ROADMAPPING PROCESS IMPROVEMENTS BY EXPERIENCE AT THE IDAHO NATIONAL ENGINEERING LABORATORY' HIGH LEVEL WASTE PROGRAM AND SYNERGISTIC INTERFACES WITH DECISION-MAKING

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ABSTRACT

Six technology roadmaps were developed for various technologies under consideration for the treatment of sodium bearing liquid and calcine wastes. In the process of creating these roadmaps, a number of process improvements were identified for each of the formal roadmapping phases as described in the Department of Energy's draft roadmapping guidance. The lessons learned, presented as beneficial improvements to the Idaho National Engineering and Environmental Laboratory (INEEL) High Level Waste Program, are proposed to be added to the draft guidance. Additionally, synergistic interfaces between the roadmapping and decision-making processes were observed and reported on. With these improvements, technology roadmapping has become an effective integration tool at the INEEL for planning technology development.

INTRODUCTION

The High Level Waste (HLW) Program at the Idaho National Engineering and Environmental Laboratory (INEEL) has treated acidic HLW liquid using a solidification process called calcination. The solid product is stored temporarily in stainless steel bins awaiting final treatment for ultimate disposition to a federal repository. The acidic liquid is temporarily stored in stainless steel tanks until it is treated. Although the "calciner" was effective in converting acidic liquid HLW to solids, the effectiveness was significantly reduced when all the liquid HLW was calcined and only acidic decontamination-type solutions called sodium bearing waste (SBW), remained in the tanks. Added to the reduction in effectiveness was the applicability of the federal maximum achievable control technologies (MACT) regulations. With the new regulations, a major upgrade project would be required to continue the use of the calciner. An evaluation was conducted to decide if some other alternative was more desirable than upgrading a twenty-year-old facility. The alternatives evaluation was conducted formally as part of an Environmental Impact Statement (EIS)[1]. The EIS scope included both the SBW remaining in the tanks and the calcine in the solids storage bins.

The several year EIS process was increasing the difficulty to be able to complete the treatment of all the liquid SBW stored in the tank farm by the Department of Energy and the State of Idaho Settlement Agreement milestone of 2012. If a major project were required to make processing possible by this date, a final technology choice, plus an expedient start of the project would be essential. The milestones associated with the solid HLW calcine stored in the bins has a Settlement Agreement completion date of 2035, leaving a little more time to choose and develop the technologies. However, since the wastes have common chemical characteristics, potential integration efficiencies might exist. Therefore, the technology alternatives were evaluated such that the waste streams could be integrated into a common facility or processed separately.

The EIS was on course for a late fiscal year 2000 selection of the preferred alternative for treatment of the SBW. However, the urgency to get the right technology developed caused discomfort with the HLW program baseline schedule. In an attempt to get a head start on the development needed, a technology roadmap was requested prior to the technology selection. This left the option to roadmap the candidate technologies or pick one knowing that it might be the wrong choice. DOE decided to ask the contractor to look at the alternatives and available discriminating data to see if a technology choice was obvious. This pre-analysis would help limit the scope that needed to be roadmapped to something manageable, decreasing the chance of having to redo it later. Thus, the contractor began an alternatives evaluation[2] that would then lead to a roadmapping effort. The alternatives evaluation was to be completed prior to DOE's formal review so that DOE could take advantage of any data and discriminators identified by the contractor.

The technology evaluation was completed over about three months with twelve people working full-time. The decision support process was performed by several of the same people who later performed the technology roadmapping. It was this coincidence that helped identify a number of interfaces between the roadmapping and decision support processes that will be shared in this paper.

Additionally, six separate technology flowsheets have been roadmapped to date; three for SBW[3] and three for calcine[4]. Many significant "lessons learned" have been identified over this time. These improvements have increased the effectiveness of roadmapping as well as the efficiencies in creating roadmaps. The improvements in the processes, coupled with the synergistic interfaces between decision-making and roadmapping, have made the concept of roadmapping an extremely useful tool to INEEL's technology development.

The first two SBW technology roadmaps took about \$300 K and three months. The third SBW technology roadmap cost \$190K and took eight weeks. These were followed by three calciner flowsheet roadmaps that were developed in parallel for a total cost of \$150K, taking six weeks to complete. These costs and times demonstrate the value of some of the process improvements that are shared in this paper. In addition, some of the roadmapping products that were found to be useful are discussed.

