Appendix C

Subcommittee on Nuclear Science and Technology Infrastructure Roadmap

Executive Summary

S.1 INTRODUCTION

The Department of Energy (DOE) manages a substantial infrastructure of nuclear science and technology assets that are used for conducting both technology directed and basic nuclear science research. Many of these DOE assets have been shutdown or placed in prolonged standby, while others are operating at or near full capacity. To assure that the DOE has adequate facilities in place to meet future nuclear mission requirements, the Office of Nuclear Energy, Science and Technology has initiated the development of an infrastructure roadmap.

The first draft of the Nuclear Science and Technology Infrastructure Roadmap was completed in December 1998. The draft documented the outcome of the first phase of the roadmapping process in which the Nation's nuclear research and development (R&D) infrastructure was cataloged and evaluated against likely science and technology requirements through the year 2020. The scope of the initial draft was limited to an examination of the Nation's hot cells, reactors, and accelerators.

For this roadmap, the universe of nuclear science and technology was divided into five areas: power technology, isotope production, space missions, national security, and general nuclear science. Research requirements were forecast in each of these areas for the next twenty years. These requirements were then compared to the capabilities of the facility infrastructure and gaps were identified. For the initial draft more than sixty scientists and engineers directly contributed to this assessment, representing more than 13 different organizations including eight national laboratories and the DOE Offices of Science, Defense Programs, and Nuclear Energy, Science and Technology.

The Nuclear Energy Advisory Committee (NERAC) reviewed the first draft of the Roadmap and made recommendations for future revisions of the document. Among the NERAC recommendations were the need for additional data on the reactors, accelerators and hot cells, their missions and associated schedules, and percent utilization; personnel needs, and the need to include additional stakeholders such as DOE-EM and non-DOE agencies in the Roadmap process. This draft of the roadmap attempts to address each of these major recommendations.

This document is Revision 1 of the roadmap and represents a second phase of the work that has been completed by DOE under NERAC's guidance. This second phase considered additional factors including personnel requirements, current and future missions, schedules, cost, and available capacity in forming independent conclusions regarding the adequacy of infrastructure and personnel.

Summary of Phase I Findings (updated in Rev 1 to include events since December 1998):

The mission requirements in nuclear science and technology are growing steadily. Expanding mission requirements include: increased demand for materials data and verification testing to support the stockpile stewardship program, increased demand for medical and other research isotopes, increased demand for tritium and other national security nuclear materials, increased R&D in support of nuclear fission and fusion programs, expanding NASA requirements to support future missions, and slow but steady growth in basic nuclear science programs.

The infrastructure is being adequately maintained and there are no end-of-life issues during the time period of interest. Since this Phase I finding the HFBR, an exception to the finding, has been permanently shutdown. Our hot cells and accelerators have no particular life limiting components and may be maintained almost indefinitely. During the Phase II assessment, anecdotal evidence from the laboratories indicated that much more emphasis should be given to maintenance activities at the facilities.

Most of today's science and technology needs are being met, but there are exceptions. Most significant is the need for a transient reactor test facility to support our nuclear weapons verification and safety programs. Presently, the ACRR is being reconfigured away form single purpose Mo-99 production to enable it to meet the need for pulsed neutrons. Another important need is highlighted by the fierce competition among researchers for the Departments neutron irradiation sources for general irradiation and neutron scattering research. The department has been historically oversubscribed for neutron beam sources and the situation is not getting any better.

There are several near term needs (5-7 years) that cannot be met by currently operating DOE facilities. In the area of national security these are tritium production (now to be produced in civilian reactors), transuranic production, proton radiography, and high-energy neutron radiography. Non-defense needs include: greater reliability in the production of medical isotopes, transient reactor testing capability to support domestic advances in reactor fuel systems, and a source of 14MeV neutrons for fusion materials testing.

