

LONG-TERM STEWARDSHIP SCIENCE AND TECHNOLOGY ROADMAP

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ABSTRACT

Due to current technology limitations and funding, there is a growing recognition that many of the world's hazardous and radioactively contaminated waste sites will not be sufficiently remediated to allow unrestricted land use. The United States Department of Energy (DOE) has the responsibility to monitor and safeguard more than 100 sites that will contain residual contamination. The DOE sponsors the Long-Term Stewardship (LTS) National Program to perform activities, including physical and institutional controls, information management, trending and remediation, and others, required to protect human health and the environment from residual contaminants.

In 2001, the Idaho National Engineering and Environmental Laboratory (INEEL) initiated an analysis of LTS science and technology (S&T) needs via the development of a "Long-Term Stewardship Science and Technology Roadmap." The Roadmap will provide the strategic direction needed for the DOE to develop the infrastructure and capabilities necessary to meet its LTS commitments in an efficient manner, thus forming a sound S&T investment strategy. As part of the Roadmapping effort, the INEEL will interface and coordinate this effort with existing DOE programs and Focus Areas, industry, academia, regulators, other stakeholders, and other aspects of the LTS National Program.

INTRODUCTION

The mission of the overall LTS National Program is to maintain and continuously improve protection of human health, safety, and the environment at sites assigned to the DOE for such purposes. Specific program elements may include:

- Providing sustained human and environmental well-being through the mitigation of residual risks and the conservation of a site's natural, ecological, and cultural resources
- Maintaining "post-cleanup" controls on residual hazards
- Maintaining engineered controls, infrastructure, and institutional controls
- Seeking to avoid or minimize the creation of additional "post-cleanup" LTS liabilities during current and future contamination
- Enabling the best land use and resource conservation within the constraints of current and future contamination
- Periodically re-evaluating the priorities and strategies in response to changes in knowledge, science, technology, site conditions, societal values, or regional settings
- Coordinating activities to identify and promote additional research and development efforts needed to ensure protection of human health, safety, and the environment and to incorporate new S&T developments that result in increased protection of human health and the environment and lower costs.

Another essential aspect of the LTS National Program is obtaining a solid understanding of the technologies needed to accomplish the LTS mission, what technologies are currently available, and what technologies need to be developed or improved, then developing a systematic, defensible investment strategy that will ensure critical, mission-relevant technologies are available in a timely and cost-effective manner. Declining budgets make this level of technology planning even more critical. Successful execution of the program mission will involve engaging stakeholders; regulators; and local, state, and tribal governments in determining the future use of sites within the constraints and risks posed by the sites' residual contamination.

In 2001, the INEEL initiated an analysis of LTS needs via the development of an LTS S&T Roadmap. The following description of roadmapping and its applicability to LTS is extracted from the *Multi-Year Program Plan for the Long-Term Stewardship National Program [Draft]*, Revision B:

Roadmapping is a disciplined, consensus building, analysis, solution development, a decision-making methodology that supports strategic programmatic and project planning. Roadmap preparation will focus all parties on the needs, risk-reduction alternatives, desired capabilities, and the paths that will lead to efficient and timely resource investment. Roadmapping is a highly effective way to forecast critical new technology development requirements and is a valuable planning tool for decision-making. The roadmapping process clarifies critical missions, applies collaborative realism to solve complex problems, and builds consensus to address near- and long-term S&T needs. The Roadmap will include planning for scientific research and engineering development, with the end goal of stewardship mission accomplishment. As a collaborative process for defining the LTS S&T investment strategy, the Roadmap will identify what to do, when to do it, and why it needs to be done, leading to consensus on priorities and path forward. The Roadmap will not identify who will do it, where to do it, or how to do it. The Roadmap will establish a consensus on near-term (5-10 year), intermediate-term (10-20 year), and long-term (20-50 year) general research and development needs. Through the Roadmap development process, the technical risk will be identified, a vision and consensus about needed capabilities will be developed, a consensus forecast will be developed, and a framework to plan and coordinate S&T developments within the LTS Program will be provided.

