

Development of an Execution Strategy Analysis (ESA) Capability and Tool for Storage of Used Nuclear Fuel (UNF)

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Abstract. An Execution Strategy Analysis (ESA) capability and tool is being developed to evaluate alternative execution strategies for future deployment of a consolidated Interim Storage Facility (ISF) using a consent-based siting process per the Administration's *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste (Strategy)*. Application of an ESA approach not only leverages on but also goes beyond traditional project analysis tools. The ESA tool allows for on-going performance assessment of the evolving project execution plan that takes into account significant assumptions, risks, and uncertainties throughout the project lifecycle. The ESA process and tool are used to support the development of plans, budgets, and alternative execution/ implementation strategies for meeting the goals in the *Strategy*. The paper describes the process by which the ESA capability and tool are continuing to be developed and addresses the value of applying such a process in implementing a long-term strategy for managing used nuclear fuel (UNF) and High Level Radioactive Waste (HLW).

Key Words: dynamic simulation modeling; project performance assessment; risk-informed decision support; alternate implementation strategies.

1. Introduction

In 2010, the U.S. Secretary of Energy chartered the Blue Ribbon Commission on America's Nuclear Future (BRC) to conduct a comprehensive review and recommend a plan of action for the back end of the nuclear fuel cycle: namely the management and disposal of the nation's UNF and HLW. In January 2012 the BRC issued its final report [1], which included a number of recommendations.

In January 2013, the U.S. Department of Energy (DOE), released the Administration's *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste (Strategy)* [2] in response to the BRC's recommendations.

Since late 2012, the DOE's Office of Nuclear Energy (DOE-NE) has been conducting planning activities within the Nuclear Fuels Storage and Transportation Planning Project (NFST) to lay the groundwork for implementing interim storage, including associated transportation, per the Administration's *Strategy*, within existing legislative and budgetary authorizations.

Beginning in mid-2013 the NFST began developing a dynamic simulation modeling capability for use in the analysis of alternative execution/implementation strategies and plans associated with an integrated nuclear waste management program. The initial focus is a consolidated Interim Storage Facility (ISF) using a consent-based siting process. The Execution Strategy Analysis (ESA) capability provides an approach and a tool for ongoing performance assessment of the evolving project execution plan that takes into account significant assumptions, risks, and uncertainties throughout the project life cycle. This effort also provides fully capable risk assessment and management tools and analyses to support improving the decision-making process.

2. NFST Integrated Waste Management System Analysis

The mission of the NFST is to lay the groundwork for implementing interim storage,

including associated transportation, per the Administration's *Strategy*. An overarching objective is to develop options for decision-makers on the design and implementation of an integrated waste management system. Equally important is the need to identify and prioritize near-term activities that would allow future implementation milestones to be readily achieved faster and with less risk. To reach these goals it is necessary to understand all elements associated with deploying consolidated interim storage, including: milestones, activities, and their dependencies; constraints; uncertainties; and risks and opportunities.

The NFST is developing and applying a variety of integrated waste management system analysis capabilities and tools for the identification and evaluation of options for the future phased and adaptive deployment of a comprehensive nuclear waste management system. System analysis and system engineering principles are being applied to evaluate an integrated approach to transportation, storage, and disposal in the waste management system with an emphasis on providing flexibility to respond to evolving national policy/direction. These analyses support the establishment of functional and operational requirements for the UNF management system, provide the framework for future planning activities (e.g., transportation hardware procurements), and provide information to inform future decisions regarding strategies for accepting UNF from U.S. shutdown and operating commercial nuclear reactors.

In parallel with the ESA development, a Multi-Objective Evaluation Framework (MOEF) is being developed for identifying and evaluating alternative execution strategies and approaches for the management of UNF and HLW while considering a range of programmatic objectives and associated metrics. The NFST MOEF is utilizing accepted decision analysis techniques to identify the information needed to be obtained to support and fully document the bases behind future important decisions. The NFST MOEF is being used to evaluate information currently being developed and collected by other NFST activities. The NFST MOEF allows for:

- The identification of alternatives that offer the greatest value to all stakeholders.
- The explicit analysis of tradeoffs and compromises that must be considered so that meaningful discussions can be had toward finding the best overall alternative.
- Ensuring the transparency, integrity, and comprehensiveness of choosing a waste management system.