The roadmapping process used by the HLW program closely followed the draft DOE guidance provided to Environmental Management science and technology programs.[5] The guidance provides a basic four phase process namely, initiation, technical needs, technical responses, and technology implementation. The process and product improvements found over the past year is discussed relative to the phase of the process these improvements are focused towards. These discussions are followed by the discussion of the synergistic interfaces between decision-making and roadmapping processes.

PHASE I IMPROVEMENTS - ROADMAPPING INITIATION

During Phase I, the scope of the roadmap is defined. A few key tools were found to help keep the scope of the roadmap manageable. The draft guidance recommends defining the charter, mission, system boundary, scope, product definition, and team participants prior to actually creating the roadmap. In the course of performing the six roadmaps noted earlier, a few additional considerations were found to be valuable in defining the scope.

There were two purposes for HLW program technology roadmaps created over the last year. The first purpose was to help select a technology for implementation. The second purpose was to determine what development was necessary to select a technology. The difference in these two purposes has a great impact on the level of detail included in the roadmap. In the case where a technology is being implemented, the technical needs and risks can be prioritized by the project phases. Definition and resolution of the highest risks is desirable early in the project design, whereas lower risks can be dealt with later. In the case of technology selection, the research and development is focused on demonstrating that the technology can work and needs to include enough preliminary performance data that shows that the new technology can compete with existing technologies. Any technology alternative that lacks data to demonstrate application and performance will not likely be selected.

By knowing the purpose, the decision being affected can be defined. Every program implementing a technology passes through decision points. A project has pre-conceptual phases that are used to evaluate multiple alternatives and a conceptual design phase where a selected technology is adequately designed to understand the construction and operational aspects. Additionally, other decision points for construction and operations exist. As the program or project moves through these phases, risk should be decreasing. It is desired to resolve the highest risks first, followed by intermediate risks, followed by lower risks. Knowing the phase of a project helps to focus on the right set of technical needs that would support the program or project's next decision point. For example, development directed to resolving operational optimization needs should be a minor concern during a technology selection when large needs or uncertainties that could result in technology failure or major cost escalation exist. By defining the project decision points that technology development can support, the focus of the development activities can be commensurate with the needed risk reduction. This will be further discussed in a prioritization step under the Technical Response phase. If the decision point is left undefined, the roadmap scope could be much larger than needed to support the project and this could lead to schedule delays, cost overruns, or lack of responsiveness to the project needs.

In summary, the suggested improvements to the roadmapping initiation phase are:

- Identify the purpose of the roadmap at the beginning; and
- Define which decision points the roadmap needs to influence during this phase of roadmapping.

PHASE II IMPROVEMENTS - ROADMAPPING TECHNICAL NEEDS

Technical needs vary in importance. The needs, as identified by the technical experts, were found to have a great deal of subjectivity. As these needs were identified, it became important to create a process to decrease the subjectivity. There was some disagreement as to what was a need and how to identify it consistently between technologies. There were also issues recognizing what were assumptions versus facts.

The first improvement was to change the term "need" to "uncertainty" and define it in terms of lack of information or data that could lead to a potential consequence that would have either positive or negative effects on the design or operation of the technology. A consequence was identified instead of assigning a risk category to avoid the subjectivity of evaluating probabilities. This definition helped clarify what was an uncertainty and what wasn't. Levels of consequences were useful in a prioritization method performed as part of Phase III described in the Technical Response section.

Many of the uncertainties that were found were associated with the technologies in the supporting unit operations. Often, the main process technology gets most of the attention but it was not where most of the uncertainty was found.

Using the uncertainty definition, flowsheets were evaluated for areas where there was a lack of knowledge. The potential consequence for that lack of knowledge was documented by the team to help determine the level of importance of the uncertainty. Consequence statements helped define each uncertainty, examining what was not known about each unit operation's performance, specific applications, and interfaces between unit operations. Uncertainties with a large potential consequence were often discovered while evaluating smaller uncertainties. It was important to not limit the identification of uncertainties during this phase but to be sure to describe them in terms of potential consequence.

In summary, the suggested improvements to the roadmapping technical needs phase are:

- Define needs in terms of uncertainties where the potential consequence is documented;
- Ensure data availability or the issues are uncertainties. Avoid accepting long-standing "assumptions" that have no data backup as "fact";
- Look for uncertainties throughout the flowsheet especially in the supporting technologies; and
- Do not limit the uncertainty identification to the current decision point being supported by the roadmap. Otherwise, important uncertainties might not be identified.

