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Systems Engineering Activities (SEA) Profiler

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Abstract

A Systems Engineering Activities (SEA) Profiler has been constructed as a useful tool for application in complex and enterprise systems engineering endeavors. The SEA Profiler is primarily intended to be used by a systems engineer, program manager, or project leader, for characterizing the systems engineering (SE) being done on their program/project within a given environment and timeframe. We explain the profiler in detail. We encourage people to take time to realistically assess their situation and to provide an honest and accurate assessment of what they are actually doing in SE. This can lead to process improvements on a give program/project. Also, comparing the results of different profiles can be illuminating and stimulate discussions across programs/ projects that could lead to collaborations and improved system developments.

Introduction

The Systems Engineering Activities (SEA) Profiler[1] of Figure 1 (White and Semy 2010) is primarily intended to be used by a systems engineer, program manager, or project leader, for characterizing what type of systems engineering (SE) is being done

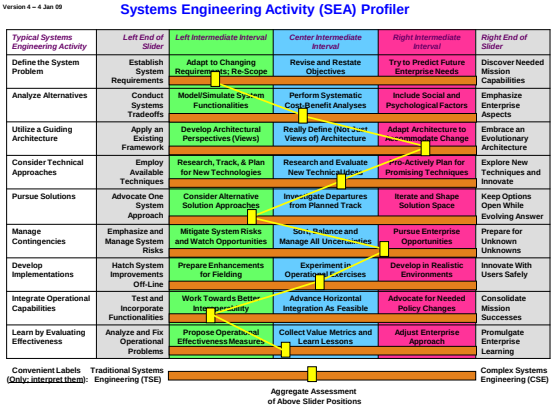

Figure 1. SEA Profiler.

on their program/project within a given timeframe. The basic notion is to select positions of the "sliders" (the yellow rectangles in Figure 1), to depict your characterization. Here we have chosen seven possible positions of the slider in each of the nine rows of the SEA Profiler. Figure 1 shows an arbitrary position of the sliders. A slider positioned on the left is closer to what is viewed as a more conventional or traditional SE activity for that row. Similarly, a slider on the right is closer to a more complex SE activity.

After this profiler was developed, the author became aware of an important body of work aimed at profiling systems of systems; (Firesmith 2010) utilizes sliders, as well, but in a different fashion.

The SEA Profiler can be used in conjunction with the Enterprise Systems Engineering (ESE) Profiler (Stevens 2008) which is primarily oriented toward characterizing the nature and degree of

[1] Constructive suggestions for improving this profiler are welcome; contact Brian White at bewhite@mitre.org.

difficulty of the environment surrounding the program/project effort. In short, the ESE Profiler helps you characterize your situation, and the SEA Profiler helps you characterize what you're doing about it.

One might say, even if I utilized these two profilers, "So What?!" Let's be clear. We are not trying to tell anyone how to do SE. Rather we are simply encouraging people to take some time to realistically assess their situation and to provide an honest and accurate assessment of what they are actually doing.

Loosely comparing the results of the two profilers can be illuminating. For example, if you're situated mainly in the outer ring of the ESE Profiler, you likely should be operating towards the right end of the SEA Profiler. To the extent you are not, some changes in your SE approach may be warranted. Suggestions on what to do next, especially in the more difficult situations, may be found elsewhere (White 2008).

Details of the SEA Profiler are explained below.

Explanation of Profiler Columns

We treat the SEA Profiler (refer to Figure 1 above) columns as rows of text below because of space limitations.

Typical Systems Engineering Activity. Logically one could argue that these activities could be performed in this top-to-bottom order, especially in developing a new system. However, it is better think of these activities as generic tasks that are performed continually, in parallel, and in an iterative fashion, very much dependent upon the application domain and current timeframe. If the labels in these rows were turned 90 degrees (counterclockwise) they could be viewed as a life cycle. That would be a mistake because that would only accentuate the tendency to treat these activities in a "linear" fashion that is really devoid of reality for most problems we face. Furthermore, one should keep in mind that these activities are not necessarily mutually exclusive.

Left End of Slider (refer to Figure 2). These activities are intended to characterize and be most closely associated with the "traditional" practice of conventional or prescriptive SE utilizing the best known techniques that apply and work well in situations that are described within the interior ring of the ESE Profiler. Here the situation is less difficult, e.g., one has a significant amount of control, stakeholders are generally supportive, the environment is relatively stable, requirements are well-defined, and one can use reductionist techniques effectively to improve a system's capabilities.