It is clear that the Department is hot cell rich (32 currently operating) and reactor poor. In Phase I only a qualitative assessment was made on facility availability vs. mission demands. This has been surpassed in Phase II with a more rigorous quantitative assessment. As a result, the text that appeared here in the December 1998 draft has been deleted. Borrowing from the Phase II assessment, we can state that the Department is facing a near term exhaustion of unclaimed reactor availability, and that while there is still excess capacity in the hot cells, many of them are operating at or near full capacity/availability.

Phase II:

The second phase of the Roadmap consisted of gathering additional information to address the recommendations made by the NERAC. Additional information was obtained from several sources, including certain NERAC subcommittees, DOE-EM, universities, and two NERAC data requests.

Responses to two data requests sent to eight DOE laboratories by the NERAC provided information to address some of the data needs regarding human resources and facility missions. In the first data request, facility specific data was requested regarding human resources including the number of personnel and age distribution of those personnel for the overall laboratory and each reactor, accelerator and hot cell. Data was requested for each reactor, hot cell, and accelerator including a listing of currently funded missions and projected missions through FY2005, expected start and end dates of each mission, customer for each mission, and the technical requirement for each mission; the percent unused availability capacity of each facility for the years1995 though 2005; the primary function of the facilities and any co-locate facilities and key licensing and compliance issues. In addition, information was requested specifically for hot cells included the size of specimen that can be handled by the hot cell, capability to handle plutonium and aqueous processing capability; and the types and quantities of each isotope produced annually. In the second data request, the laboratories were asked to provide ages and distribution of their nuclear workforce.

As part of the second phase, several reports prepared by various organizations were reviewed to determine their impact, if any, on the Roadmap. The review included the Manpower Supply and Demand in the Nuclear Industry prepared by the Nuclear Engineering Department Heads Organization (NEDHO), pre-release draft of the NERAC Isotope Research and Production Planning Report, pre-release draft of the NERAC Long Term Research and Development Plan, and the pre-release draft of the Integrated Nuclear Materials Management Plan.

A review of the NEDHO Manpower Supply and Demand in the Nuclear Industry Report, which assessed the supply and demand for nuclear engineers out to the year 2003, indicated that the demand for nuclear engineers graduating from college with B.S. and M.S. degrees currently exceeds the supply and there is an anticipated increase in the gap through the year 2003. A continuation of this trend could potentially impact the availability of nuclear engineers to enter the work force in the long term.

A review of the pre-release draft of the NERAC Isotope Research and Production Planning Report indicated that the NERAC Report supports the analysis and conclusions in the Roadmap. No new concepts, missions, projects, or initiatives were introduced that would impact reactor, hot cell, and accelerator capacity which has not been presented in the Roadmap.

The pre-release draft of the NERAC Long Term Research and Development Plan focused on research and development needs over the next 10 to 15 years. The perceived projects, plans, and budgets presented in the report have not been approved and are not sufficiently detailed to accurately determine the impacts to reactor, hot cell, and accelerator capacities. At best a postulation of possible or potential impacts on capacity can be made. A table has been included at the end of Appendix H that summaries potential or possible impacts. If and when these projects become funded, their potential impacts can be integrated into the Roadmap.

The pre-release draft of the EM Integrated Nuclear Materials Management Plan analyzed DOE requirements in 2025. Several conclusions were draw in this plan about DOE requirements in 2025 and are presents below.

- DOE will need a robust, modern, technically flexible, and integrated suite of functions and facilities. This will include significant capability for fabrication, storage, processing, monitoring and disposal, and moderate capability for irradiation and separations.

- Mission areas are closely linked, depending on each other's skills, equipment, facilities, capabilities, and capacities.

- Primary production and handling functions are tightly coupled and critical to overall Department success. They will remain a relative constant. Multiple missions will need the same or similar functions, perhaps simultaneously. Because integration will eliminate redundancy, each function will need fairly significant capacity.

