Designing Program Roadmaps to Catalyze Community Formation

A Case Study of the Long-Term Stewardship Science and Technology Roadmap

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Abstract

A number of broad perspective technology roadmaps have been developed in the last few years as tools for coordinating nation-wide research in targeted areas. These roadmaps share a common characteristic of coalescing the associated stakeholder groups into a special-interest community that is willing to work cooperatively in achieving the roadmap goals. These communities are key to roadmap implementation as they provide the collaborative energy necessary to obtain the political support and funding required for identified science and technology development efforts.

This paper discusses the relationship between roadmaps and special-interest communities, using the recently drafted Department of Energy's Long-Term Stewardship Science and Technology Roadmap as a case study. Specific aspects this roadmap's design facilitated the development of a long-term stewardship community while specific realities during roadmap development impacted the realization of the design.

INTRODUCTION

Science and Technology roadmapping is a structured strategic planning process used by companies, industries, and government agencies to plan technology development. For each planning case, development is driven by perceived or predicted needs. Need is in turn driven by market forces (for companies) or mission requirements (for government agencies). The U.S. Department of Energy (DOE) has been using roadmapping as a planning tool within its Environmental Management (EM) program for several years. The primary emphasis has been on selection of technical approaches for large capital projects, such as waste treatment facilities [1, 2, 3]. EM has also used roadmapping as an integrating tool to help coordinate general research across a technical area [4, 5].

Program Roadmaps versus Project Roadmaps

In 2000, EM drafted a roadmapping guide to help standardize development of roadmaps [6]. The guide explicitly recognized the difference between roadmapping to support a specific technical decision (a "project-level" roadmap) and roadmapping to support general development in a technical area (a "program-level" roadmap). While this distinction made for a clear delineation between the two roadmap types, there are a number of additional differences.

One important difference, and the focus of this paper, has to do with the purpose of the roadmap. Project-level roadmaps have very clear drivers:

- They are based on a well-defined mission (typically to treat or disposition a specific type and quantity of waste).
- They usually have a set timeframe.
- A specific organization has sole responsibility to accomplish the mission.

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On the other hand, program-level roadmaps often have vague drivers:
- They are based on moving forward an area of technology typically supporting a broad spectrum of projects.
- The timeframe is usually self-defined. It relates to the timing of associated projects, but is not necessarily driven by them.
- There may be no specific responsible organization, but rather one or more sponsors who see value in the informal coordination of the activities of multiple organizations.

The difference in the clarity of mission drivers results in different purposes for the two types of roadmaps. The primary purpose of a project-level roadmap is to manage the technical risk associated with accomplishing the defined mission. The primary purpose of a program-level roadmap is not as obvious, but usually involves developing a shared vision of the future and direction on how to prepare for that future. Thus a program-level roadmap is less about how to accomplish a mission and more about how to define the mission.

Private Sector Roadmaps

The private sector equivalent of EM's project-level and program-level roadmaps are company-internal and industry roadmaps respectively. Company internal roadmaps tend to focus on delivery of a specific product line on a specific schedule, and managing the associated technical risks. Industry roadmaps are broader and less specific, developing a general vision of the industry's future. In the process, the industry roadmap defines an industry "mission".

Like a project-level roadmap, company-internal roadmaps have a clear supporter in the manager in charge of the product line. The same is not true for an industry-level roadmap. There is no single, responsible person but instead some type of consortium (formal or informal). This consortium is in effect a special-interest community.

Implementation of industry-level roadmaps is dependent on the consortium members individually deciding to follow its vision. There are two contributing (potentially balancing) factors that affect support for the vision:
- Vision quality – The better the vision, the easier it is to adopt. Roadmapping emphasizes inclusion of a diverse set of participants. These participants generally have different perspectives that, when merged, produce a well-rounded collective view that enhances and improves vision quality.
- Community identity - The stronger the individual consortium members identify with the group, the greater the energy (based on group pressure) to adopt a shared vision. However, the more diverse the perspectives of the community members, the weaker the community identification and support.