The NFST MOEF and ESA efforts are closely linked as shown in Figure 1. In this sense, the ESA capability provides information regarding how alternative implementation strategies perform in meeting the Administration's *Strategy*. The ESA capability is being developed to help answer the types of questions that are typically asked related to the implementation of interim storage, including:

1. What are the implementation approaches to meet the *Strategy*?
2. What are the critical path milestones and activities?
3. What are the interdependencies across program elements?
4. What are the key program risks and potential mitigation strategies?
5. What are the impacts of various policies and potential legislation?
6. What are the long lead-time activities that must be started now?
7. What near-term activities could be started to provide schedule benefits and reduce risks?

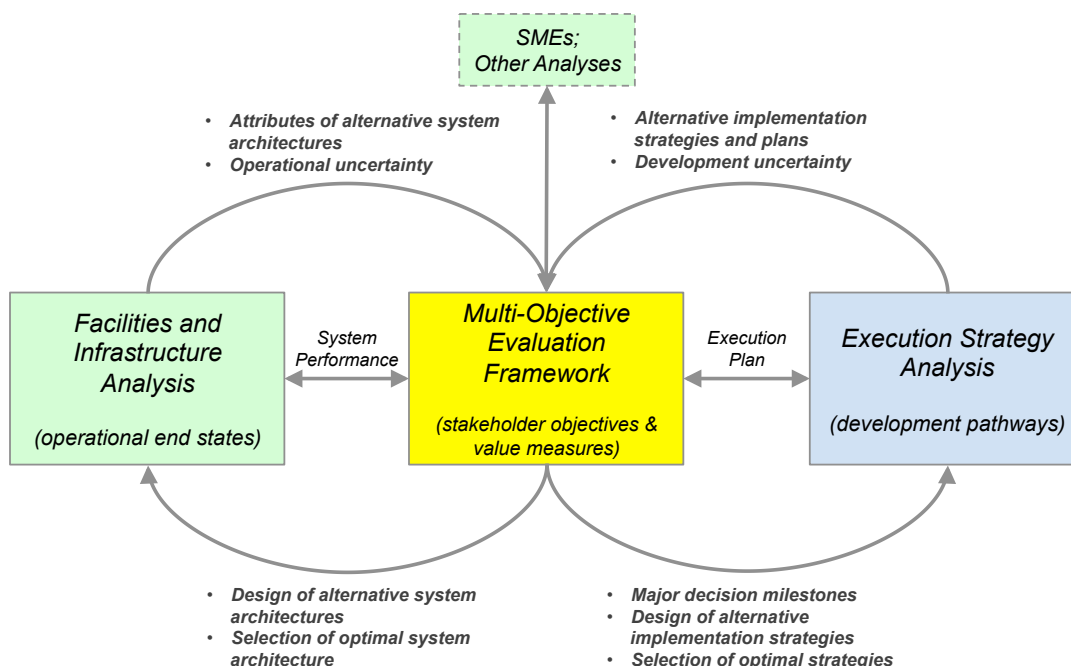


Figure 1. NFST Integrated Waste Management System Analysis Tools

3. The Execution Strategy Analysis Approach

The ESA approach builds on traditional project management tools (i.e., Gantt charts) to provide additional insights. It has been applied extensively in nuclear and non-nuclear projects not only in the U.S. but also internationally. The ESA capability provides a comprehensive, fully integrated systems planning process and tool, allowing for high-level total system integration that is achieved through dynamic simulation of project implementation with explicit consideration of uncertainties and risks. The dynamic simulation tool is used to identify and examine alternative strategies for achieving project objectives. This process and tool are helping to develop sound, risk-informed business practices and communicate/defend future program execution decisions to multiple stakeholders by the following actions:

- Capturing linkages among waste management program/project elements (e.g., transportation, component fabrication, facility construction, licensing/permitting).
- Capturing uncertainties associated with program/project activities.
- Capturing consequences of changing funding structures and priorities.
- Capturing technical and non-technical risks, including those due to linkages between waste management program elements.
- Identifying and tracking key metrics (i.e., cost, schedule, etc.).
- Quantifying the effects of uncertainties and risks on key metrics.
- Evaluating alternatives for prioritizing activities and evaluating mitigations.
- Helping to foresee the potential consequences of proposed decisions.
- Helping to identify opportunities for optimization or efficiency.
- Helping to improve the ability to reduce programmatic risks.