- Internationally, issues related to nuclear materials are broad and differ by country. For the United States to provide leadership, the Department must retain a depth and breadth of expertise in nuclear materials, energy, defense, space, medicine, and nonproliferation.

- Each mission area must plan for great uncertainty in scope, capacity, and technology needs.

- Analysis of long-term requirements for the nuclear materials complex will be refined and periodically revisited to ensure a sound foundation for decision-making. And this analysis must be integral to the Department's long-term planning.

A summary of the current findings in Phase II is provided below:

Summary of Phase II Findings:

Over 80 percent of the overall workforce and 76 percent of the nuclear workforce at the facilities responding to the data request is more than five years away from retirement. Within the next five years, only 20% of the overall workforce will be at age 55 or above. Twenty four percent of the nuclear workforce will be at or above age 55. This would indicate that overall the facilities are in no danger of losing their existing technical expertise within the next five years. However, according to the NEDHO Manpower Supply and Demand Report, there could be a potential problem with too few nuclear engineers graduating from colleges and entering the workforce to replace the technical expertise. Although the NEDHO Report only looked out to 2003, if this trend continues, eventually DOE will be affected, probably in the 15 to 20 year range. It should be further noted that looking 10-15 years out, approximately one-half of the workforce is eligible for retirement.

Approximately 12 percent of the overall workforce and 10 percent of the nuclear workforce are currently below the age of 35. Given that employment at a national laboratory generally requires a Ph.D. and several years of experience, this may account for the low percentage of workers in this age range.

The median age of the overall workforce and median workforce is between 45 and 55 years old. This is slightly higher than the median age of 38.7 in the national labor force. This is not unusual given the nature of the work performed at the facilities and the requirements for employment.

The available data show that the current utilization is approximately 82 percent for reactors, 71 percent for accelerators, and 83 percent for hot cells. In a few cases, certain facilities are currently and projected to be fully engaged or have limited availability to accept new missions or they are already oversubscribed. However, based on the current utilization, the hot cells have available capacity to support new missions.

S.2 BACKGROUND

DOE manages a substantial infrastructure of hot cells, accelerators and reactors used for conducting both technology directed and basic nuclear science R&D. Many of these DOE facilities have been shutdown or placed in prolonged standby, while others have operated at or near full capacity. To assure that DOE has adequate facilities in place to meet future nuclear mission requirements, the Office of Nuclear Energy, Science and Technology was tasked under Secretary Moniz to initiate an assessment of the infrastructure's long term availability and capability for meeting the Nation's R&D requirements through the year 2020, and to develop a Nuclear Science and Technology Infrastructure Roadmap.

While the NERAC has been asked to prepare the actual roadmap (see Appendix A), the Office of Nuclear Energy, Science and Technology has led a collaborative effort to prepare an initial infrastructure roadmap assessment. Key participants included: the Office of Science, the Office of Defense Programs, Argonne National Laboratory, Brookhaven National Laboratory, Idaho National Engineering and Environmental Laboratory, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory, and Sandia National Laboratory. Representatives from these organizations met on August 6, 1998 for a framing meeting to develop a consensus position on the scope of the study, the development process, and to identify those organizations whose participation was needed to ensure a quality product.

For the initial infrastructure roadmap, the scope was limited to an examination of the Nation's hot cells, reactors, and accelerators, as they pertained to neutron science. The large accelerators used to explore the more fundamental particle behaviors were excluded from the study. As illustrated in Figure 1, the process selected for the study consisted of first identifying and cataloging facility capabilities and R&D requirements, and then evaluating the ability of the facilities to meet the R&D requirements. To generate R&D requirements, the universe of nuclear research was divided into the areas of power technology, isotope production, space missions, national security, and general nuclear science. Eight teams were formed to accomplish this task. Appendix B provides a listing of the teams, their membership, and organizational affiliations.