A program-level or industry-level roadmap should explicitly design for a diversity of participants and should include a methodology that gives those participants a sense of community.

Examples of Community Development

The National Technology Roadmap for Semiconductors [7] is an example of community development. This roadmap was the first widely successful industry-level roadmap. The initial roadmapping in 1992 was a major effort of the Semiconductor Industry Association. The group effort in developing the initial roadmap and its multiple updates has solidified the semiconductor community. This community has transformed the technical development of the industry from one of domestic competitiveness to domestic and (since 1999) international cooperation [8].

A second example of community formation through roadmapping is from the recently completed Generation IV Nuclear Energy Roadmap [9]. This roadmap was initially an effort within the United States involving the Department of Energy's laboratory system and the electrical power industry. By design, each roadmap working group had laboratory and utility co-chairs and a diversity of participants. The roadmap quickly grew into an international effort involving ten countries that are now energized to work together to develop the next generation of nuclear energy plants and systems.

LONG-TERM STEWARDSHIP ROADMAP CASE STUDY

Precursor Activities

The Long-Term Stewardship Science and Technology Roadmap [10] was developed with a sense of community development in mind. The effort to promote community establishment was an outgrowth of lessons learned from a previous, related national level roadmapping effort, the National Roadmap for Vadose Zone Science & Technology [11].

Community Related Lessons Learned from the National Vadose Zone Roadmap

The Vadose Zone roadmap was the first DOE-wide programmatic roadmap developed by EM. This roadmap addressed long-term science and technology development related to subsurface contamination. An important objective was to unite the efforts of multiple universities and government laboratories under a single vision of what research was most needed, how the areas of research should combine and support each other, and what additional supporting infrastructure was needed.

This roadmap owed much of its success to the mix of participants involved. By design, the community of participants included experts from DOE laboratories, other national and state agencies (U.S. Dept. of Agriculture, U.S. Geological Survey, Texas Bureau of Economic Geology, etc.), a range of U.S. and Canadian universities, representatives from industry (primarily oil and gas), and a member of the Russian Academy of Sciences.

The diverse community together with the high caliber of participants provided the Vadose Zone roadmap with substantial credibility and broadened its exposure. However, during development it was recognized that the selected group still didn't include all pertinent perspectives. Viewpoints missing included those of end users and regulators. As a result, a cleanup manager was added to the Executive Committee and a meeting of end users was held late in the roadmap's development to address these omissions.

Chartering the Long-Term Stewardship Roadmap

To increase the likelihood of success for the LTS roadmap, two key personnel involved in the Vadose Zone roadmap were included in the core LTS roadmap production team. Lessons learned about roadmap organization, work group size and composition, and diversity of participants were all considered during initial chartering of the LTS roadmap. Key considerations included:

- End-user ownership and participation – Where the Vadose Zone roadmap was primarily science focused, the LTS roadmap should be very application oriented. Thus, end-users needed to be more than just participants – they needed to be in lead roles where they could assume a sense of ownership. The end users would be key to the LTS roadmap's implementation.
- Diversified participants – Long-term Stewardship's impact was recognized as reaching beyond the DOE-EM program to include potential future land owners such as other federal, state, or local agencies and the surrounding communities. Key considerations for stewardship were not just technical, but also social.
- "Creative Stress" – A large part of the success of the Semiconductor Industry's roadmapping efforts was due to the stress level shared by the participants. They felt they had to do something, or the domestic industry could be completely lost to foreign interests. This stress facilitated

teaming and prioritization. The long time horizon of the Vadose Zone roadmap hadn't provided the same level of stress and motivation. In part to generate some stress level and in part for funding and scheduling reasons, a decision was made to develop the LTS roadmap in phases with the first phase focused on what could be realized in the near term.

Chartering was completed with the development and approval of a roadmap project execution plan that would guide the design, development, and implementation of the roadmap. The plan included four roadmap process steps: Roadmap Initiation, Technical Needs Assessment, Roadmap Development, and Roadmap Review and Implementation.