As part of the Roadmapping effort, the INEEL will interface and coordinate with existing DOE programs and Focus Areas, industry, academia, other stakeholders, and other aspects of the LTS National Program. The final Roadmap will provide the strategic direction needed for the DOE to develop the infrastructure and capabilities necessary to meet its LTS commitments, reduce program expenditures, and improve programmatic operations. Ultimately, the Roadmap will help DOE fulfill its LTS Program vision:

DOE will avoid, delay, or reduce the frequency or impact of harmful exposure to hazardous substances remaining after DOE cleanup projects and other operations are completed...ensure that design, construction and operation of new facilities avoid creating waste and contamination problems that will require long-term stewardship...use improved technologies and institutional structures that improve the reliability and reduce the cost of long-term stewardship (as posted on the DOE Office of Long-Term Stewardship Webpage at <http://lts.apps.em.doe.gov/vision.asp>).

PROJECT OVERVIEW

The LTS National Program will coordinate activities to identify and promote S&T development that increases protection of human health and the environment, mitigates risk, and decreases life-cycle costs. The LTS Roadmapping effort will aid in the coordination activity by identifying the S&T needs and technology gaps and formulate response plans for those gaps to support LTS National Program activities in order to provide DOE with adequate information to establish a sound S&T investment strategy. This Roadmapping effort involves broad representation of independent experts from across interested and affected parties, and will follow accepted DOE and industry standards for conducting roadmapping activities.

The principle goals and objectives for the LTS Roadmapping effort are:

- Communicate the vision of the Roadmap
- Establish working partnerships with DOE National laboratories, other federal agencies, universities, and industry to collaboratively address LTS S&T needs
- Obtain life-cycle cost data and identify cost reduction opportunities
- Provide a Roadmap that:
 - Specifies the major technology areas, drivers, and targets for critical S&T that must be conducted to address LTS needs
 - Identifies technology alternatives and investment strategies
 - Establishes a basis for sound decision-making relative to LTS S&T needs
 - Recommends S&T developmental activities that should be pursued
 - Recommends resource allocations to support the LTS Program
- Monitor development progress
- Establish a path forward that, if followed, will reduce projected LTS life-cycle costs by 15%.

Achieving these goals and objectives will require the sponsorship of high-ranking DOE management; participation from a wide-range of organizations and stakeholders, both internal and external to DOE; and the allocation of resources and funding to support development of a sound, defensible investment strategy for LTS S&T.

PROJECT DESCRIPTION/DETAILED PROCESS DESIGN

A collaborative, phased approach is being implemented for developing an S&T Roadmap that will integrate DOE's end-state operational plans, S&T needs, and ongoing R&D. Each of the phases will consist of four major tasks: Roadmap Initiation, Technical Needs Assessment, Roadmap Development, and Roadmap Review and Implementation.

Phased Approach

The LTS Roadmapping effort will be completed in three phases: Phase 1 addressing regulatory compliance for current and projected DOE LTS operations; Phase 2 addressing improvements to DOE LTS operations; and Phase 3 addressing the integration of DOE LTS with other federal, state, international, and private sector LTS programs.

Phase 1 - Operational Compliance. The initial phase of the Roadmap will focus on integrating S&T to the functions required to maintain and operate the current and projected DOE LTS end-states. Specifically, the first phase will:

- Focus on ensuring compliance through operations, surveillance, and maintenance of DOE's LTS sites in their current and projected end-state conditions.
- Include a representative set of issues and types of DOE LTS sites (e.g., EM, detonation, science sites, etc.).
- Utilize national expertise focused on DOE's LTS challenges.

