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Guidance For Environmental Management Science And Technology Roadmapping

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Abstract

Science and technology roadmapping is a planning process to help identify technical capabilities needed for both project- and program-level cleanup efforts, map them into technology alternatives, and develop plans to ensure that the required scientific knowledge and tools will be available when needed.

Application of science and technology roadmapping within Environmental Management (EM) requires significant flexibility to accommodate the variations between different projects and programs and the different levels of roadmapping application. The author has provided direct support to EM's Office of Science and Technology (OST) in the development of draft guidance for science and technology roadmapping in EM. This paper provides a summary of this guidance and a synopsis of lessons learned from the application of roadmapping to a number of EM projects and programs.

INTRODUCTION

Science and technology roadmapping was initiated in private industry and has gained widespread use by various government agencies. It has emerged as a highly effective means of forecasting critical new technology development requirements, and as a valuable planning tool for decision-making. This process is now being applied to enhance planning of Environmental Management (EM) programs. As part of that application, a roadmapping guidance document has been drafted (1). This paper discusses the history and philosophy behind the document, provides a summary of the guidance, and discusses its application in current EM roadmapping efforts and related lessons learned.

Background

Application of science and technology roadmapping within EM requires significant flexibility to accommodate the variations between different projects and programs and the different levels of roadmapping application. The EM roadmapping guide was developed to address these needs.

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The development of roadmapping guidance for EM was initiated after the first EM roadmaps were completed and had demonstrated the value of roadmapping for addressing high technical risks in key cleanup projects and programs. These first roadmaps also indicated the need for and value of applying roadmapping at multiple levels.

The initial EM roadmaps included two roadmaps addressing alternatives for processing of high level waste salts at the Savannah River Site (2, 3). These roadmaps were developed as part of the actions to recover from the high visibility failure of the original salt processing approach, In-Tank Precipitation. After review, roadmaps for two additional alternatives were developed and all four are now in implementation.

The other initial EM roadmap was for the Groundwater/Vadose Zone integration project at the Hanford Site (4). This roadmap was broader in scope, encompassing the needs of multiple individual site characterization and remediation activities. This roadmap was developed to address the high level of uncertainty associated with subsurface cleanup decisions at Hanford.

Concurrent with the development of these initial roadmaps, EM was completing the Environmental Management Research and Development Program Plan (5). This report introduced multi-level roadmapping as a key planning tool, while emphasizing end-user ownership and multi-disciplinary participation as basic values for the planning process.

The roadmapping guide was developed by expanding on the philosophy of the EM R&D Program Plan. It addresses roadmapping at both the project and program levels, based in part on the experiences of the Savannah River and Hanford roadmaps. The next section of this paper provides a summary of the draft guidance document, which is available for download at http://emi-web.inel.gov/roadmap/guide.pdf

ROADMAPPING GUIDANCE SUMMARY

What is Roadmapping?

Roadmapping is a planning process to help identify technical capabilities needed for both project- and program-level cleanup efforts, map them into technology alternatives, and develop plans to ensure that the required technologies will be available when needed.

Technology is defined in The American Heritage Dictionary as "the application of science". Within EM, science and technology roadmapping includes planning of both scientific research and engineering development, with mission application as the end goal.

As a solution-driven, collaborative process for defining an R&D strategy, roadmapping:

- Identifies what to do, when to do it, and why it needs to be done
- Does not identify who will do it, where to do it, or how to do it

Key Principles of Roadmapping

EM science and technology roadmapping is:

A. Solution-driven

- Is owned by the cleanup project/program
- Identifies activities and capabilities required to accomplish mission/project objectives
- Identifies where activities or capabilities are insufficient or missing
- Identifies solution(s) to insufficient or missing capabilities

B. Fully integrated

- Is a consensus building process—process is as important as the product
- Facilitates participation of problem owners, solution provider(s), customers and stakeholders. This may include "internal" (safety, maintenance, etc.) and "external" groups (regulators, State/tribal oversight, citizen groups, NAS, etc).

C. Comprehensive

- Addresses life-cycle of program/project (near-, mid-, and long-term needs)
- Considers full range of potential solutions (from basic science to applied research, technology development, demonstration, deployment, and technical assistance.)

D. Credible and defensible decision process

- Identifies the data used, the alternative solutions considered and the criteria employed to arrive at a decision
- Documents the bases of the decision
- The quality of the process determines the value of the product

When Should Roadmapping be Used?