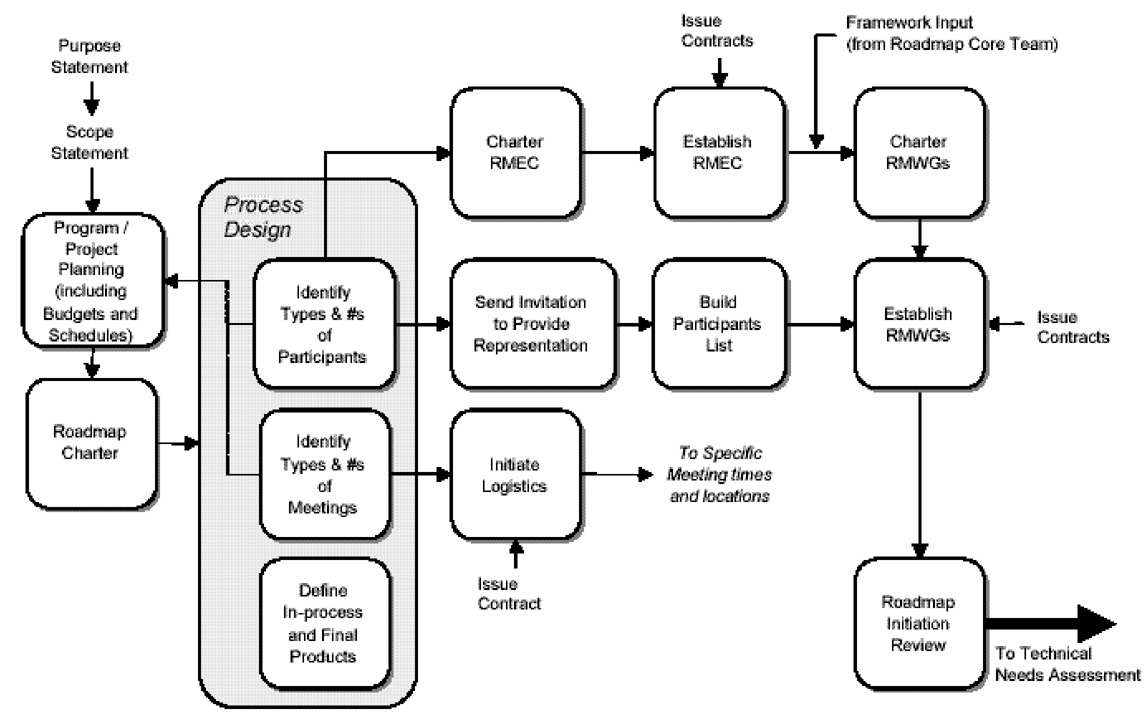

Figure 1 - LTS Roadmap Initiation Process

Design Considerations

Figure 1 shows the process for the roadmap design and initiation. Primary considerations in the design of the LTS roadmap included general organization and composition of participants. The overall organization is shown in Figure 2.

The Executive Committee was envisioned as the central coordinating group for the roadmap. This would include development of overall goals and vision and oversight and review of products developed by the working groups. The Steering Committee would provide a two-way interface with the working groups. The working groups themselves would produce the bulk of the roadmap, including assessment of technical targets, gaps, and development pathways. A Core Team would provide logistics support, meeting facilitation, and other services.

Organization of Working Groups

The working groups themselves needed to cover a broad spectrum of topical areas. An initial list of 11 areas was developed and grouped to come up with the four final focus areas for the working group.

Two of the working groups would focus on the traditional "hard" sciences associated with fate and transport of contaminants and the physical systems engineered to detect and block their movement.