PHASE III IMPROVEMENTS - ROADMAPPING TECHNICAL RESPONSES

The problem with attempting to identify all the uncertainties is the amount of work it takes to define the technical responses for them. The technical responses were defined by the technologists or engineers that would need to perform the work to resolve the uncertainty. Technology and engineering personnel created, in early roadmaps, a response for each and every uncertainty. There were two major problems with this approach, time and money. The amount of scope identified would take years to complete and cost too much. There were two improvements identified to help these technical responses to be worthwhile.

The first improvement was to prioritize the uncertainties. Using the potential consequence, uncertainties were placed into viability, footprint, and optimization categories. Viability uncertainties had a potential consequence that could lead to failure of a technology to meet the functional requirements of the system. The footprint category were those that have a potential consequence of changing the size of the major unit operations and effectively, changing the implementation cost. The third category, optimization uncertainties, were those that may affect how the technology is operated and other small changes but would not influence the viability or largely affect the implementation costs. These categories were selected because they lined up well with the major project decision points. The viability uncertainties usually must be resolved before a technology can be seriously considered or selected. The footprint-type uncertainties must be resolved to properly baseline the project cost, and the optimization uncertainties support operations.

The second improvement was to group the uncertainties into common problem statements and technical responses. An evaluation of the uncertainties and grouping by a problem statement yielded technical responses that resolved more than one uncertainty. Prioritizing and grouping the uncertainties defined the right scope and yielded technical response tasks whose costs were less than expected.

As the roadmaps were developed, it was unclear as to what relationship information needed to be maintained. Each roadmap was basically a series of activities to resolve uncertainties. Each activity was placed into a project schedule. The schedule logic and resource needs were kept with each activity. Initially, it was difficult to ascertain the uncertainties and potential consequences and to define the problem statement and relationships. Each roadmap continued to improve upon these data and interrelationships. The final roadmap included improvements in maintaining the data structure that is needed as well as resource loading the activities in the schedule.

The data structure for the calcine roadmap has been most useful in capturing the important relationships thus far and is shown in Figure 1. The project decision points, defined in the roadmap initiation phase, became the main organization points. In this example, the technology selection decision was planned using three critical decision points, numbers 1-3. These decision points represent the points in time when a program or project must have certain information to be able to move forward. By defining these specific decision points, the related uncertainties can be prioritized. Listed under each decision are each of the relevant unit operations of a flowsheet. All unit operations were included, even those without uncertainties, for completeness and understandability. Within each unit operation, the prioritized uncertainties are connected to the technical responses that resolve them. If more than one activity is needed to resolve the uncertainty, schedule logic ties are used to keep the tasks in the correct order.