Phase 2 - End-State Improvements. The second phase of the Roadmap will build on the work and lessons learned from Phase 1 to address improvements to DOE's projected LTS end-state conditions. Specifically, the second phase will:

- Update or enhance relevant aspects of the Phase 1 Roadmap effort.
- Address improvements (e.g., reduce risk, enhance controls, improve measurements, provide more efficient operations, reduce costs, optimize land-use, etc.), in the end-state conditions of DOE's LTS sites.

Phase 3 - Full Integration/LTS Leadership. The third and final phase of the Roadmap will build on the work and lessons learned from Phases 1 and 2. During Phase 3, the scope of the Roadmapping effort will be expanded to include establishing LTS criteria for new projects and interfacing with other federal, state, international, and private sector LTS programs. Specifically, the third phase will:

- Update or enhance relevant aspects of the Phase 1 and 2 Roadmapping efforts.
- Establish new program and project criteria relative to LTS to ensure full life-cycle planning (LTS minimization) for new DOE programs and projects.
- Provide the opportunity for DOE to take a leadership role in interfacing with other federal agencies, state and local governments, international governments, and the private sector entities in addressing national and global LTS programs, projects, challenges, and S&T applications.

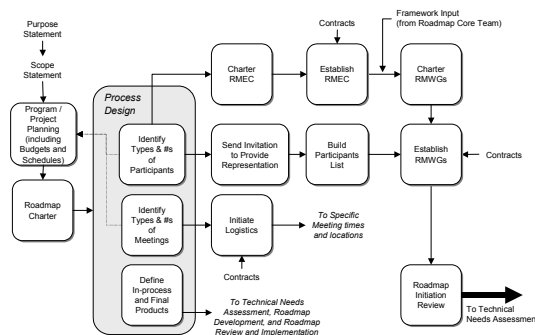


Fig. 1. LTS Roadmapping Process Design for Phase 1 (subtasks will vary for Phases 2 and 3)

Each of the three phases will consist of four major tasks: Roadmap Initiation, Technical Needs Assessment, Roadmap Development, and Roadmap Review and Implementation. The Roadmap Process Design for Phase 1 is presented in Figure 1. The detailed process designs (see Figures 2 through 5) discussed below are typical of all three phases; however, some subtasks may not apply to Phase 2 and 3 activities. Additionally, activities not needed for Phase 1 may be included in Phases 2 and 3. The applicability of each task will be reviewed during the detailed project planning for each phase. The processes outlined below closely follow the OST draft roadmapping guidance, *Applying Science and Technology Roadmapping in Environmental Management*.

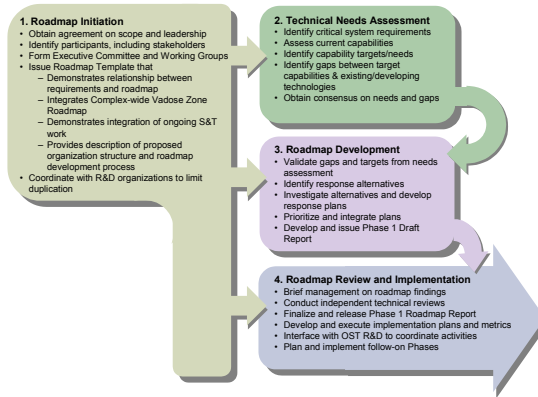


Fig. 2. Roadmap Initiation Process

Roadmap Initiation. The Roadmap Initiation task focuses on preparation for the Roadmapping process and includes obtaining agreement on the Roadmap's scope, leadership (i.e., a Roadmap Executive Committee, Roadmap Working Groups, and Roadmap Core Team), participants (including stakeholders), and deliverables. Figure 2 further defines the Roadmap Initiation process.