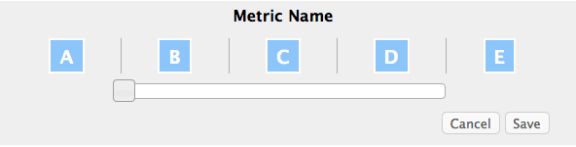

Figure 2. Left End of Slider.

Left Intermediate Interval (refer to Figure 3). These activities are intended to characterize and be associated with practices that lie more toward the left-end extreme of the SE spectrum utilizing techniques that may apply in situations that are described by a combination of the interior or middle ring descriptors of the ESE Profiler. Here the situation is of significant but still moderate difficulty. One might also associate these activities mostly with a "directed" system of systems (SoS).[2]

[2] A directed SoS is built and managed to fulfill specific purposes. It is centrally managed during long-term operation to continue to fulfill those purposes as well as any new ones the system owners might wish to address. The component systems maintain an ability to operate independently, but their

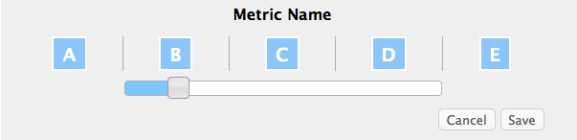

Figure 3. Left Intermediate Interval.

Center Intermediate Interval (refer to Figure 4). These activities are intended to characterize and be most closely associated with practices that lie midway between the two extremes (left and right ends) of the SE spectrum utilizing techniques that may apply in situations that are described within the middle ring of the ESE Profiler. Here the situation is of moderate difficulty. One might also associate these activities mostly with an "acknowledged" SoS.[3]

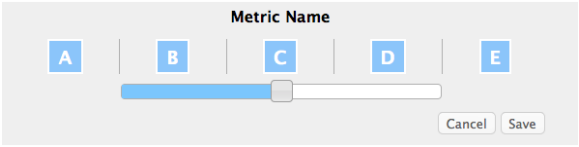

Figure 4. Center Intermediate Interval.

Right Intermediate Interval (refer to Figure 5). These activities are intended to characterize and be associated with practices that lie more toward the right-end extreme of the SE spectrum utilizing techniques that may apply in situations that are described by a combination of the middle or outer ring descriptors of the ESE Profiler. Here the situation is of moderate to great difficulty. One might also associate these activities mostly with a "collaborative" SoS.[4]

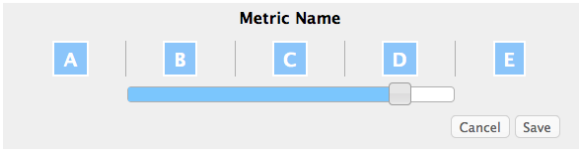

Figure 5. Right Intermediate Interval.

Right End of Slider (refer to Figure 6). These activities are intended to characterize and be most closely associated with the emerging practice of complex (or enterprise) SE utilizing specialized techniques that may apply in situations that are described within the outer ring of the ESE Profiler. Here things are most difficult, e.g., one can only influence (having little or no control), stakeholders are generally non-supportive (or even antagonistic), requirements are ill-defined, and one must use holistic (and non-reductionist) techniques to improve enterprise capabilities. One might also associate these activities mostly with a "virtual" SoS.[5]

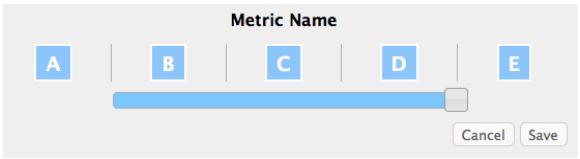

Figure 6. Right End of Slider.