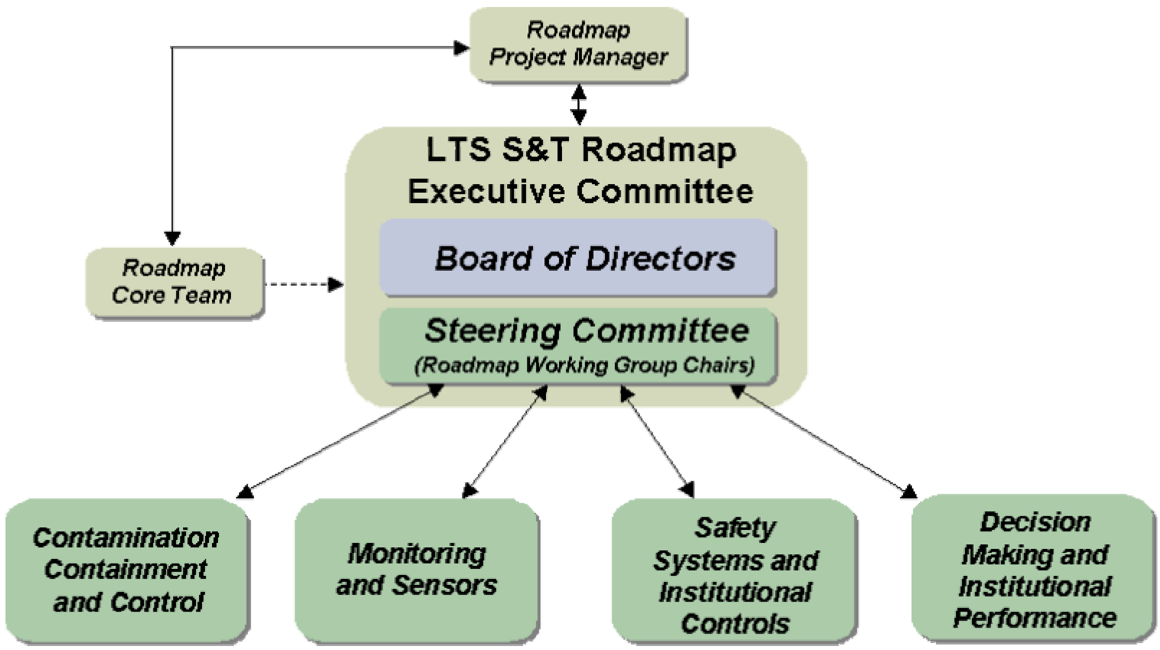

Figure 2 - LTS Roadmap Organization Structure

The Contaminant Containment and Control Workgroup would focus on issues and methods associated with the design, preservation, maintenance, and repair of containment barriers and waste stabilization systems. A particular emphasis would be the emulation of natural systems to reduce maintenance costs.

The Monitoring and Sensors Workgroup would focus on instruments and systems for environmental monitoring and containment systems monitoring, as well as methods to detect intrusions by people, burrowing animals, etc. Much of the emphasis of this second workgroup would be on longevity of instruments, data transmission, processing, and storage, and cost effective designs of full monitoring systems.

The other two working groups would focus on "soft" science areas typically ignored by environmental research programs.

The Decision Making and Institutional Performance Workgroup would focus on the human systems necessary to manage and maintain long-term controls. These included decision-making methods to support changes in stewardship levels over time. They also included the non-physical methods of land use control, such as legal methods (zoning, etc.) and general community communication methods.

The fourth group, Safety Systems and Institutional Controls, would focus on overall system performance (with emphasis on management systems). Related issues included system performance prediction and verification, and long-term records management. This group also assessed the effectiveness and maintenance of physical land use controls, such as fencing and signage.

Identification of Participants

The LTS roadmap was to include 40-50 participants and be completed in ~9 months. Diversity of participation was a primary design goal, based on lessons learned from the recently completed Vadose Zone roadmap.

Working Group Composition

The initial design for the LTS roadmap working groups was for the four groups to each include 6-8 members. The professional facilitator on the core team recommended this as the ideal size for optimal efficiency – more members would result in some people becoming watchers/listeners instead of full participants

To achieve diversity of views and representation, each working group was to include:

- One or two DOE laboratory members (applied researchers)
- One or two DOE field contractor members (management end users)
- A university member (basic researcher)
- An industry member (technical end user)
- A national or state regulator member (regulatory perspective)
- A national stakeholder group member (community perspective)

Typically, getting researchers and end users together required some effort. The additions of regulators and stakeholders would put the roadmap team composition in new territory.