Technical Needs Assessment. The Technical Needs Assessment task assesses the technical capabilities needed to achieve the LTS National program goals and objectives and is the most important phase of the Roadmapping effort. Needs will be based on the end-states and technologies identified as part of other LTS efforts, and on input from current end-user needs identification processes. This task includes a structured, systematic approach to identifying technical issues and LTS National Program functions, assessing those issues and functions to identify capability and usage gaps (i.e., areas where S&T is needed to address technical issues and satisfy program functions), and establishing associated program goals for S&T. The Roadmap Executive Committee will oversee the efforts of several working groups in accomplishing this task. Needs workshops will also be held to aid in (1) defining technical and programmatic needs and functions as a result of anticipated end-states and available technologies defined in the LTS Technical Baseline and Technology Profile reports, respectively, and (2) finalizing objectives for the Roadmap. The workshops will involve participants from regulatory agencies; local, state, and tribal governments; other stakeholder groups; multiple DOE sites and laboratories; other government agencies; academia; industry; and non-DOE future LTS sites. The workshops will take issues and concerns from the participants and transform them into programmatic and technical S&T requirements. This task is complete when consensus is reached and documented by the Roadmap Executive Committee on the programmatic and technical needs and the overall direction for the Roadmap. Figure 3 displays the overall Technical Needs Assessment process.

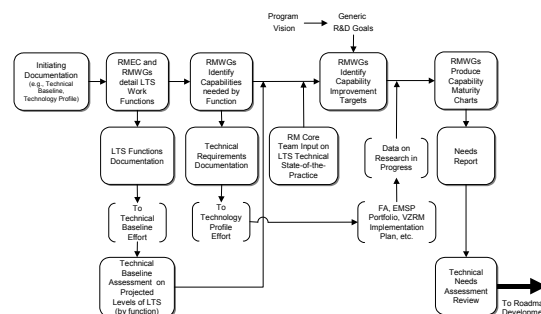


Fig. 3. Technical Needs Assessment Process

Roadmap Development. The Roadmap Development task involves identifying and documenting approaches to respond to the targets identified during the Technical Needs Assessment task and developing the Draft Roadmap. Roadmap Development will utilize current technology development data obtained from DOE Office of Science and Technology (OST) Focus Areas, Environmental Management Science Program (EMSP), and Crosscut Programs, and from other government agencies to further analyze the current DOE S&T portfolio (including identified technology gaps) and aid in the development of response plans. Where Technical Needs Assessment will focus on the LTS community and the R&D of technologies to provide those capabilities, Roadmap Development will focus on the R&D community and the R&D of technology to provide those capabilities. The Roadmap Working Groups will validate the gaps and targets from the Technical Needs Assessment task, identify and investigate response alternatives, and draft response plans (in the form of capability maturity and development path charts). This information will be discussed at additional workshops, after which the response plans will be prioritized and associated response schedules integrated. Once the response plans and schedules are finalized and documented, these products will support the S&T development task such that sound investment decisions can be made. This task will interface with other LTS teams (e.g., Information Management, Technical Baseline, Technology Profile, and Performance Assessment and Decision Analysis) and use information developed by those teams to assess the value of making various technology investments. Figure 4 illustrates the overall Roadmap Development Process.

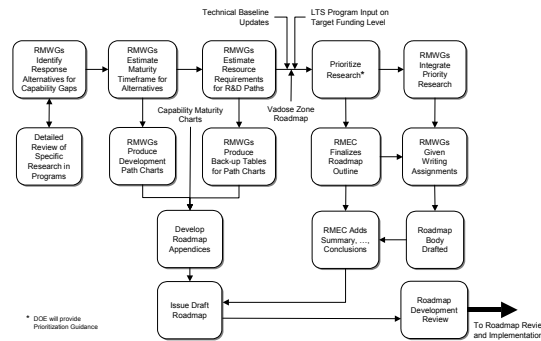


Fig. 4. Roadmap Development Process

Roadmap Review and Implementation. In the Roadmap Review and Implementation task, the Roadmap will be reviewed, released, implemented, and updated as necessary. This task will include management briefings on the Roadmap findings, independent technical reviews, and Roadmap finalization. After release of the Roadmap, implementation plans will be developed by the Roadmap Executive Committee; R&D plans coordinated with Focus Areas, site LTS work managers, and other funding mechanisms, and R&D work plans executed to meet LTS needs. Implementation progress will be tracked and the Roadmap and associated implementation plans periodically revised and updated to support sound decision-making and ensure the timely and cost-efficient availability of S&T needs for program success. Figure 5 shows the overall Roadmap Review and Implementation process.