Explanation of Define the System Problem (Row 1 of SEA Profiler) (refer to Figure 7). Engineering is about methodically conceiving and implementing viable solutions to existing problems. Early on in any SE endeavor, with your

normal operational mode is subordinated to the central managed purpose. (Dahmann, et al. 2008)

[3] An acknowledged SoS has recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, and funding, as well as development and sustainment approaches. Changes in the systems are based on collaboration between the SoS and the system. (Dahmann, et al. 2008)

[4] In collaborative SoS, the component systems interact more or less voluntarily to fulfill agreed-upon central purposes. The Internet is a collaborative system. The Internet Engineering Task Force works out standards but has no power to enforce them. The central players collectively decide how to provide or deny service, thereby providing some means of enforcing and maintaining standards. (Dahmann, et al. 2008)

[5] A virtual SoS lacks a central management authority and a centrally agreed-upon purpose for the SoS. Large-scale behavior emerges—and may be desirable—but this type of SoS must rely upon relatively invisible mechanisms to maintain it. (Dahmann, et al. 2008)

constituents on the program/project, it is important to discuss, understand, and try to define, agree-to, and record a clear statement of the fundamental or core system problem to be solved; this process can and should be iterated as situations change.

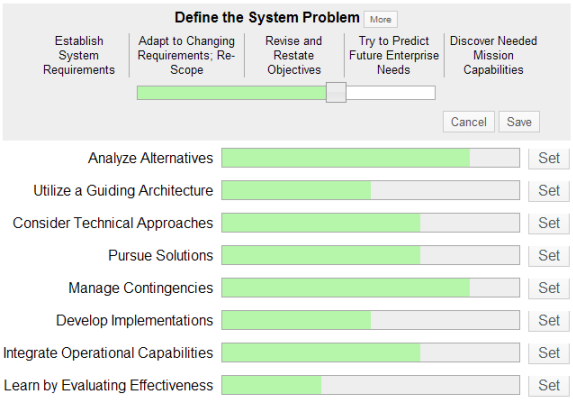

Figure 7. Define the System Problem.

Establish System Requirements. Sometimes the problem space is clear enough that a reasonable set of initial requirements can be established relatively easily and soon. In this case, the slider for this row can be positioned furthest left in this row. However, in more difficult cases, this SE activity will be dependent upon the outcomes of other SE activities such as those of Analyze Alternatives, Utilize a Guiding Architecture, and Consider Technical Approaches. Then this slider can be positioned accordingly but will likely move to the right.

Adapt to Changing Requirements; Re-Scope. Often requirements change, and this necessitates some degree of flexibility that may include a re-scoping (either constraining or expanding) the effort. So when the requirements are not stabilized the slider can be placed within this column's interval.

Revise and Restate Objectives. Taking a broader viewpoint, one may not even wait for requirements to be established or change, but rather one can become more proactive by changing (either restricting or expanding) the overall system objectives; this is akin to reshaping the desired outcome spaces based on knowing more about the problem. So when adopting this objectives focus the slider can be placed within this column's interval.

Try to Predict Future Enterprise Needs. Adopting an even more general viewpoint, one may attempt do more to satisfy "horizontal" integration and interoperability needs as part of the local system development, as well as the more usual "vertical" ("stove piped") integration requirements. The ability to do this well would benefit from a clearer understanding of the present and potential future needs of enterprise or enterprises of which your system is part. So if the emphasis is on future enterprise needs the slider can be placed within this column's interval.

Discover Needed Mission Capabilities. Here the problem-solving focus is mainly on evolving the system to discover and achieve the critical mission capabilities most useful to the end users. If this is the principal effort the slider can be positioned furthest right in this row.

Explanation of Analyze Alternatives (Row 2 of SEA Profiler) (refer to Figure 8). This SE activity can be viewed as a pre-requirements set of actions that consider various ways of solving the system problem, and that might also be started before other SE activities such as those of Utilize a Guiding Architecture, and Consider Technical Approaches.

Again, keep in mind that the rows of the SEA profiler should not be thought of as being entirely distinct or having to be performed in a certain order.

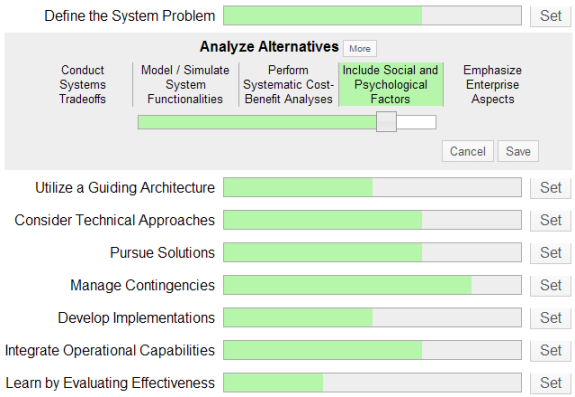

Figure 8. Analyze Alternatives.