Roadmapping is a powerful high-end planning tool. In general, its use should be restricted to those programs or projects where there is:

1) A high potential for mission failure;
2) Significant consequences if failure occurs;
3) High dollar costs, high worker exposure, or high environmental impact; or
4) Multiple, diverse efforts working on a common problem.

Value of Roadmapping

At both the program and project levels, science and technology roadmapping has several potential benefits, including:

- Developing a consensus about a set of needs and the knowledge and technologies required to satisfy those needs.

- Identifying key cleanup technology decision points and the scientific and technical information necessary to make informed decisions.

- Providing a framework to help plan and coordinate science and technology developments within a project or an entire program area.

Science and Technology Roadmapping Process and Products

The roadmapping process includes workshops where participants with responsibility or expertise in different disciplines increase the collective knowledge base through open dialog and feedback. Attributes of this proven methodology are:

- The process will codify knowledge and technology needs,
- Compare these needs to the current state of science and technology,
- Identify gaps and shortfalls between the current and the needed state,
- Develop defensible alternatives for meeting shortfalls, while also identifying ways to leverage R&D investments through coordinating research activities
- Develop schedules and priorities to maximize benefit from scarce resources, and
- Synthesize understanding into a conceptual path forward for R&D activities.

There are four phases to the roadmapping process: roadmap initiation, technical needs assessment, technical response development, and roadmap implementation. These phases and the products developed in each phase are shown in Figure 1. Figure 2 shows a typical sequence of roadmapping meetings, workshops, and other activities used to accomplish workscope and products from Figure 1.

During the roadmap initiation phase, the need for a roadmap is validated. Next, sponsorship is secured, the scope and boundary conditions of the roadmap established, the roadmapping project and product designed, and participants identified. Participants should include a broad spectrum of people with interest in the project – cleanup managers, process and operations experts, science and technology providers, and regulators. Phase I includes the first two boxes of Figure 2.

In the technical needs assessment phase, system flow sheets are developed and specific system components identified. Areas are identified in the system where there are significant technical uncertainties. Existing technical capabilities are assessed to determine gaps between what is needed and what exists. Specific research and development (R&D) goals are identified to address each capability gap. These goals are in the form of measurable functional capabilities related to system performance. This phase is performed in the next two boxes of Figure 2.

During technical response development, technology alternatives are identified and prioritized for each R&D goal. To bridge each capability gap, a path forward is designed that includes initial development of multiple alternatives, decision points to narrow down advanced development to only one technology and delivery of the needed capability on a schedule aligned with the supported cleanup project. All the technology needs and responses are prioritized, an integrated schedule developed, and a roadmap report prepared. This phase is started in the fourth box of Figure 2, and completed in the fifth box.

In the final phase, roadmap implementation, the report is reviewed, validated, and publicized and an implementation plan developed. Implementation is monitored, progress reviewed, and plans updated as needed.