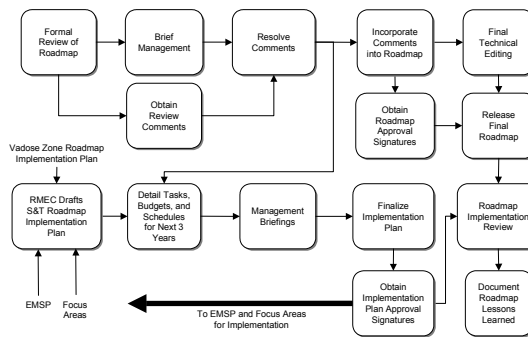


Fig. 5. Roadmap Review and Implementation Process

PROJECT EXECUTION

Specific elements key to the success of the Roadmap Project include the organizational structure (including the Roadmap Executive Committee and Working Groups), as well as the workshops necessary to develop a sound S&T investment strategy for the DOE. It is anticipated that Phases 2 and 3 will follow a similar execution strategy, incorporating lessons learned from Phase 1.

Organizational Structure

Based on the objectives of the Roadmap, EM draft roadmapping guidance, and lessons learned from previous roadmapping efforts, an organizational structure has been established to promote the broad participation and collaboration of interested and effected parties. The Roadmap Executive Committee is delegated leadership of the Roadmap effort as defined and bounded by DOE. A Roadmap Core Team, composed of INEEL staff reporting to the Roadmap Manager, will support the Roadmap Executive Committee. Roadmap Working Groups will be responsible for investigating various S&T issues associated with the Roadmap and for developing the Roadmap text for their respective topical area. Figure 6 illustrates the organizational hierarchy for the LTS Roadmap.

Roadmap Manager. The Roadmap Manager is responsible for the quality of the Roadmap products and for delivery of the Roadmap to DOE. As such, the Roadmap Manager will review the technical, administrative, managerial, and budgetary targets of the Roadmapping effort and take appropriate actions to ensure progress toward achieving them. The Roadmap Manager and the Roadmap Executive Committee provide a communication channel with DOE and INEEL management, regulators, site contractors, and other stakeholders.

Roadmap Executive Committee. The Roadmap Executive Committee is delegated leadership of the Roadmap effort as defined and bounded by DOE. The Roadmap Executive Committee will be composed of a Board of Directors and a Steering Committee of Roadmap Working Group Chairs, as described below.

Roadmap Board of Directors. The Board of Directors will oversee the Roadmapping process, define the overall technical scope of the Roadmapping effort based on guidance from the Roadmap Manager, and ensure that all technical topics required for an integrated roadmap are being covered by the Roadmap Working Groups. The Board of Directors will review participants selected by the Steering Committee and provide suggestions to ensure that overall work group membership reflects the broad perspectives that must be incorporated in this effort. The Board of Directors will review and comment on the major S&T objectives identified by the Roadmap Working Groups through interaction with participants during and between Roadmap meetings and workshops.

The Board of Directors will be chaired by a recognized environmental expert with relevant DOE site and end-user experience. The remaining directors will include a site contractor operations manager, a recognized S&T R&D specialist, a recognized scientist from academia, a national Environmental Protection Agency manager, and a representative from a stakeholder organization. Other members will include the Chief Scientist and Assistant Manager for R&D at DOE Idaho Operations Office and the INEEL Roadmap Manager, who will serve as liaisons between the Roadmap Executive Committee and the DOE LTS National Program Management and INEEL LTS National Program, respectively.