ESA at its core is the performance assessment of potential alternative execution strategies for a complex project that has large uncertainties and a long lifecycle. It explicitly models and

assesses the impacts of uncertainties (activity durations, costs, funding profiles) and constraints (policy, legislation, regulatory) and risks (both technical and non-technical).

The ESA development effort has been driven by several goals, including:

1. Integration of existing concept information and associated risks from other NFST activities and tools.
2. Simulating the integrated project throughout its lifecycle at a high level.
3. Evaluating the performance of high level “what if” questions in areas such as: alternative funding levels, management approaches, strategies and priorities.
4. Calculating projections of how a particular strategy plays out and then comparing the alternatives using appropriate metrics.
5. Evaluating the probabilities of unplanned events and “soft” non-technical risks using a Monte Carlo simulation approach.
6. Determining the importance of uncertainties/risks that affect the success of a particular strategy and then evaluating potential mitigation actions.
7. Meeting transparency objectives for communication with a wide variety of stakeholders in a defensible way.

The ESA approach is a top-down dynamic simulation model development effort. The approach is to develop the model in a different way than many projects are designed. The process starts with identifying “What is success?” and then works backwards, using precedence requirements to establish the logic of a project and how it should perform. The intent is to concentrate on the integration and coupling of all system components in a coherent way so that options can be weighed at a strategic level. Key activities are represented by approximations in high-level depictions and parameters; additional details are added as needed to capture important activities. The intent is to remain focused on total system performance without getting lost in what may prove to be unnecessary details at a strategic level.

A properly designed top-down model tends to be only as complex as necessary; that makes it better organized and generally easier to understand and explain to stakeholders. Such a model allows for rapid evaluation of alternatives by simply changing model input parameters (i.e., cost and/or duration parameters) to reflect a different scope. It also provides flexibility to rapidly include logic that represents different activities or a different sequencing of activities for alternative scenarios under consideration by decision-makers. This capability supports a more rapid evaluation of “what if” scenarios in hours or days, not in weeks as some complex models might require.

A key component of the ESA approach is the use of subject matter experts (SME) to capture and correlate key attributes such as activities, durations, costs, uncertainties, and risks. Little “hard information” is typically available related to alternative strategies and approaches that are either completely new, have not previously been implemented within the U.S. nuclear waste management context, or are an extrapolation of approaches that have been deployed. Subject matter expertise is essential to establish a credible and defensible simulation tool. Thus, SME input that augments the data and information that is available is the foundation of the ESA capability.

The formal process for developing the performance assessment of a project is meant to elicit the subjective uncertainties of SMEs and to quantify those uncertainties using probability encoding techniques into probability distributions for Monte Carlo simulations. The process

follows several steps that lead to the creation of the dynamic simulation model of the project. However, it is more than just a model; it also is a formal process of specific steps emphasizing the importance of the elicitation process itself to significantly enhance the SMEs' understanding of their own project through dialogue and collaboration. Again, SMEs are vital participants during all steps in the process. It is an iterative process in which the results of the process guide the SMEs to explore the areas of the project and its uncertainties that need more detailed attention. The formality of the process is meant also to address the "Garbage in, garbage out" concerns by providing defensibility for the model inputs and further iterations of the model as more understanding is gained about the project and its performance.