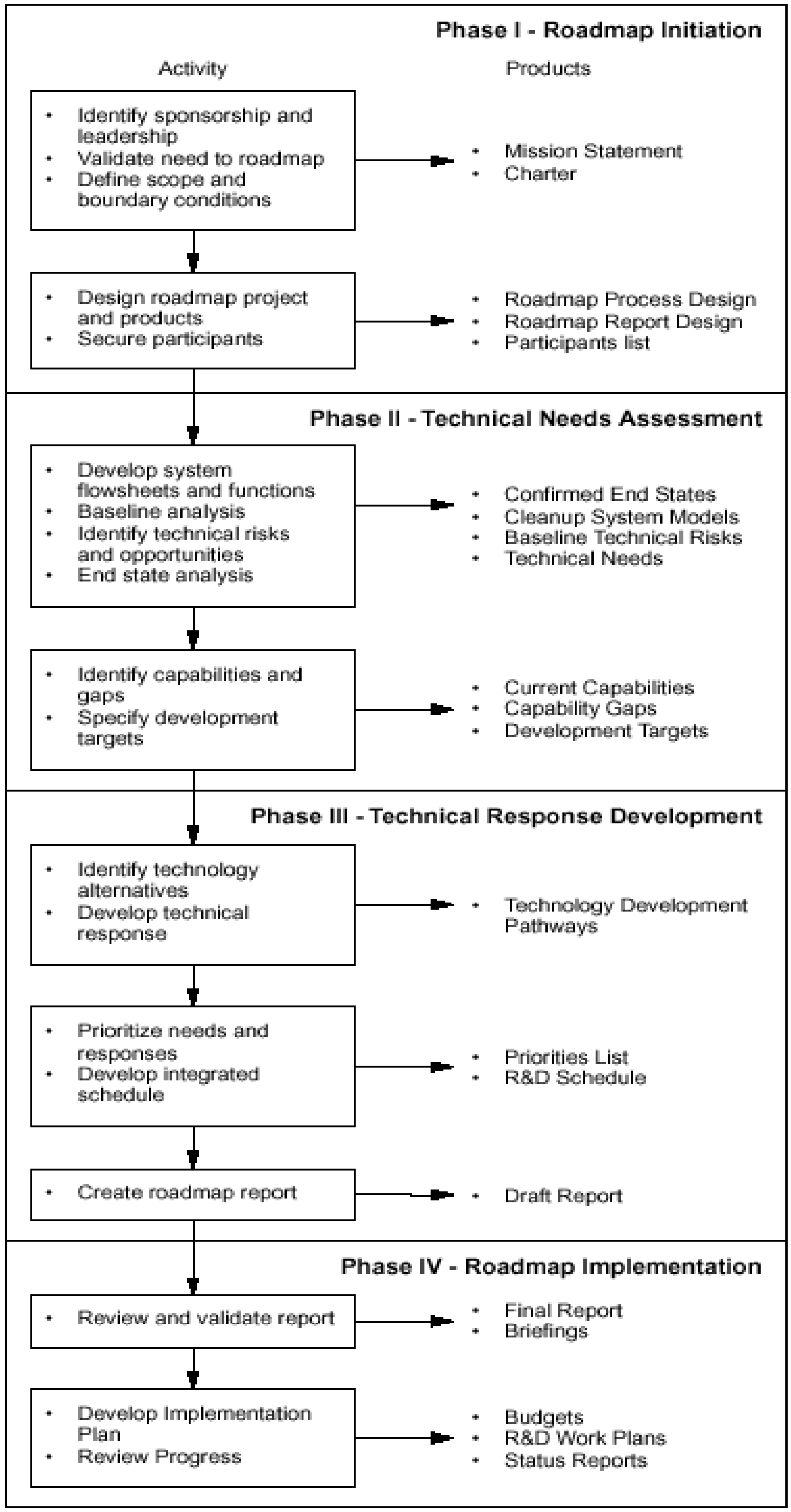

Figure 1 - Roadmapping Process and Products

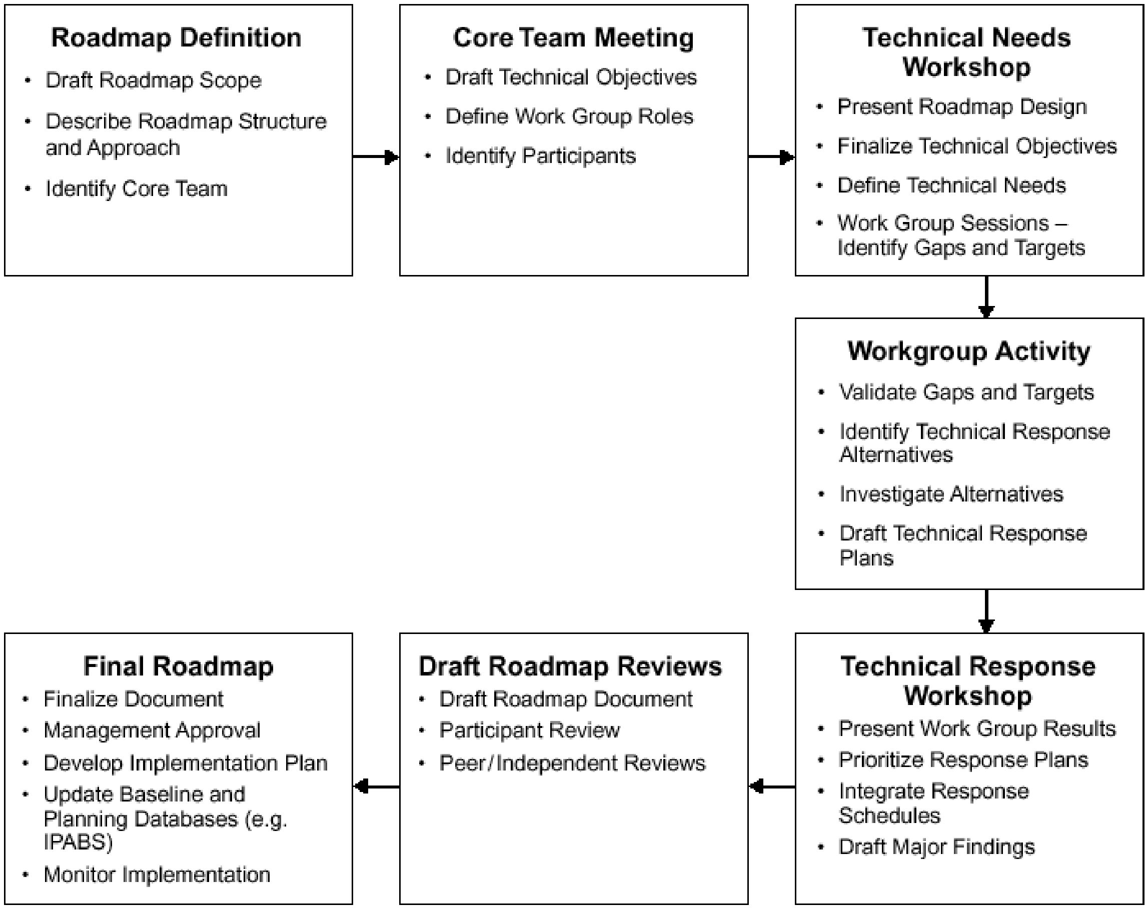

Figure 2 - Example roadmapping activity sequence

ROADMAPPING GUIDANCE APPLICATION AND LESSONS LEARNED

Several new EM roadmaps have been initiated or completed either concurrent with the roadmapping guidance development or subsequent to the draft guidance publication. Each has followed or been influenced by the guidance to some degree. Lessons learned from these roadmaps support validation of and improvement on the guidance.

The roadmaps that have most closely followed the guidance are two project-level roadmaps related to high level waste at the Idaho National Engineering and Environmental Laboratory (INEEL)(6,7). Both roadmaps focus on alternative designs for waste treatment and dispositioning. The focus of these roadmaps is on reduction of technical uncertainties for each alternative to support informed decision-making on which alternative to develop. The roadmap reports include details on technical uncertainties for each design, the research and development pathway to address the priority uncertainties, and an integrated schedule with resource estimates.

The roadmap coordinator for both these roadmaps found the guidance to be generally useful, but only at a high level. The roadmaps were sponsored by the cleanup organization responsible for dispositioning the subject waste streams. Multi-disciplinary teams were used in the roadmap development. The general order of identifying and prioritizing needs, then developing and integrating responses was followed. However, they found that for best utility, needs should be identified relative to each specific alternative design, rather than to the general project requirements suggested in the guidance. Needs prioritization was based primarily on the potential impact, with design viability issues ranked higher than design scaling, performance, and economic issues. Early establishment of the key decision points was another important lesson learned.

It is worth noting that many of the same personnel were involved in both these roadmaps. While the scope was similar, the time to complete the second roadmap was less than half that required for the first. The coordinator attributed this primarily to the personnel being comfortable with the process the second time around, and therefore more willing to provide the dedicated effort required.

Another recent project-level roadmap (8) found that budget or schedule limitations can impact the quality of the roadmapping process. The tank characterization roadmap was both time and budget constrained. It followed the guidance process, but was designed to get through only part of Phase III. In addition, meetings with cleanup managers and technology providers were limited to two one-day meetings. The early end to the roadmap resulted in no detailed research and development activity schedule. The reduced group interaction time limited buy-in and ownership of the roadmap results by the participants. Both factors have contributed to limited progress in implementing the roadmap recommendations.

The gas generation roadmap (9), a small program-level roadmap, was also budget constrained. This roadmap involved a team of participants from across the country. To hold down travel costs, only one face-to-face meeting of all participants was held, and most communication was via e-mail and conference calls. The roadmap coordinator felt that by limiting face-to-face meetings, the process actually took longer. As a comparison, the three project-level roadmaps mentioned above have each taken 2-6 months to complete, while this roadmap has taken 9 months and a final report has yet to be issued.