The selection of stakeholders was a difficult challenge by itself, as there were a number of groups who could participate. The plan was to send letters of invitation to four stakeholder groups, asking for 2-3 nominees. One member would then be selected from each group based on availability and willingness to participate. The proposed groups included a national organization of DOE site citizen advisory boards, a national organization of Indian tribes, and two national environmental groups.

Executive Committee Composition

Where the working groups needed to include multiple functional perspectives, the Executive Committee also needed to include representation of multiple organizations involved in stewardship. This committee included the four working group chairs. The remainder of the membership included:

- Chair – A senior DOE contractor manager (DOE field site)
- Vice-chair – The roadmap project manager (DOE laboratory)
- A national Environmental Protection Agency stewardship manager
- A national Department of Defense stewardship manager
- A DOE site cleanup/stewardship manager
- An industry member
- A university member
- A regulatory agency member
- The DOE Idaho Assistant Manager for R&D (ex-officio)

A Dose of Reality – The Impact of External Events

"As built" systems are often somewhat different than the original design. Changes are driven by new information and unexpected events. In the case of the LTS roadmap, two independent events resulted in several important design modifications early in the roadmap's development.

Redefining the Environmental Management Mission

The change of administration in 2001 resulted in a refocusing of the EM mission to accelerate cleanup completion – get the job done so EM could disband. "Completion" applied well to everything in the program except LTS – By definition, LTS is the long-term follow-on to cleanup completion. To accomplish the goal of having EM disband, LTS must be moved out of EM. This issue should be resolved when LTS is transferred to a different program office.

While beneficial in the long term, the timing of this change was not the best for the LTS roadmap in the short term. LTS remains an important issue for DOE, but most management energy was now focused on cleanup acceleration, reducing direct support for the roadmap and putting into question the source of funding for the research it would recommend.

There was, however, a positive impact. The roadmap team felt greater responsibility to define LTS technology needs – someone needed to do it, and they had the assignment. This shared feeling provided a base for many of the discussions that followed.

Adjusting to 9-11 Schedule Impacts

While the effects of future management change were rippling through the LTS program, the roadmap was proceeding on schedule. The core team was fully staffed and Executive Committee membership was in the final stages of identification. The first meeting of the executive committee was scheduled for late September 2001, when working group charters would be finalized and working group membership developed. The only snag was a delay in DOE's approval of the executive committee chairman.

The events of 9-11 changed everything. A freeze on non-essential airline travel hit DOE, and the kick-off meeting of the executive committee was cancelled. For a few weeks, it looked like the roadmap might be put on an indefinite hold. Then the roadmap project manager was given the go-ahead, with instructions to compress the development schedule and complete the roadmap on time.

Design Realizations

With the start of the roadmap delayed, the end date unchanged, and the executive committee not yet in place, some changes had to be made.

Executive Committee Schedule

The first problem was the kick-off for the executive committee. Given the level of people involved, rescheduling would take some time. The earliest the Executive Committee could meet now would be in late November. The core team would have to make all decisions until the executive committee met and became functional.

To stay on schedule, the working group chairs had to be finalized and initial lists of working group members drafted before the November meeting. The core team quickly identified the working group chairs and the Steering Committee formed. This much smaller group was able to meet together in October.

While these changes positively addressed short-term items needed to get the roadmap underway, they also resulted in a longer-term negative consequence. With many of the early Executive Committee actions already completed, the November meeting had less urgency and the group took much longer to "gel". The core group and Steering Committee had become the defacto leadership of the roadmap, and the Executive Committee didn't really take on that role until late in the roadmap's development.

Working Group Composition

At the October Steering Committee meeting the individual working group chairs were given latitude to identify participants and form their own working groups. This was again a practical matter driven by the need to compress the development schedule. The chairs were informed of the planned working group composition, but not held to it. This modified the planned composition and diversity in two ways.