Conduct Systems Tradeoffs. The analysis of alternatives involves brainstorming and evaluating various possible system solutions from several different points of view that may be qualitative, quantitative, or both. If there is little or no modeling/simulation or cost-benefit analysis, the slider could be placed furthest left in this row. Outcomes of the SE activities Utilize a Guiding Architecture and/or Consider Technical Approaches could be inputs to this process. The results of these tradeoffs could lead to a change (narrowing or widening) of the target system's scope, and the slider would likely be more to the right.

Model / Simulate System Functionalities. More can be learned about the likelihood of eventually achieving desired system functions by conducting detailed and technical modeling and simulation studies and analysis. Again, these results could lead to a change (narrowing or widening) of the target system's scope. So with emphasis on modeling/simulation the slider can be placed within this column's interval.

Perform Systematic Cost-Benefit Analyses. Even more might be learned of the target system's ultimate viability by a more rigorous estimation of cost-benefit and business case analyses of each contemplated system alternative. Again, these results could lead to a change (narrowing or widening) of the target system's scope. So with emphasis on costs and benefits the slider can be placed within this column's interval.

Include Social and Psychological Factors. The more one views the system as being "complex", in particular, viewing people (stakeholders as well as operators) as being part of the system, the more important are non-technological political, economic, social, psychological, organizational, and institutional factors. Inclusion of these factors could lead to a change (narrowing or widening) of the target system's scope. So with emphasis on people concerns the slider can be placed within this column's interval.

Emphasize Enterprise Aspects. At this end of the SE spectrum, the greatest emphasis is given to the enterprise or enterprises of which the system is a part when analyzing alternatives. Again, these results could lead to a change (narrowing or widening) of target system's scope. If there is great emphasis on the enterprise, the slider could be placed furthest right in this row.

By now the reader should understand to type of reasoning associated with the placement of the SEA Profiler sliders. Hence, slider placement will not be discussed explicitly any further.

Explanation of Utilize a Guiding Architecture (Row 3 of SEA Profiler) (refer to Figure 9). It is important to develop and adopt a basic architecture to guide your SE work. Although not viewed as a rigid construct, a good architecture should not change very much compared to evolutionary changes in the system being developed or upgraded. The underlying architecture should drive the system development or upgrade, not the reverse. Also, do not misconstrue descriptions (views) of the architecture as the architecture itself. Such artifacts are only

representations intended to communicate the nature of the architecture to others.

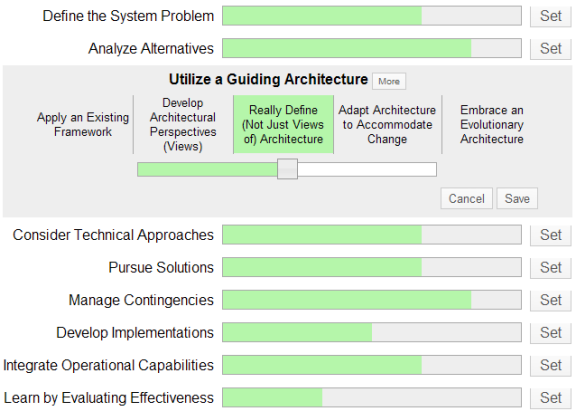

Figure 9. Utilize a Guiding Architecture.

Apply an Existing Framework. There are many architectural frameworks that might be applied to describe the architecture; one that seems appropriate for the problem domain could be chosen. Again, do not confuse the framework with the architecture itself.

Develop Architectural Perspectives (Views). Some frameworks include recommended architectural perspectives that purport to show certain aspects of the architecture; these are sometimes called views. Often preparation of these views is mandated by sponsors or customers. Again, do not confuse the views with the architecture itself.

Really Define (Not Just Views of) Architecture. A more mature process will include a thorough development of the underlying architecture, and that will receive more emphasis than the architectural framework and much more emphasis than merely its views.

Adapt Architecture to Accommodate Change. Significant changes may need to be made in the underlying architecture to better accommodate an uncertain future as one encounters and learns more about complex environments (where people are involved). However, these changes are not simply in response to changes in the system itself; the architecture guides the solution, not the reverse.

Embrace an Evolutionary Architecture. In the most complex and difficult environments (highly dependent upon behavior of other people), one may wish to adopt and be better off embracing an enterprise architecture that is more fluid compared to architectural approaches for single systems.