In mid-October 1998 each team provided a report documenting their findings. The team reports are given as Appendices C through J. The first three team reports are for the reactor, hot cell, and accelerator facilities. These reports comprise a catalog of the Nation's facility capabilities for conducting neutron irradiation based science. The currently operating infrastructure is listed in Table S-1. The remaining five team reports document an assessment of researcher needs through the year 2020. Each report stands alone and expresses an individual vision, goal, and objective. Taken collectively, these five reports represent the spectrum of needs that the DOE must be ready to meet in the coming years.

In October 1999, DOE NE, on behalf of NERAC, issued a data call to eight national laboratories to obtain information related to the number and age distribution of the current DOE technical workforce. A subsequent data call was issued to more closely target the nuclear workforce only. Responses to the first data request have been received from seven of the eight laboratories. Responses to the second data call have been received from five of the eight laboratories. The responses to the data request varied widely in content and completeness, although they provided more than sufficient data to form reasonable conclusions.

Error! Not a valid link. ***Figure S-1. Process Flow Diagram for Infrastructure Assessment.***

In the data request, facility specific data was requested regarding human resources including the current and 10 year projection of the number of personnel and age distribution of those personnel for the overall laboratory and each reactor, accelerator and hot cell; the early, average, and late retirement ages; and historical career span.

Additionally, data was requested for each reactor, hot cell, and accelerator including a listing of currently funded missions and projected missions through FY2005, expected start and end dates of each mission, customer for each mission, and the technical requirement for each mission; the percent unused availability capacity of each facility for the years1995 though 2005; the primary function of the facilities and any co-locate facilities and key licensing and compliance issues. In addition, information was requested specifically for hot cells included the size of specimen that can be handled by the hot cell, capability to handle plutonium and aqueous processing capability; and the types and quantities of each isotope produced annually.

On November 3rd and 4th, a Needs Identification Workshop was held in which the requirements identified in the team reports were matched to facilities capable of meeting them. Attendees of the Needs Identification Workshop are listed in Appendix K. The outcome of this workshop is given as Table S-2. Table S-2 summarizes all of the needs from the requirements reports and matches them to appropriate facilities. Table S-2 is formatted in the order of reactors followed by accelerators and then hot cells. It lists all facilities that were identified as suitable for meeting the future R&D requirements. The operational status of each facility is noted if other than fully operable. Table S-2 was delivered to the participants in a Gap Analysis Workshop, held on November 18th and 19th, where participants analyzed and evaluated unmet needs and where a rudimentary facility mission balancing was performed. Attendees of the Gap Analysis Workshop are listed in Appendix L. As developed during the Gap Analysis, Table S-3 shows the research needs that cannot be fully met using only operational facilities. Taken together, Tables S-2 and S-3 effectively summarize the knowledge developed in the eight team reports and the two workshops.

S.3 ANALYSIS

Overview:

Our operating facilities are meeting the majority of our current R&D needs, and they are not yet fully loaded. For the most part, there are no end-of-life considerations for these facilities during the next twenty years. Table S-4 shows the life-limiting factors for a representative sample of our reactor facilities. Note that accelerators and hot cells can be maintained almost indefinitely. Even given the ongoing availability of most of our critical facilities, projections for increased demand will overtax the system in the near future. In every area examined, the demands on the system are expected to rise. Isotope production, in particular, could easily sustain an additional HFIR class facility by the year 2020. We suspect that by 2010, or possibly sooner, all of our operating reactors will be fully engaged and a number of needs will go unmet. Staffing is remarkably a non-issue at this time. The laboratories are adequately staffed and report no difficulty in attracting and retaining talented engineers and scientists.

Staffing:

The age distribution of the DOE Laboratory technical workforce is similar no matter which laboratory is being examined. More than 50 percent of the technical workforce are in the age range of 35 to 55 years old, with a median age between 45 and 55 years old. The age distribution of the nuclear workforce closely resemble those of the technical workforce. Because of the nature of the work performed at the national laboratories and the requirements of an advanced degree and several years of experience, the median age tends to be older at the laboratories than the median age of 38.7 in the national labor workforce.