Two larger program-level roadmaps have also been initiated (10,11). Both involve the vadose zone, and are focused primarily on capability improvements over a longer time period than the project-level roadmaps above. A significant difference with the other roadmaps is that both these roadmaps have been primarily sponsored by the science and technology provider organizations instead of the cleanup/user organizations. This is contrary to the guidance. In both cases, the roadmap participants were initially primarily researchers, resulting in some difficulties in establishing priorities, schedule drivers, and linkage to cleanup programs. Again in both cases the breadth of participation was subsequently expanded to include cleanup program managers, primarily to address these deficiencies as they were discovered.

Both of these program-level roadmaps are multi-year efforts and are still in process. While the scope of these efforts is much broader than the other roadmaps discussed and therefore expected to take longer, it isn't clear how much the schedule could be reduced in similar subsequent efforts based on lessons learned.

ANALYSIS AND CONCLUSIONS

Experience to date on application of the roadmapping guidance is limited, but sufficient to make some general conclusions. For example, it is evident there is the need for two types of roadmaps as described in the guidance.

Project-level roadmaps work well when the objective is clearly determined up front by the cleanup sponsor. They can be completed in a relatively short time (~3-4 months), but require a strong commitment of resources to be developed effectively. This suggests the focus of the roadmap must be solution of a key problem of the sponsor, preferably with not just technical risk but also some schedule urgency. If the problem isn't important enough, or the roadmap has some driver other than the project's central cleanup responsibility, it may receive insufficient resources (both budget and key personnel availability) to be completely successful.

Program-level roadmapping experience is more limited, due in part to the time to complete. This leaves more questions than conclusions. For example, the guidance indicates a cleanup sponsor is needed up front. However, sometimes a problem needs working which doesn't belong to any specific existing cleanup organization, and therefore isn't squarely on that group's critical path for mission completion. This seems to be the nature of the problems being worked by most of the program-level roadmaps to date. In the case of the Hanford roadmap, an organization was formed at about the same time as the roadmap was prepared. The two more recent vadose zone roadmaps are working to show support for multiple environmental restoration projects, but are also addressing a problem which has a longer time horizon than any of those projects individually. More experience on program-level roadmaps is needed to understand how to improve their efficiency and utility.

One particular difficulty for EM program-level roadmapping has been setting of measurable goals for capability improvements. Program-level roadmap goals tend to say "improve" without saying how much. This area of the guidance was developed based on review of industry roadmaps. The primary difference is the length of time between technology "generations". Within private industry, new generations of products occur every few years, and there is ample history available for extrapolation in setting future generation performance standards. Within EM, the market is limited and most projects use technologies only once rather than repeatedly over a period of many years. This makes it much more difficult to understand and define the performance requirements for next generation tools that will replace current capabilities.

The guidance suggests the development of system flow sheets during the Technical Needs Assessment phase. Flow sheets or "functional flow diagrams" were employed on all of the project-level roadmaps to date, but with the exception of the gas generation roadmap they have not been used at the program level. It isn't clear if this indicates a lack of applicability at the program level or just a lack of effort to use these tools. While the program-level roadmaps are generally addressing multiple, related problems rather than a single problem with multiple possible solutions, they also seem to have difficulty in focusing the multiple problems into an integrated theme. It isn't clear whether flow sheets could help with this issue.

The guidance also suggests the involvement of regulators and even stakeholders during roadmap development. In general, this hasn't occurred, and regulator and stakeholder involvement has been limited to information exchanges rather than direct participation. It isn't clear what impact this will have on the ease of deployment of new technologies resulting from roadmap implementation. Program-level roadmaps have been more likely to provide the information exchanges.

A final conclusion is that roadmapping does seem to work best on important, difficult problems, and possibly should be limited in its application to only those problems. One key observation is the number of independent reviews performed both during roadmap development and implementation. Those roadmaps with significant reviews have tended to exhibit better commitment of resources, better follow-through on recommendations, and generally a tighter and higher quality effort. Since high levels of independent review are usually limited to a few key projects or programs, one new metric for deciding whether to roadmap is to consider whether significant independent reviews are already contemplated. If so, a roadmap may be a key planning tool. If not, a roadmap may be overkill.

REFERENCES

The references listed below are only those directly cited in the text. A more complete list of roadmapping references with web page links is contained in the draft EM roadmapping guide "Applying Science and Technology Roadmapping in Environmental Management", available at http://emi-web.inel.gov/roadmap/guide.pdf

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