Explanation of Consider Technical Approaches (Row 4 of SEA Profiler) (refer to Figure 10). System developments or upgrades are implemented by technical means. This may mean more than just the application of information technology, say. The technical approach may depend on politics, economics, sociology, psychology, organizational change management, etc., and on outputs from the SE activity Analyze Alternatives, e.g., cost-benefit and business case analyses.

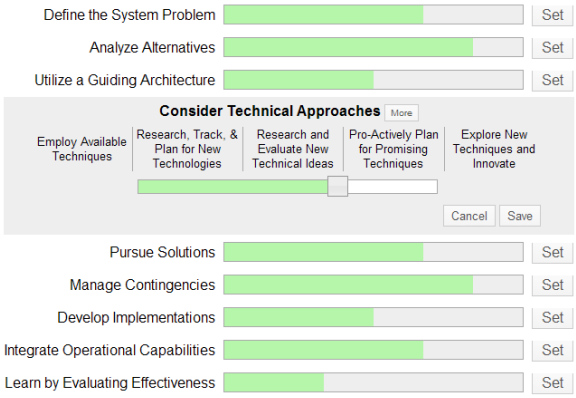

Figure 10. Consider Technical Approaches.

Employ Available Techniques. Clearly one wants to be able to apply the most appropriate techniques that are likely to be available within the timeframe of the system development or upgrade endeavor. However, it is dangerous to count on unproven technology, especially if it is immature or not mature enough when really needed. So decisions on which technologies

to pursue should be objective and devoid of emotional attraction.

Research, Track, & Plan for New Technologies. It is prudent to continually investigate and contingently plan for several new or developing technologies or techniques that may be applicable to a solution to be better prepared should they become viable.

Research and Evaluate New Technical Ideas. Depending on the level of complexity (determined by various roles of and dependence on people) and difficulty involved, disciplines other than electrical engineering, the computer sciences, physics, and mathematics may be relevant. The utility of other more wide-ranging and "soft" scientific methods and techniques (e.g., from the social sciences) might be considered to the extent possible.

Pro-Actively Plan for Promising Techniques. Planning on just how to introduce the most fitting techniques, and when, is a difficult exercise, to say the least, in the more complex and difficult environments, but this can ultimately pay dividends in system performance.

Explore New Techniques and Innovate. Investing resources to help advance the state-of-the-art of ESE, particularly in the "soft" science aspects, can help the entire enterprise.

Explanation of Pursue Solutions (Row 5 of SEA Profiler) (refer to Figure 11). This class of activity naturally follows the sorts of SE activities listed above but can also be invoked in an iterative fashion as the system development or upgrade progresses, especially when unforeseen difficulties materialize.

Advocate One System Approach. A single path toward system development or upgrade may be taken to the extent one has strong confidence in a successful outcome.

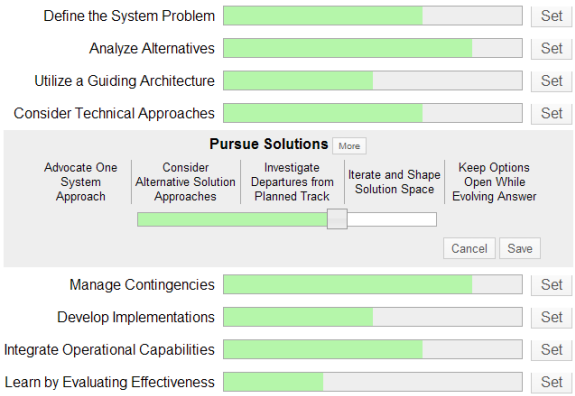

Figure 11. Pursue Solutions.

Consider Alternative Solution Approaches. Although it generally takes more resources to pursue multiple paths toward a solution, it may be worthwhile to carry along one or two promising alternatives should the main solution become untenable.

Investigate Departures from Planned Track. As one learns more about the situation and likely rate of progress in pursuing the current path(s), there may be a higher degree of confidence that, with sufficient remaining resources, one can explore a new path with the promise of greater or faster success.

Iterate and Shape Solution Space. The desired outcome space can be continually reshaped as things (e.g., requirements, external constraints or systems development/ upgrade experiences) change. Considering broader issues, affecting the enterprise(s) of which the given system is a part, may lead to even more rewarding opportunities than would be in play if one stayed with the current game plan. This may induce adjustments in your approach to either accelerate progress or revisit previous activities in this or other areas.