First, the working group chairs generally selected people they already knew – and they mainly knew researchers and end users. Second, time restrictions made it difficult to go through a formal invitation process for the stakeholder groups, resulting in only one stakeholder representative on the working groups (a tribal member). This meant relatively fewer regulators and stakeholders were involved than originally planned (see Figure 3 for the final composition).

The Formation of a Community

Although initial formation of the LTS roadmap community was complicated by external events, the subsequent roadmap development meetings were instrumental in bringing the group together.

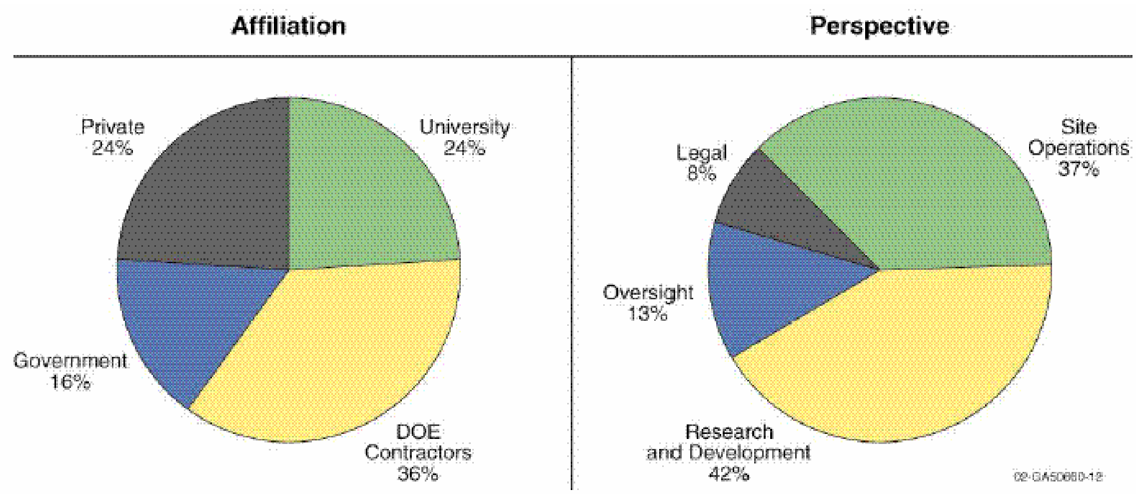

Figure 3 - Composition of LTS Roadmap Participants

Roadmap Development – A Seed Forms

Roadmap development included two multi-day meetings of the working groups. The first meeting focused on technical needs assessment. The needs assessment resulted not only in a good description of technical issues facing LTS, but also in good cooperation among the variety of participants. This cooperation didn't come easily. One working group spent most of the first day of the meeting hammering out the wording for one issue statement, only to have the chair totally change it overnight.

Between the first and second meetings, the working groups continued development and validation of the identified technical needs. This effort culminated in the finalization of 23 technology enhancement targets to support long-term stewardship (see Table 1). The targets covered the full range of issues facing DOE's LTS program.

Communication during this time was primarily by e-mail, with occasional conference calls. The e-mails were important for sharing the actual work being produced with the rest of the team. Conference calls were important for continuing community formation, as they allowed for general banter and sharing of emotions not easily transmitted in e-mail notes.

CONTAIN Residual Contaminants
- Key Capability 1 Site Conceptualization and Modeling Tools
  - Enhancement 1.1 Improve geologic-hydrologic-biological-chemical-thermal conceptual modeling for long-term forecasting
  - Enhancement 1.2 Provide tools for long-term forecasting of environmental conditions relevant to predicted end states
  - Enhancement 1.3 Provide tools for modeling the community at risk
  - Enhancement 1.4 Conceptualize and predict containment/control system performance, including potential failure modes and levels of failure
- Key Capability 2 Contamination Containment & Control Systems
  - Enhancement 2.1 Engineer the geologic-hydrologic-biological-chemical-thermal environment to limit contaminant toxicity and mobility
  - Enhancement 2.2 Design, build, and operate alternative (next-generation) containment systems