4. Development of the Execution Strategy Analysis Tool

The broad steps in the ESA process include:

1. Identification of the requirements for successful project completion – creation of a Success Precedence Diagram (SPD).
2. Determining data requirements and data availability to support the choices of metrics by which success is measured.
3. Mapping the project plan (if one exists) to the SPD, looking for gaps/omissions.
4. Identification of risks and quantification of uncertainties through the formal elicitation process.
5. Developing the initial dynamic simulation model.
6. Using the model to simulate project strategies and analyzing results to identify parameter sensitivities and importance factors for the key risk drivers affecting performance.
7. Iterating the model and refining execution strategies by evaluating mitigation or optimization activities.

The program to develop the ESA capability has evolved in multiple iterations, working through the seven broad steps above, that began in late 2013 and are continuing. The initial effort over a 6-month period was focused on developing a dynamic probabilistic simulation model using the GoldSim™ software application [3] in conjunction with a small group of SMEs from within the NFST and early, limited data inputs to demonstrate the tool's capability to support integrated waste management system analysis. Following a successful demonstration, the next effort over the following 6-month period was targeted at enhancing its capabilities and usefulness to support near-term NFST planning activities and to improve linkage with the MOEF that was being developed in parallel. Development is continuing as alternative execution strategies and approaches are being identified and additional information is becoming available from other NFST activities.

The SPD, shown in Figure 2, is a graphical tool that describes the basic logic structure of the project as reflected in the components and sequences of milestones that must be achieved in order to attain the defined outcome. Development begins with SMEs agreeing about the desired outcome and then holistically adding details about the various precedence requirements and their pathways that lead to the desired outcome. This step serves to independently identify all of the logical precedence requirements for the project's success, either for developing an execution strategy in its early stages or for comparison to an existing project baseline. Completeness in identifying all critical milestones and their linkages and any alternative approaches is vital because the SPD becomes the skeleton for the dynamic simulation model.

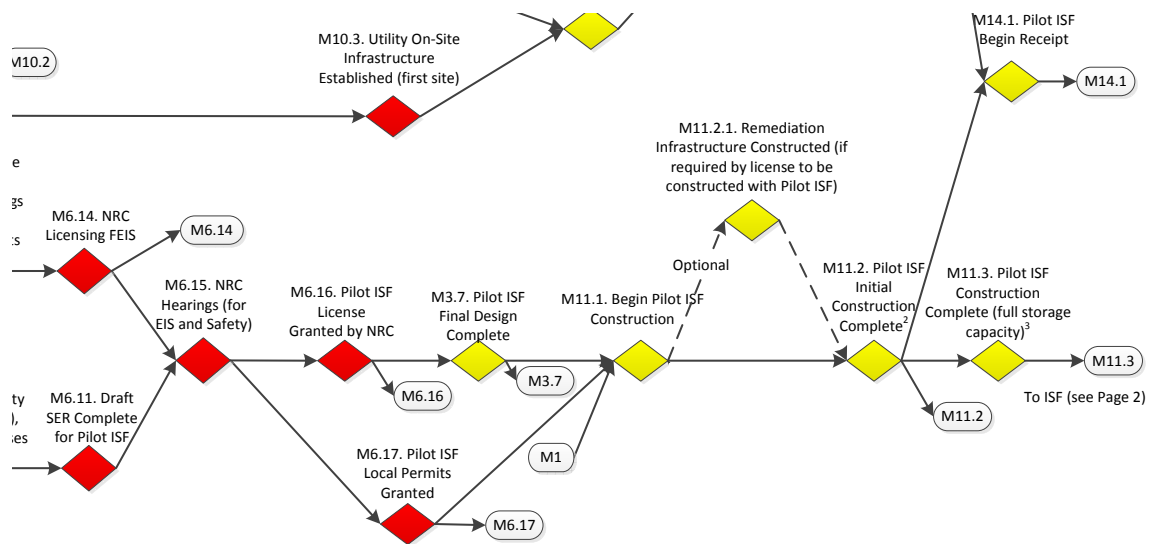


Figure 2. Example Portion Of A Success Precedence Diagram

For the ESA model the desired outcome is the initiation of operations at an ISF and the logic includes the following correlated activities:

1. ISF siting
2. ISF design
3. Licensing, regulatory compliance, and permitting
4. Transportation hardware acquisition
5. Transportation planning (routing, emergency responder training)
6. ISF construction
7. Transportation operations
8. Stakeholder consultation and cooperation

The next step in the ESA process is, with SME involvement, to identify key activities associated with each project milestone and parameterize the metrics associated with them (i.e., duration, capital costs, operating costs, resources needed). As discussed above, this is not done to a deep level. Instead the activities are modeled at a high level while capturing the important aspects related to achieving each milestone. It is important to estimate the uncertainty associated with those parameters. This step, in conjunction with the SPD, establishes the foundation of the ESA model. The activity definitions, parameters, and their bases are documented in a form that can both be viewed/printed and serve as input to the dynamic simulation model. Note that the activity parameters can be changed to assess different implementation scenarios.

The identification and quantification of “broad spectrum” risks affecting the project and its strategies are next in the ESA development process. Risks include not only technical and programmatic risks (related to design, regulatory framework, construction, etc.) but also the “soft” non-technical risks (ex. public acceptance, legal challenges). Frequently it is the “soft” risks that determine how an implementation strategy will perform (i.e., with respect to schedule and cost). These risks are elicited from the SMEs who must identify the likelihood of the risk occurring and the consequences, usually measured in the impacts to activity durations, costs, and the overall logic. The outcome of this step is the creation of a risk register for the

project. Decisions can then be made whether they are “controllable” or “non-controllable” by the organization responsible for executing the project plan. Also it must be decided whether to include the risks in the model or to note them for future model development or analysis.

The risk register is in a form that can not only be viewed/printed but also serve as input to the dynamic simulation model. Note that the risk parameters can also be changed to assess different implementation scenarios.

Once the SPD, data inputs and quantified risks are completed, the dynamic simulation model can be created and tested. When it is operational and the model’s outputs have been established for analysis, then the evaluation of various project scenarios and options can be performed. Uncertainties in schedule, costs, and other defined metrics can be analyzed to identify the sensitivity of key outputs to the various input factors and the relative importance of specific activities and milestones to the overall program critical path. The results can be used to examine the potential benefits through further refinements of the model’s inputs for reducing the impacts of the uncertainties in activities or the probabilities/consequences of key risks on project objectives. For the project and the model, this initiates a continuous sequence of iteration, refinement, evaluation, and analysis.

The ESA model produces these key outputs for the analysis of implementation scenarios:

1. Probability distributions for key metrics including key milestones dates and program costs. (Figure 3).
2. Annual spending profiles (Figure 4).
3. Key risk/uncertainty drivers for cost/schedule results.
4. The likelihood that activities and milestone are on the critical path (Figure 5).
5. Comparisons of individual project execution strategies with and without risks, not only individually but also between scenarios (Figure 3).

6. Conclusion

The NFST ESA tool has been in continual development since late 2013. It has been and is being used to develop useful insights into meeting NFST’s objectives to support the deployment of interim storage to meet the goals in the Administration’s *Strategy*.

Initial analyses confirmed the importance of the early start of non-site specific foundational activities; these early activities could accelerate the implementation schedule when full-scale deployment of a consolidated interim storage program in the U.S. begins. Key risks to implementing consolidated interim storage were identified also. This led to the creation of an integrated priority list of activities and associated budgets to inform annual planning.

Mitigation strategies are being developed to address the consequences of key risks/opportunities and uncertainties associated with the implementation of an ISF. Alternate implementation scenarios are being identified and evaluated also. Cost estimates are being reconsidered and a capability in the ESA model is being developed to analyze constrained funding scenarios. A range of scenarios is being analyzed to provide defensible inputs for advancing the *Strategy* by identifying key factors that could influence implementation and deployment outputs. These efforts are informing the development of program plans that look out several years; they include linked spending profiles based upon order of magnitude costs that can be assessed to smooth out spending peaks.

Understanding the effects of uncertainty and the potential impacts of risks and opportunities is important. The Execution Strategy Analysis process and tool can be applied globally to long-term strategies to manage UNF and HLW.