The average retirement age for the laboratories overall is 61 years old. Within the next five years, approximately 20 percent of the current workforce will be at or above the average retirement age. An analysis of the personnel data received in the NERAC data request is included in Appendix N. Within the next 10-15 years, approximately one-half of the workforce will be eligible for retirement. There is an ongoing NERAC investigation of manpower needs for the Nuclear industry. The results of the study will be factored into the analysis of DOE requirements in the next revision of the Roadmap.

Facility Availability:

The data obtained in the data request was used to evaluate the current utilization of the facilities and their ability to accept new missions. General percentages of utilization were determined for each of the major categories of facilities: reactors, accelerators, and hot cells. Weights were assigned to each facility using qualitative factors based on relative size (physical dimensions and number of workers). The weighted averages were calculated from the reported available capacity percentages. The available capacity and missions was analyzed to assess missions with little or no available capacity and facilities with excess capacity.

The data indicated that the overall utilization of NE research reactors is about 82 percent of capacity. The data analyzed indicated that, due to current missions, only one reactor exists with excess capacity that is available to produce pulsed neutrons, SNL SPR III. The ACRR has the capability to produce pulsed neutrons, but like the SNL SPR III, is fully engaged with current missions and has only limited availability until 2005. The SNL SPR III has a projected excess unused availability of only 20 percent in 2005.

The ACRR produces steady state neutron beams but as indicated above, it is fully engaged with current missions and has no excess unused available capacity until 2005. The ATR has 15 percent availability in excess of current missions in 2000 and a projected excess availability of 5 percent in 2005. Given its large neutron flux, it should have available capacity for known missions. Data indicates that sufficient thermal neutron capacity and availability exists at the NRAD and ATR for known missions.

An analysis of the missions and utilization based on the data reported is included in Appendix O.

The data indicated that the overall utilization of NE accelerators is approximately 71 percent of capacity. The only facility that indicated it can accelerate positrons is the APS Linac. It has a 27 percent unused availability in 2000. The only two facilities that indicated they accelerate electrons are APS Linac and LLNL Linac. The unused availability, in excess of current missions, of the APS Linac and LLNL Linac are 27 percent and 50 percent, respectively in 2000.

The data indicated that the overall utilization of hot cells is about 83 percent of available capacity.

The following discussion will focus on the needs identified during the Gap Analysis and listed in Table S-3, those that cannot be met with existing operating facilities.

Current Needs

Vulnerability (transient) testing:

One of the shortcomings of the current infrastructure is the lack of transient reactor testing capability. At present, the national security community has a significant near-term need for transient reactor testing capability. The ACRR is being reconfigured to meet the need for defense related transient testing.

Neutron Beam Research:

Another need we are not presently meeting is for more access by researchers to neutron beam sources. All of the Nation's neutron beam sources are currently oversubscribed. Taking into consideration the permanent shutdown of the HFBR, even with the addition of the SNS, there will be far more demand for research neutrons than supply.

Near-Term Needs

Improvements in the reliability of the medical isotope supply:

A number of projections have been made regarding the future demand for medical isotopes. Appendix F explains these in detail. Since the medical isotopes market operates on classic business models of supply and demand, it is essential that a reliable supply be available or the business will not develop. Physicians are expected to turn increasingly to nuclear medicine as a viable treatment, but only if they can be assured of a steady isotope supply. Already there is some difficulty in assuring supply. In the near term, as demand begins to grow, the need for stability in supply will become critical. There are management and administrative changes that can help alleviate this need in the short term, but only in part. To fully address this need there are a number of options including: the reactivation of the Fast Flux Test Facility (FFTF), the addition of specialized equipment for short-term irradiations to the Advanced Test Reactor (ATR), the construction of a new HFIR class reactor, the use of a Light Water Reactor (LWR), the use of the Annular Core Research Reactor (ACRR), or some combination of these.