Keep Options Open While Evolving Answer. An excellent planning accomplishment is the ability to keep all relevant options open for future

consideration until one can be assured that the needed system capabilities are benefiting the end users.

Explanation of Manage Contingencies (Row 6 of SEA Profiler) (refer to Figure 12). One needs to expect things to go wrong (as well as right) so considerable attention must be paid to how to deal with uncertainties.

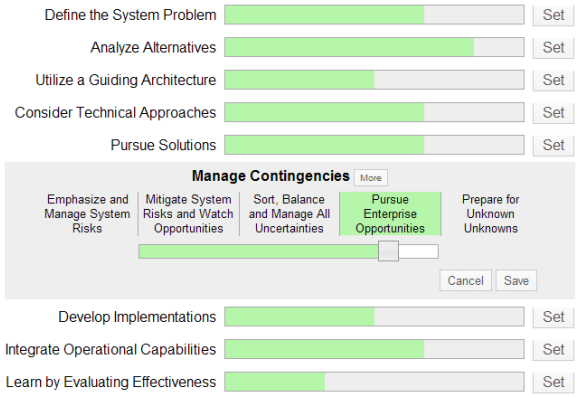

Figure 12. Manage Contingencies.

Emphasize and Manage System Risks. In many organizations and domains resources are so limited that one only emphasizes risk management, mainly trying to protect oneself from possible negative consequences.

Mitigate System Risks and Watch Opportunities. To the extent possible, being more alert for opportunities, and their promise of positive impacts, can pay off, perhaps in ways that conserve future resources.

Sort, Balance and Manage All Uncertainties. A balanced approach treating risks and opportunities on an equal footing may lead to improved decision making over the entire course of the endeavor.

Pursue Enterprise Opportunities. Considering broader issues, affecting the enterprise(s) of which the given system is a part, may lead to even more rewarding opportunities than would be forthcoming if one merely tried to preserve the status quo.

Prepare for Unknown Unknowns. The biggest payoff might ultimately result from being more skeptical about (what might seem like) paths to success, while planning how to manage the possibility of a devastating but unpredictable surprise.

Explanation of Develop Implementations (Row 7 of SEA Profiler) (refer to Figure 13). This set of activities is closely related to those of the SE activity Pursue Solutions but reflects what actually is being done materialistically.

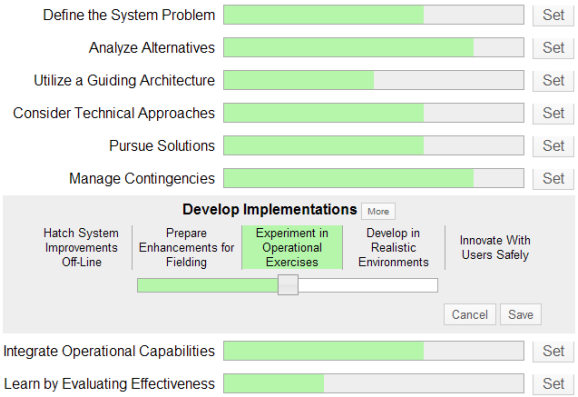

Figure 13. Develop Implementations.

Hatch System Improvements Off-Line. The more conventional approach is to work on subsystems in the laboratory or other isolated development environments.

Prepare Enhancements for Fielding. While developing subsystem improvements it is desirable to pay proper attention to interfaces, standards, and integration issues.

Experiment in Operational Exercises. Experimenting in well-posed and planned exercises that simulate real operations can teach much about user needs and the eventual utility of system improvements.

Develop in Realistic Environments. The more realistic the development environment, the more likely the eventual product will satisfy user needs.

Innovate With Users Safely. Ultimately, the most effective and efficient progress can be made by developing

capabilities with the end users, if this can be done without jeopardizing people's safety!

Explanation of Integrate Operational Capabilities (Row 8 of SEA Profiler) (refer to Figure 14). This set of SE activities is generally most associated with the completion and delivery of a new system or system upgrade to the sponsor, customer, and/or end user.