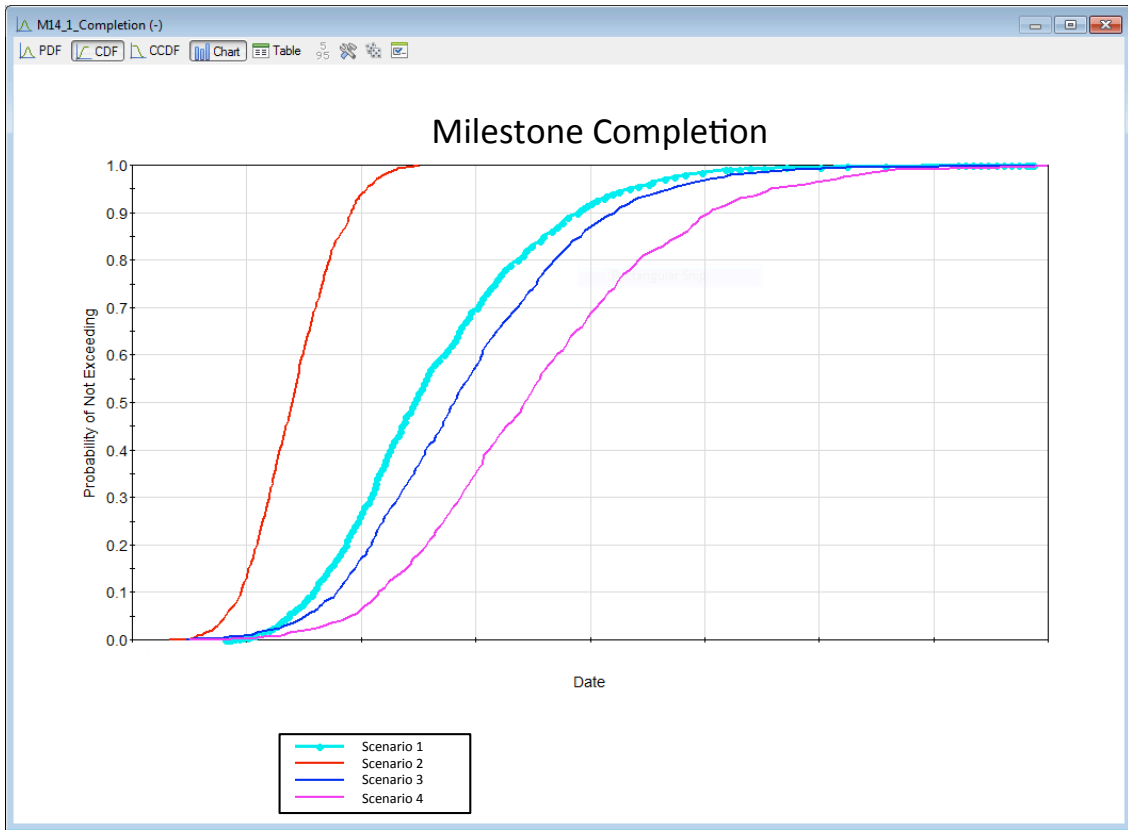


Figure 3. Example ESA Output – Probability Distribution Of Milestone Completion For Alternative Implementation Scenarios

