Laboratory's cooperation, if any, with other R&D institutions?

7. **MANAGEMENT.** How do you manage for sustained scientific and technological excellence and mission success?

8. **QUALITY AND SAFETY.** How do you assure quality, safety, environmental protection and security? What is your performance in these areas, and are you satisfied with it?

9. **PUBLIC AND COMMUNITY RELATIONS.** How active is the Laboratory in outreach, community and public relations, and what types of programs or activities are most important?

10. **CHALLENGES.** What are the most significant challenges to scientific quality and world leadership and how do you overcome them?

11. **GOVERNANCE AND OVERSIGHT.** What is the nature of the governance and advisory structure of the Laboratory? How are the highest-level decisions made?

12. **ADVICE.** What advice from your Laboratory's experience would be most important to benefit from in establishing the Idaho National Laboratory?

Appendix D

Survey Instrument and Questionnaire

Dear Research Professional:

As you are well aware, the U.S. Department of Energy (DOE) is in the process of planning the establishment of new nuclear energy research and development laboratory at the Idaho National Laboratory (INL) building on the talents and facilities of the current Idaho National Engineering and Environmental Laboratory (INEEL) and Argonne National Laboratory – West (ANL-W). DOE has asked its Nuclear Energy Research Advisory Committee (NERAC) to identify the characteristics, capabilities and attributes a world-class nuclear laboratory should possess, and what needs to be done to enable INL to become a world-leading nuclear research laboratory within a decade. NERAC has in turn established a Subcommittee on Nuclear Laboratory Requirements. The members of this subcommittee are Dr. Beverly Hartline, Dr. Robert Long, Dr. Robert Schock, Dr. Michael Sellman, and I.

We would greatly appreciate your time, or that of your staff, in answering some questions and providing input to our discussions and deliberations concerning DOE's development of the INL.

Thank you very much for your participation.

Please email your responses to klein-wcl@oregonstate.edu , by August 1, 2004 to be most useful to the subcommittee. If you care to print out and mail your responses, please mail them to me at 100 Radiation Center, Oregon State University, Corvallis, OR 97331-5902.

Sincerely,

Andrew C. Klein
Chair
NERAC Subcommittee on Nuclear Laboratory Requirements

Questions to R&D organizations:

1. The National Research Council has established the following definition for a world-class R&D laboratory (Reference, National Research Council, "World-Class Research and Development," National Academy Press, Washington, DC, 1996.):

   "A world-class R&D organization is one that is recognized by peers and competitors as among the best in the field on an international scale, at least in several key attributes."

   Do you agree with this definition?

   If not, how would you change or improve it?

2. What do you consider to be the key characteristics, capabilities and attributes of a world-class R&D organization?

3. What do you consider to be the key characteristics, capabilities and attributes of a world-class nuclear-energy R&D organization?

4. What do you consider to be the primary challenges to achieving and sustaining a world-class R&D organization?

5. What do you consider to be the primary challenges to achieving and sustaining a world-class, government-funded, nuclear energy R&D organization?

6. What do you consider to be the primary challenges to achieving and sustaining a world-class nuclear energy R&D organization at the new Idaho National Laboratory?

7. If there are additional key questions related to its charge that you think the committee should have asked, please ask and answer them here.

8. What additional input, if any, do you have related to the charge of the subcommittee?

Background information questions:

1. Name of Organization or Laboratory:

2. Name and contact information for person completing survey:
   Name:
   Address:
   Phone:
   Fax:
   Email address:

3. May we contact you for additional information, if we have questions or would wish to visit?

If your organization is a Laboratory or has a significant R&D component, please answer the following questions for the entire Laboratory or the R&D component of the larger organization. For brevity, we use the term "Laboratory" to refer to either the entire organization (if it is an R&D Laboratory) or to the R&D component (if it is in a larger organization).

4. What is the mission and vision of the entire Laboratory?

5. What is the Laboratory's approximate total annual budget (for 2003)?

6. Who are the primary sponsors of the Laboratory, and what approximate fraction of the budget does each provide? (A budget pie chart by sponsor may be provided).

7. What is the total staff of the Laboratory?

8. What is size of the scientific/engineering/technical workforce of the Laboratory? What are the terminal degrees of this workforce (please indicate the approximate number or fraction with none, associates degrees, bachelors degrees, masters degrees, doctoral degrees; a pie chart may be provided)? What are the average ages in each of these categories?

9. Within the total annual budget (question 4), how much is for new construction or major upgrades? How much is used for facility maintenance?

10. What are the Laboratory's major facilities?

11. If you have facilities that are open to use by the technical community at large, what are the major ones and what is the size of their external user communities?

12. In your mission area, who are your leading global competitors, and how do you believe your Laboratory ranks?

Thank you very much for taking time to complete this questionnaire and for your help in defining the characteristics, capabilities, and attributes of a world-class nuclear energy R&D laboratory.