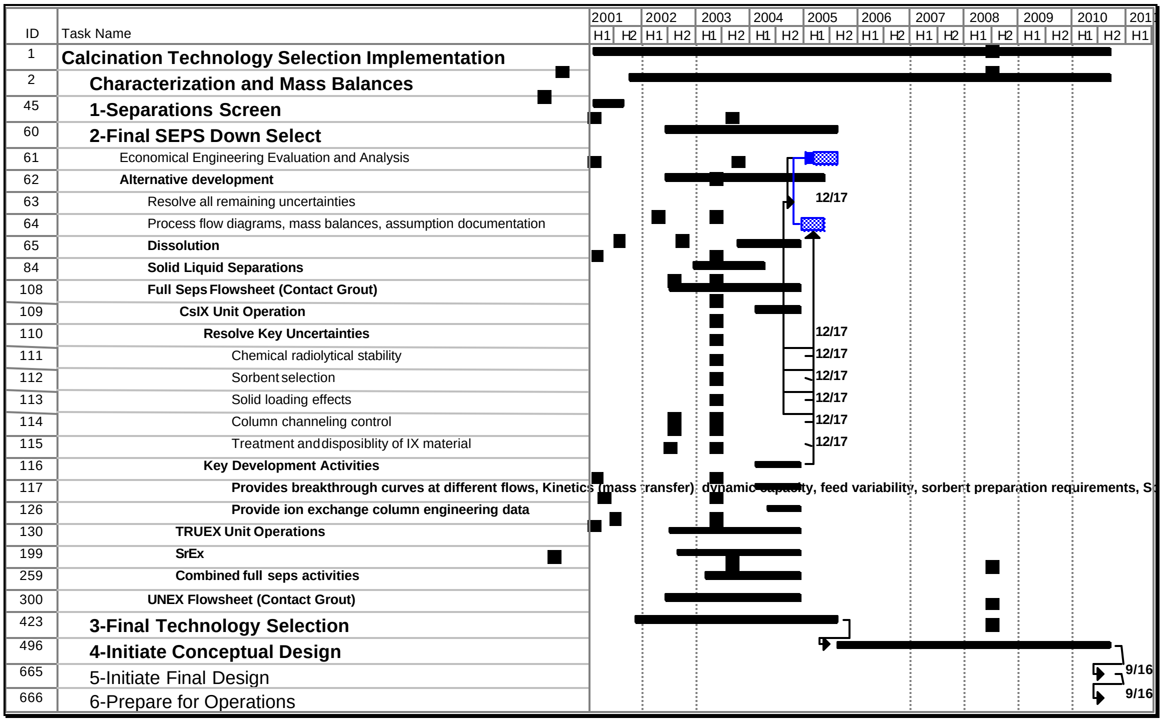

Fig. 1. Calcine Roadmap Example

The SBW roadmap was focused on resolving the uncertainties needed to support conceptual design and to establish the cost baseline. Uncertainties that are potentially significant to the cost baseline were used to define the scope of the roadmap. Uncertainties and activities needed to support later project decision points were set aside until later in the project schedule. As development continues, it is expected that these issues will be addressed.

The calcine roadmap was developed to support technology selection. Those uncertainties not associated with technology viability or significant cost issues were set-aside until later in the project schedule. With three technologies being considered, the amount of effort that could be expended without prioritization could delay technology selection for many years. Once the selection is made, the chosen technology can be further developed, starting with the list of uncertainties that were set aside.

In summary, the suggested improvements to the roadmapping technical responses phase are:

- Prioritize uncertainties before building technical responses;
- Prioritize consequence categories and align with the project decision points. Place only the necessary uncertainties in each consequence category;

- Group the uncertainties and describe them with problem statements. This grouping of the uncertainties can help reveal if development activities can solve more than one uncertainty at a time;
- Be sure that the relationships that need to be maintained among the roadmapping elements improve the likelihood that the development work will accomplish what is needed; and
- Develop technical responses, in an iterative fashion, that follow the project decision points and schedule. Save the next decision point's uncertainties for later consideration, after the issues for the current decision points are nearing completion.

PHASE IV IMPROVEMENTS - ROADMAPPING TECHNOLOGY IMPLEMENTATION

Resource loading of the technology tasks often present yearly funding needs that has large peaks. In order to level the budget, activity schedules are shifted until allowable funding levels are achieved.

Building the roadmap using project management software provides some help for resource loading the development schedule and performing funding analysis. For the roadmaps discussed in this paper, the roadmap schedule, even though it was input into a project management software package, is not used to manage the work. However, by building the relationship of the roadmap activities to the company responsibility matrix and the work breakdown structure (WBS), the roadmap was useful to summarize the work, funding, milestones, interfaces and resources for each technology development activity for use in the company project management/control system.

In summary, the suggested improvements to the roadmapping technology implementation phase are:

- Build the roadmap in a project management software system so resource loading, budget profiles, and schedule logic can be manipulated and used to analyze the technology development schedules; and
- Build a WBS responsibility matrix into the roadmap to allow direct reporting of the roadmap information to the company work package managers.

SYNERGISTIC INTERFACES BETWEEN DECISION-MAKING AND ROADMAPPING PROCESSES

As mentioned in the Introduction, the coincidence of roadmapping and the decision process by some of the same people proved useful to both processes and products. In decision-making, understanding the discriminators for choosing among alternatives is important. When evaluating technologies, the criteria used, such as technical maturity or implementation confidence, are often very subjective. Though subjective, these judgements generally are made by competent and knowledgeable personnel. However, as other criteria are evaluated, the results usually don't get any better. This can effectively slow down a selection if more effective discriminators cannot be further defined.

The roadmapping process identifies uncertainties and defines what is necessary to resolve them. The first evaluation phase of the roadmap identifies the uncertainties. The SBW roadmap team defined the uncertainties for many technologies being considered by DOE. Although the uncertainty definition was necessary for the roadmapping process, it was the more detailed technical maturity data that provided some of the necessary discrimination between the alternatives. By this process the technologies were selected for consideration during the next phase of roadmapping.

Phase III of the roadmapping process prioritized the uncertainties and identified the technical responses and schedule logic and duration. The results of this phase were optimistic schedules for each of the remaining three alternatives in the SBW alternatives analysis. A consequence reduction curve was drawn from these schedules. Figure 2 shows how the three finalist alternatives compare. These graphs provided information for another level of discrimination since one of the three remaining technologies was much slower to mature than the other two.