Tritium Production for National Security Needs:

In a December 22, 1998 press release, Secretary Richardson said "the Tennessee Valley Authority's Watts Bar and Sequoyah reactors are to meet the Department of Energy's tritium needs."

Transuranic Production for National Security needs:

The Gap Analysis team identified a need for the production of certain transuranic products for national security needs. An LWR facility would be most suited for the production of these materials but the FFTF could also produce them.

Proton Radiography:

There is a national security need for proton radiography that will require either a new accelerator based facility or a modification to an existing accelerator.

High Energy Neutron Radiography:

Again, this is a national security need and can be met by accelerator facilities with the proper modifications.

Non-defense related transient test capability:

This is primarily a nuclear reactor fuel safety test and demonstration need. As the research into proliferation resistant and long-lived fuels grows in the future, so will the need to test them under reactivity insertion conditions. Already there is significant international interest in transient fuel testing being conducted by the French. The best alternative for the US is the irradiation of TREAT for pulse testing.

Materials irradiation (14MeV neutrons for fusion materials testing):

The fusion R&D program needs to understand the effects on materials from collisions with the 14MeV neutrons that are born in a fusion reaction. At present, there is an international testing facility being designed to meet this need. The facility will be constructed in Europe, with US participation.

Long-Term Needs

Greater Capacity for Medical Isotope Production:

Although improvements in the reliability of supply can be made, in part, with administrative and management changes, ultimately, there will be more demand than can be met with existing facilities. Should demand grow anything like the "high" case projections, significant new resources will be needed and are not addressed here. Following the "mid" case projections, the solutions listed under the near-term needs category would apply to the longer term as well. Ideally, though, a new HFIR class machine and a new 70 MeV accelerator would be built and collocated with supporting hot cells dedicated to isotope production. This need is listed under both headings because of its potential for substantial growth in the period 2010-2020.

Non-proliferation Materials Dispositioning:

This points to the need to eliminate, as a nuclear threat, the world's inventory of excess weapons grade fissile materials. The Office of Material Disposition is empowered to deal with these materials. The use of civilian LWRs to burn mixed oxide fuels is one of the leading candidates for disposing of these materials.

Other Waste Materials Dispositioning:

In the 2020-2050 timeframe it is likely that technologies will be developed for the annihilation of various nuclear waste materials. Such a concept as accelerator transmutation of waste is an example of technologies that may be deployed to clean up nuclear waste products.

Additional facilities for Boron Neutron Capture and other Medical Therapies:

Boron Neutron Capture therapy has suffered a set-back with the termination of clinical trials. Although this technique has great promise, better and more selective doping agents must be found prior to any increased need for irradiation facilities.

Long Term Fast Flux Material and Fuel Irradiation:

A number of needs have been identified requiring the long term exposure of fuel or other materials to a fast flux fission environment. The development of space reactor technology to support potential NASA missions such as a possible manned mission to mars may require the use of the FFTF or similar facility. Research and development focusing on the Accelerator Transmutation of Waste (ATW) and or liquid metal cooled reactors would also require a fast neutron fission spectrum reactor for materials irradiation.

As the fusion program proceeds into more of an engineering development phase, material irradiation in the FFTF (or similar facility) would be beneficial to obtain long term exposure data for material property tables. Many of these needs could become reality in the 2005-2010 timeframe. Based on materials research, as identified by the Long-Term Planning for Nuclear Energy Research NERAC Committee, additional reactor irradiation space for non-fast flux neutrons may also be required.