Roadmap Steering Committee. The Steering Committee will manage the Roadmap development process. It will ensure that schedules are met and will resolve issues that arise within and between the Roadmap Working Groups.

The Steering Committee will be composed of the Chairs of the Roadmap Working Groups. The Chair of each Roadmap Working Group will be a recognized authority in a respective S&T topical area with experience in the application of R&D to cleanup issues.

Roadmap Working Groups. The Roadmap Working Groups will define the overall technical scope of the Roadmapping effort for their respective S&T topical areas. The Roadmap Working Groups will draft the major technical objectives for the Roadmap, refine objectives through interaction with the other Roadmap Working Groups, and coordinate with other Roadmap Working Groups to ensure a coherent, consistent, and reasonable Roadmap.

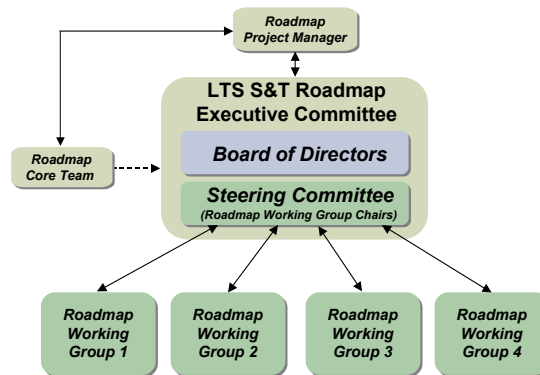


Fig. 6. Roadmap Organizational Hierarchy

Roadmap Working Group Topical Areas. The following is a preliminary list of topical areas relative to LTS and will be considered in the establishment of the Roadmap Working Groups:

- Institutional Controls
- Environmental Monitoring
- Natural Processes
- Engineered Controls
- Engineered Barrier Monitoring
- Barriers and Remediation
- Environmental and Human Health
- Intergenerational Concerns
- Decision Science/Decision Making
- Information Management/Maintenance

Roadmap Working Group Members. Each Roadmap Working Group will be comprised, as appropriate, of end-users from DOE field contractor organizations and industry; S&T developers from DOE National laboratories, industry, and academia; national or state regulatory agencies; and national or site stakeholder groups.

INTEGRATION OF OTHER ROADMAPS

The Roadmap will integrate the findings of the Complex-wide Vadose Zone Roadmap by directly involving numerous participants from the vadose zone roadmap in the development of the LTS S&T Roadmap. An additional interface will exist with organizations such as OST and its Environmental Management Focus Areas and EMSP, and other DOE organizations to establish a "profile" of current technology and developments. This interface will continue throughout the life of the project.

DOE Complex-wide Vadose Zone Roadmap

In FY-2000 and FY-2001, DOE sponsored the development of a detailed Complex-wide Vadose Zone Roadmap, published under the title *A National Roadmap for Vadose Zone Science and Technology: Understanding, Monitoring, and Predicting Contaminant Fate and Transport in the Unsaturated Zone*. The vadose zone is the area of the subsurface from ground level down to the water table, which includes many if not most of the engineered waste disposal facilities, inadvertent discharges, and residual soil and rock contamination areas of concern to LTS. The vadose zone roadmap covers aspects of scientific understanding, modeling, and measurement of the vadose zone. In order to capitalize on this effort, the Roadmap will utilize the vadose zone roadmap to address issues related to understanding, characterizing, and monitoring the subsurface. Key personnel from the vadose zone roadmap development will be included on the LTS S&T Roadmap Working Groups to ensure seamless integration of the two efforts.

While the vadose zone roadmap sufficiently addresses issues related to understanding geological, hydrological, chemical, and biological processes related to subsurface contaminant fate and transport in the vadose zone, the LTS Roadmap will address some additional issues specific to the saturated zone (i.e., below the water table). Such issues include, but are not limited to, a specific path forward for improvements in the cost, reliability, or field hardening of the related instruments needed to acquire the data and a means of data

transmission from in-situ instruments needed to acquire the data and a means of data transmission from in-situ instruments or waste management of samples. The Roadmap will also address remediation technologies, as well as surface and airborne contaminant fate and transport modes.