MONITOR the Site and the LTS System
- Key Capability 3. Sensors and Sensor Systems for Site Monitoring
  - Enhancement 3.1 Identify contaminant monitoring needs for all media of potential transport or exposure and fill sensor technology gaps where monitoring solutions are needed
  - Enhancement 3.2 Establish site-specific parameters for environmental exposure routes and for both occupational (on-site) and non-occupational (community at risk) human routes of exposure
  - Enhancement 3.3 Provide sensors and sensor systems for monitoring active and passive safety systems

COMMUNICATE Within and Beyond the LTS System
- Key Capability 4. Preservation and Communication of Site Information
  - Enhancement 4.1 Provide components for an integrated information visualization and display system
  - Enhancement 4.2 Provide an information system module for communicating system performance data
  - Enhancement 4.3 Provide options for intergenerational information archiving
- Key Capability 5. Site–Community Relations
  - Enhancement 5.1 Improve understanding of what affects public trust and confidence
  - Enhancement 5.2 Involve the community in the conduct of site stewardship
  - Enhancement 5.3 Identify and solve problems that can undermine reliability and constancy in LTS institutions

MANAGE the LTS System
- Key Capability 6. LTS System Performance Verification and Monitoring
  - Enhancement 6.1 Provide techniques and technologies to improve planning, design, implementation, and decision-support capabilities of Contamination Containment & Control systems and their associated monitoring systems
  - Enhancement 6.2 Provide tools to verify performance of Contamination Containment & Control and monitoring subsystems
  - Enhancement 6.3 Provide tools to verify and monitor the overall (technical and nontechnical) performance of the LTS system
  - Enhancement 6.4 Integrate preventive maintenance requirements into site subsystems
  - Enhancement 6.5 Provide tools for collecting, analyzing, evaluating, and disseminating performance data
  - Enhancement 6.6 Develop science to ensure continuous improvement in stewardship implementation
- Key Capability 7. Effective and Survivable Land-Use Controls

Table 1 - LTS capability enhancements

The working groups also started investigating technologies as a lead into the second team meeting, focusing on roadmap development. Investigations included status of technology development and likely availability of the technology in time to produce near-term impacts. Some of these investigations involved contacting additional technical specialists outside the roadmap team – an activity that not only gathered key information for the roadmap, but also started the process of sharing the roadmap goals and vision with a broader community.

During the roadmapping development meeting, the working groups focused on near-term achievable impacts associated with each of the technology enhancements. This resulted in the identification of 28 specific near-term development targets. It also resulted in thoughtful discussions about what could be accomplished in the near term and what could be delayed or had to have more time to be developed. The roadmap participants were feeling real stress due to the time constraints placed on the first phase of the roadmap. There was a concern the next phase wouldn't be developed and LTS would not get all the technologies it needed. The constraints had become a uniting force.

Next, development pathways were drafted for each target, outlining the steps from initial investigation through development, testing, and fielding to achieve the targeted capability. The tension the participants had been experiencing now had a creative outlet. For each pathway, the individual activities and in-process products were identified, along with cost and duration estimates for the work. This material and the related technologies were collected into a 140-page appendix to the main roadmap report.

The final task of integrating and aligning the working group products fell on the executive committee. This included the relative scheduling of R&D development paths and any needed prioritization. The slow start experienced by the executive committee was finally overcome during this effort, as the committee finally became a team that felt ownership over the forming report. During this process, a number of synergies between development pathways were identified. Figure 4 depicts the identified interdependencies.