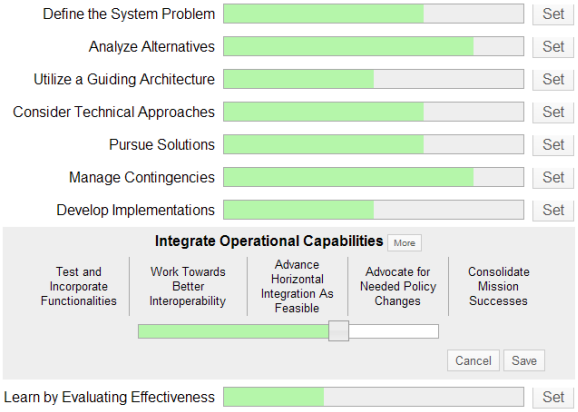

Figure 14. Integrate Operational Capabilities.

Test and Incorporate Functionalities. This covers the testing and integration of the subsystem components.

Work Towards Better Interoperability. Here considerable attention is paid to "horizontal" interfaces and standards critical to achieving greater interoperability with other systems.

Advance Horizontal Integration As Feasible. Even more important for achieving interoperability across the enterprise is to exert a proactive effort to do what is good for anyone that might wish to utilize the core value of the system, as opposed to just "satisficing" all known end users.

Advocate for Needed Policy Changes. As more is learned about what is necessary to achieve enterprise interoperability, advocacy for suitable changes in standards or acquisition policies to help accelerate progress may be warranted.

Consolidate Mission Successes. This activity would include the gathering of performance information about how well other systems in the enterprise are performing relative to the local system, looking for ways to enhance the utility of the local system in those environments.

Explanation of Learn by Evaluating Effectiveness (Row 9 of SEA Profiler) (refer to Figure 15). This set of SE activities is focused on the continual evaluation of how well things are proceeding toward delivering needed capabilities to end users.

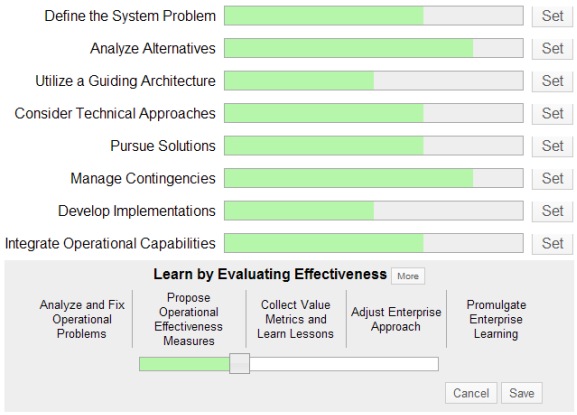

Figure 15. Learn by Evaluating Effectiveness.

Analyze and Fix Operational Problems. It is important to stay in touch with what's happening in the field with respect to how the local system is being utilized and try to rectify unforeseen problems of operation.

Propose Operational Effectiveness Measures. Here a more proactive approach is instituted to predefine systematic performance measures that can lead to a more focused gathering of data once the system is fielded.

Collect Value Metrics and Learn Lessons. This represents an added effort to systematically gather and analyze performance metrics which will inform

decisions as to how to enhance the next system iteration.

Adjust Enterprise Approach. Here a broader enterprise view is taken to discover how the local system can be modified to be of greater utility across the enterprise(s) of which it is a part.

Promulgate Enterprise Learning. Sharing what is learned about making available fundamental unique values of each system to anyone who can benefit, particularly from the perspective of the end users, can help further the enterprise(s) of which the local system is a part.

Conclusion

We have attempted to introduce a useful tool for characterizing what you are doing within the entire spectrum of SE on your program/project. The Systems Engineering Activities (SEA) Profiler, embodied with a set of sliders that can be set in a finite number of discrete positions, provides a snapshot of your current SE approach. We recommend that you use this tool for discussing whether this approach makes sense considering your working environment and externally imposed constraints. The SEA Profiler can also be used to compare and contrast your SE approaches over time on your program/ project, or with the SE characterizations of other programs/projects.

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Biography

Brian E. White received Ph.D. and M.S. degrees in Computer Sciences from the University of Wisconsin and S.M. and S.B. degrees in Electrical Engineering from M.I.T. He served as an Air Force Intelligence Officer, and for 8 years was at M.I.T. Lincoln Laboratory. Dr. White spent 5 years as a principal engineering manager at Signatron, Inc. In his nearly 28 years at The MITRE Corporation, he has held a variety of senior technical staff and project/resource management positions. His most recent role was Director of MITRE's Systems Engineering Process Office.