Focus Area Roadmaps

During the last two months of FY-2001, the LTS Technology Profiling project performed an initial assessment of S&T development activities being conducted by DOE OST Focus Areas, Crosscut Programs, and the EMSP to identify S&T relative to LTS. OST Focus Areas included Transuranic and Mixed Waste, Tanks, Subsurface Contaminants, Nuclear Materials, and Deactivation and Decommissioning; Crosscut Programs included Characterization and Monitoring and Sensor Technology, Efficient Separations and Processing, and Robotics. The overall results of the profiling effort will provide a strong basis for the Roadmap Working Groups to begin the development of the Roadmap.

The Technology Management System (TMS) and the respective Focus Area and Crosscut Program websites were evaluated with respect to the eight proposed topical areas to determine the initial profile of technologies viewed as potentially having an application to LTS. Over 1,000 technologies were reviewed during this effort. Upon completion of the initial profile, the compiled information was sent to the Focus Areas, Crosscut Programs, and the EMSP for their review. Additionally, the information was sent to the Environmental Management Core Laboratories (EMCL) working group for their independent review and comment. The EMCL also coordinated with the Focus Areas to provide information on strategic planning efforts - including roadmaps - that the Focus Areas were pursuing to enhance R&D efforts targeted at LTS. During future efforts on the LTS S&T Roadmap, the Roadmap project will establish its own direct interfaces with the Focus Areas to ensure the coordinated integration of strategic plans and Focus Area roadmap data into the LTS S&T Roadmap.

SUMMARY

A solid understanding of the technology needs required to accomplish the LTS mission and a strategy to fulfill those needs are essential. Understanding the program's technology needs, what technologies are currently available, what technologies need to be developed or improved, and how and when technologies must be available are important LTS technology issues. A critical LTS infrastructure need is to develop a systematic, defensible investment strategy that will ensure needed technology is available to support the mission of the Long-Term Stewardship National Program.

The Long-Term Stewardship National Program must do effective technology planning to identify and develop the technologies required to meet DOE's LTS mission. Declining budgets make this technology planning even more critical. From an economics perspective, the Long-Term Stewardship National Program must quickly and efficiently identify and develop critical, mission-relevant technologies.

To develop the investment strategy, an Operational Baseline has been prepared to understand the extent and nature of LTS across the DOE complex. From the Operational Baseline, a roadmapping process will be used to establish what LTS technology research is needed and when it is needed. Other programs, both internal and external to the DOE, will influence this strategy. Examples include the Complex-wide Vadose Zone Roadmap, DOE Focus Areas, other related government programs, and industry practices. The technology investment strategy will make certain the right technology is available at the right time to help ensure the success of the Long-Term Stewardship National Program.

The LTS S&T Roadmap will include planning for scientific research and engineering development, with the end goal of stewardship mission application. As a collaborative process for defining the LTS S&T investment strategy, the S&T Roadmap will identify what to do, when to do it, and why it needs to be done, leading to consensus on priorities and path forward. The S&T Roadmap will not identify who will do it, where to do it, or how to do it. The S&T Roadmap will establish a consensus on the near-term (5-10 year), intermediate-term (10-20 year), and long-term (20-50 year) general R&D needs. Through the S&T Roadmap development process, the technical risk will be identified, a vision and consensus forecast will be developed, and a framework to plan and coordinate S&T developments within the LTS Program will be provided.

This Roadmapping effort involves broad representation of independent experts from across interested and affected parties, and will follow accepted DOE and industry standards for conducting roadmapping activities. It will provide the DOE an assessment of S&T needs to perform its LTS responsibilities and establish an investment strategy for S&T.

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