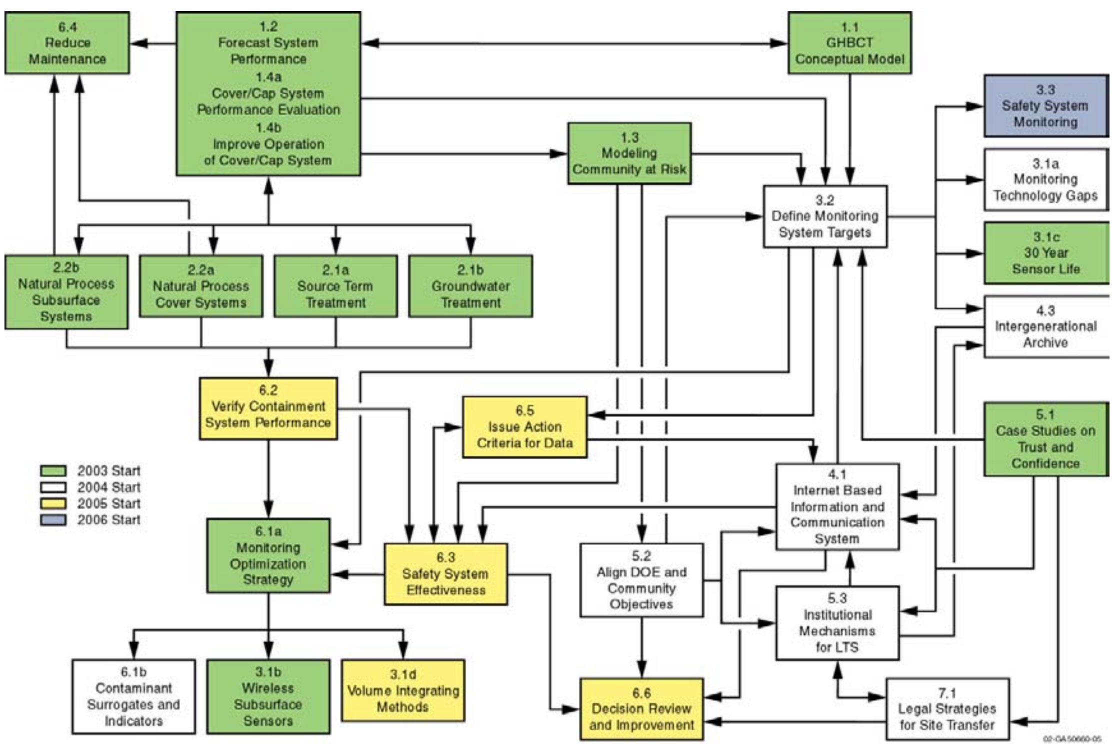

Figure 4 - Interdependency of near-term R&D targets

Roadmap Implementation – The Seed Starts to Sprout

The draft roadmap was completed in September 2002, initiating a round of reviews. The first review, by the DOE sponsors, was completed in late fall. A public review is planned but not yet underway at the time of this paper.

Along with the reviews, a number of briefings and workshops are anticipated. One key workshop was held in late September, hosted by the Environmental Protection Agency. This workshop addressed implementation issues associated with both the LTS roadmap and the Vadose Zone roadmap. This workshop expanded the number of key people aware of both roadmaps, growing the community of collaboration.

Since assuming ownership of the roadmap, the executive committee members have been active in presenting briefings and organizing workshops. A small collaborative community has been formed and is starting to expand.

OBSERVATIONS AND CONCLUSION

The use of technology roadmapping to establish R&D plans is well established. Industry-wide roadmaps have also exhibited the characteristic of catalyzing the formation of a sense of community among the participants that can become a major driving factor for the collaborative efforts often needed to achieve roadmap implementation.

The LTS roadmap was designed to include several features to help form such a community of collaboration. The case study has illustrated the reality of actual roadmapping versus the theory of design. During development of the roadmap, external factors impacted the community development features of the design.

The LTS roadmap is now in the final stage of development, the review and implementation process. The degree of community development achieved to date is not as strong as planned, but at the same time the participants have developed a strong-shared sense of the importance of working together. When the LTS program is officially transferred to a new program office, the seeds of a collaborative community will exist. With new management joining the LTS community, both support and funding for LTS technologies should be available to help catalyze the community. The next steps are to complete the review of the phase 1 roadmap and start phase 2, addressing the longer term technical needs of LTS.

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