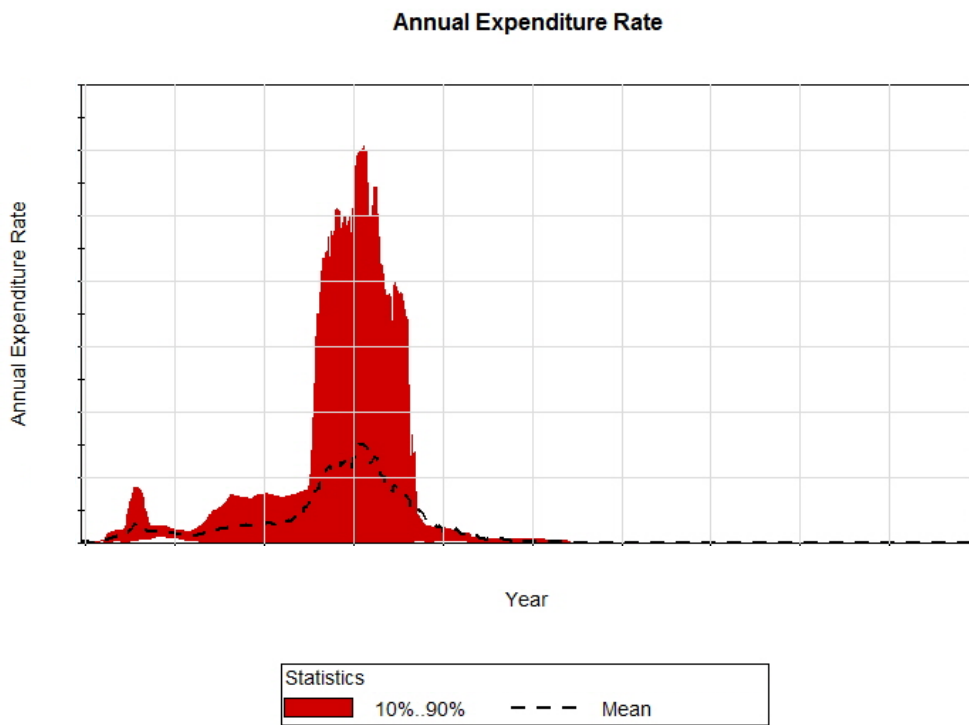


Figure 4. Example ESA Output – Annual Spending Profile

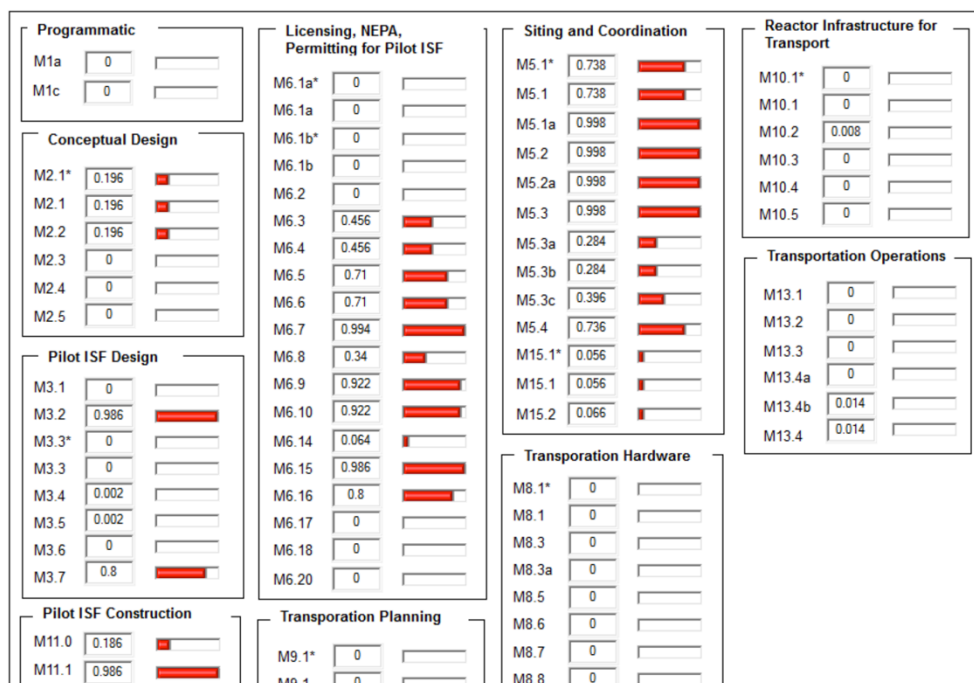


Figure 5. Example ESA Output – Likelihood Of Milestones Being On The Critical Path

7. References

- [1] *Blue Ribbon Commission on America's Nuclear Future, Report to the Secretary of Energy*, (2012).
- [2] US Department of Energy, *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*, (2013).
- [3] GoldSim Technology Group LLC, www.goldsim.com

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