Mission Balance Considerations

During the Gap Analysis Workshop the distribution of missions to facilities was discussed in general terms. The finding was that, as stated previously, the operating facilities are currently meeting the majority of needs and are not yet working (on the whole) to full capacity. Significant new missions that will more fully utilize the remaining capacity are on the horizon, such as the production of Pu-238 for use in advanced radioisotope power systems for future space applications. Other new missions will likely require the construction or acquisition of new facilities, such as tritium production. Shifting or changing existing facility missions can have a dramatic impact on the system. For example, at the time of the Gap Analysis the ACRR was regarded as being dedicated to the production of Molybdenum-99. Were this to change, the reactor could be reconfigured to pulse-burst mode to meet a number of needs identified as requiring pulse testing. Looking at Table S-2, page 11, there are listed several reactors that are in either standby or shutdown. These facilities, should they be made operational, could significantly contribute to meeting the R&D needs as shown in the table. Given the growing demands for nuclear R&D capacity, all of these facilities should be considered as viable candidates for restart.

S.4 CONCLUSION

This study provides a summary level catalog of the Nation's nuclear R&D infrastructure capabilities. It also provides projections of future requirements for that infrastructure. When comparing the two, the conclusion is that significant needs will soon go unmet unless actions are taken to construct new facilities and/or restart idle ones.

Of course, the Department is not unaware of this situation. Several new facilities are in the planning, design, or construction phase as of this writing. A notable example is the SNS. The addition of this facility will help to meet critical needs, but even so, there are areas of research that will not be covered. In the near term there is a need for a transient testing facility; in the longer term, there is the need for greater isotope production capacity. Additionally, all five areas of science covered by this report envisioned future needs that either require or would benefit from a fast flux irradiation facility like FFTF. Finally, international facilities have not been exhaustively considered in this report, but may provide additional options for meeting future needs. A list of international research facilities is given as Appendix M.

Over 80 percent of the workforce at the facilities responding to the data request is more than five years away from retirement. Within the next five years, only 20% of the workforce will be at age 55 or above. This would indicate that overall the facilities are in no danger of losing existing technical expertise within the next five years. However, there potentially could be a shortage of college graduates in nuclear engineering to enter the workforce and replace personnel who will retire in the next 10 to 20 years.

The available data show that the current facility utilization for FY00 is approximately 82 percent for reactors, 71 percent for accelerators, and 83 percent for hot cells. The projected facility utilization for FY05 is approximately 88 percent for reactors, 93 percent for accelerators, and 83 percent for hot cells. In a few cases, facilities are at 100 percent capacity. Based on the current utilization, our hot cells do have available capacity to support new missions. Reactors and accelerators have more instrument specific characteristics that can dictate their utilization and their ability to accept future missions.

It is important that this assessment be reviewed periodically and updated as facilities and needs change. The Department is a vibrant, dynamic, and complex organization and managing the nation's nuclear R&D

assets is a daunting task. It is hoped that this report is useful in making decisions regarding the future of the Department's nuclear science and technology R&D infrastructure.

In closing, Figure S-2 shows the additions to the current operating infrastructure required to meet the needs highlighted in this report. Some of these needs may be regarded as speculative, all of them are subject to change. This list is not exhaustive. Even so, Figure 2 provides a simple visual means for evaluating the mix of facilities required to meet the nuclear science needs identified in this report.

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Figure S-2. Facility Requirements, 2000 - 2020

S.5 RECOMMENDATIONS

NERAC has the following recommendations based on Revision I of the Nuclear Science and Technology Infrastructure Roadmap.

- For current and future missions, DOE should consider additional reactor facilities. In addition, DOE facilities should be maintained and upgraded commensurate with the DOE mission plans.
- The Roadmap should be revised and updated on an annual basis.
- In the next revision to the roadmap, Revision II ,the following should be addressed:

  -Maintenance and upgrade needs for the basic infracture of reactors, hot cells and accelerators.

  -DOE personnel needs for the period 5-10 years and 10-15 should be addressed. Results from the Corradini Blue Ribbon Panel on the Future of University Nuclear Engineering report should be incorporated and specific action items identified

  -A systematic R&D plan should be developed for international cooperation.

  -A systematic R&D plan should be developed for utilizing university facilitates in conducting DOE research so that long-term partnership arrangements can be developed.