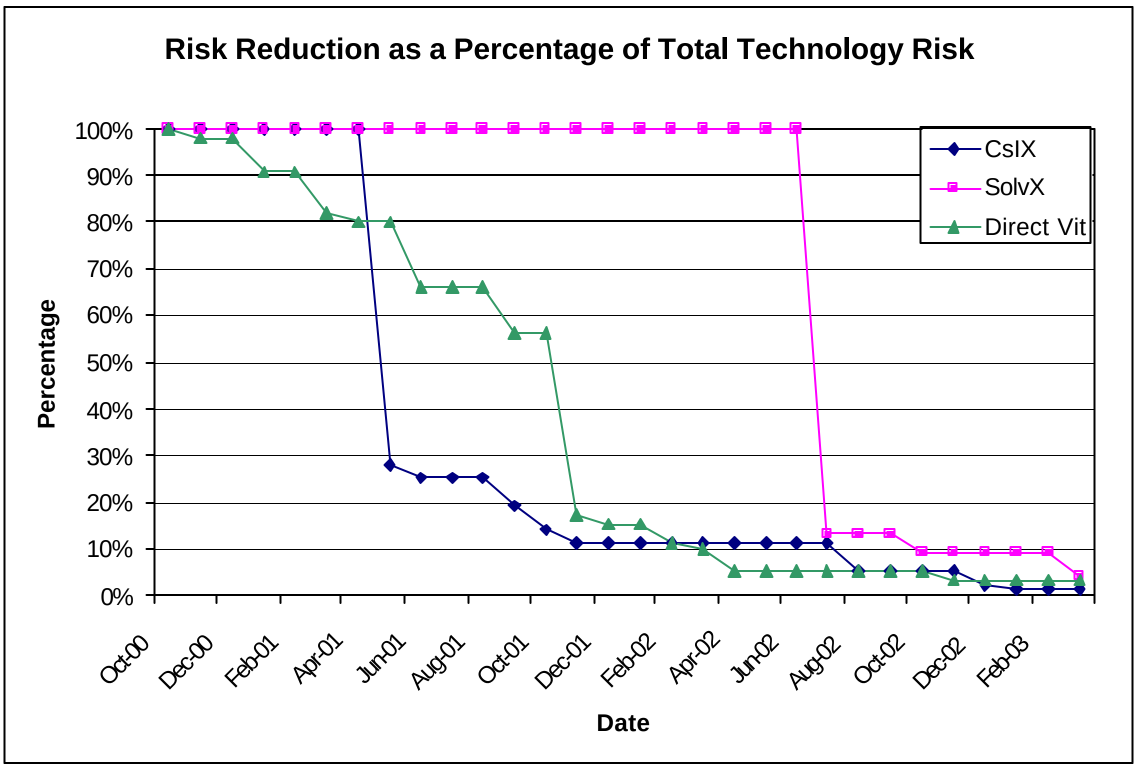

Fig. 2. Consequence Waterfall Chart Expressing Roadmap Schedules for Three Technologies.

If at all possible, it would be good to select the final technologies before progressing through the resource loading and preparations for implementation. In the case of the SBW roadmaps, there was concern that the roadmaps would take too long. During the roadmapping process, an apparently good alternative began to surface as a potential favorite; therefore the team created a resource-loaded schedule a couple of months ahead of the actual selection of a preferred alternative. The technology that was already roadmapped through Phase IV was not the one selected as the preferred alternative. The team worked quickly and thoroughly to produce the technology roadmap for the chosen preferred alternative in less time than it took to get the approval through the DOE chain-of-command. Thus, moving forward ahead of the decision process did not save time but rather caused a detailed plan to be generated that was not used.

In the calcine technology selection process, it was found that there were two key uncertainties that lacked sufficient information to make a choice. These key uncertainties became the basis to prioritize the work required. All work that could be delayed was placed in later decision points and will be addressed later.

In summary, the recommended improvements are:

- Provide the data from the roadmapping process to help with further discrimination of technologies during the selection process; and
- Make alternative down-selection and detailing of alternatives' uncertainties complimentary to each other, reducing the scope of roadmapping and increasing the confidence in the technology selections.

OVERALL SUMMARY

The preparation of several technology roadmaps has led to process and product improvements. Although these improvements have made technology roadmapping more efficient and effective, additional improvements are likely and will be identified in future INEEL roadmapping efforts as technical development and project designs are integrated.

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