  -A sensitivity analysis should be performed to examine facility requirements for various mission/priority scenarios.

  -Tables C-1 C-4, and C-6 should be completed and updated where appropriate.

Table S-1. Operating DOE Nuclear Facilities Reactors, Accelerators, Hot Cells - 1999

Location	Facility
Reactors	
Argonne National Laboratory – West (Argonne)	Neutron Radiography Reactor (NRAD)
Brookhaven National Laboratory	Brookhaven Medical Research Reactor
Idaho National Engineering and Environmental Laboratory (INEEL)	• Advanced Test Reactor (ATR) • ATR Critical Facility
Los Alamos National Laboratory (LANL)	Los Alamos Critical Assembly Facility (LACEF) - multiple critical assemblies
Oak Ridge National Laboratory (ORNL)	High Flux Isotope Reactor (HFIR)
Sandia National Laboratories (SNL)	• Annular Core Research Reactor (ACRR) • Sandia Pulse Reactor-III (SPR-III)
Accelerators	
Argonne National Laboratory	• Advanced Photon Source LINAC • Intense Pulsed Neutron Source (IPNS) LINAC • IPNS Rapid Cycling Synchrotron
Brookhaven National Laboratory (BNL)	• BNL LINAC • BNL Booster • BNL AGS
Fermilab National Accelerator Laboratory, IL	• Tevatron • Main Ring • Booster • LINAC
Thomas Jefferson National Accelerator Facility (Newport News, VA)	CEBAF
Los Alamos National Laboratory (LANL)	Los Alamos Neutron Science Center (LANSCE) LINAC
Lawrence Berkeley National Laboratory	Advanced Light Source Injector
Lawrence Livermore National Laboratory	LINAC
Massachusetts Institute of Technology (MIT)	BATES Linear Accelerator
Oak Ridge National Laboratory (ORNL)	• Holifield Radioactive Ion Beam Facility (HRIBF) - Tandem • HRIBF - Cyclotron • Oak Ridge Electrion Linear Accelerator (ORELA)
Stanford Linear Accelerator Center (SLAC)	• Main LINAC • Injector LINAC

Table S-1. Operating DOE Nuclear Facilities Reactors, Accelerators, Hot Cells - 1999 (continued)

Location	Facility	No. of Cells

Hot Cells		
Argonne - East	Irradiated Materials Facility	4
	Alpha-Gamma Hot Cell Facility	1
	Building 205	3
Argonne - West	Hot Fuel Examination Facility	2
	Analytical Lab	6
	Fuel Conditioning Facility	2
Brookhaven National Lab	Target Processing Lab	1
	Metallurgic Evaluation Lab	1
Hanford/PNNL	High Level Radiochemistry Facility	3
	Shielded Analytical Lab	8
	Mini-Hot Cell	1
	222-S West	10
	Interim Examination and Maintenance Cell at Fast Flux Test Facility	1
INEEL	Test Area North	5
	Remote Analytical Lab	2
	New Waste Calcining Facility	13
Los Alamos National Lab	Chemistry and Metallurgy Research Building	16
	Technical Area TA-48	13
Oak Ridge National Lab	Radiochemical Engineering Development Center	12 (Bldg 7920) 7 (Bldg 7930)
	Radioactive Materials Analytical Lab	9
	Building 4501	4
	Irradiated Materials Examination and Testing Facility	6
Oak Ridge National Lab	Radioisotope Development Lab	5
	Irradiated Fuels Examination Lab	6
Sandia National Labs	Hot Cell Facility	1 large canyon with 20 work stations, plus shielded storeroom
Savannah River Site	Defense Waste Processing Facility	7
	High Level Cells	16
	Intermediate Level Cells	2
	Californium Shipping/Receiving	1
	Central Lab Facility	6
Bettis Atomic Power Lab	Naval Reactors R&D	?
Knolls Atomic Power Lab	Naval Reactors R&D	?