New Challenges in Systems Engineering and Architecting
Conference on Systems Engineering Research (CSER)
2012 – St. Louis, MO
Cihan H. Dagli, Editor in Chief
Organized by Missouri University of Science and Technology

Year One of the Systems Engineering Experience Accelerator

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Abstract

Systems engineering educators are struggling to meet the workforce development demand for senior systems engineers. Systems engineers are critical for addressing a broad set of increasingly complex systems problems faced by industry and government. However, the discipline is experiencing an outflux of senior systems engineers reaching retirement age with no ready source of systems engineers available to replace them, at a time when the demand for systems engineers is increasing (NDIA, 2010). The workforce challenge is to shorten the time it takes for a systems engineer to reach the senior level. The Systems Engineering Experience Accelerator (SEEA) research project was conceived as a critical response to these needs and challenges. The SEEA focuses on a solution that leverages technology to create an experience intended to accelerate the learning of systems engineering related competencies. This paper summarizes the operation of the preliminary version of a prototype SEEA simulator after the first year of the SEEA project. A review of the plans for future research is also included.

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Keywords: systems engineering competency development, systems engineering training, prototype development

1. Overview

The SEEA research project hypothesis is:

\textit{By using technology we can create a simulation that will put the learner in an experiential, emotional state and effectively compress time and greatly accelerate the learning of a systems engineer faster than would occur naturally on the job.}
During the development of the year one prototype, the team initially focused on defining the project goals and success metrics. The goals of the project include the long-term implementation of open source architecture, technology, application and content. The team selected appropriate technologies and developed an open architecture to support these objectives. Next, the team developed a competency taxonomy model for systems engineering (DAU, 2011; Gavito, et. al, 2010; Squires, 2007), collected ‘Aha’ moments from senior systems engineers, and defined a concept of operations. An ‘Aha’ moment is a moment of realization when the learner has developed an insight, often under duress, which can be applied to a wide range of situations which fit the overall generic pattern. Once the initial planning, primary and secondary research, and requirements development work was done, the team focused on completing several primary but parallel activities:

- Defining the initial experience to be simulated
- Developing the assessment approach
- Developing the application infrastructure
- Coding the application
- Developing the experience content working with subject matter experts
- Verifying the intended operation.

1.1. Features

The first year prototype supports the following features and capabilities:

- Virtual Desktop including email, phone, voicemail, document folders, calendar,
- Profile including Experience self-appraisal and Learning Styles assessment
- Secure login capability
- Thin client operation on an browser based device supporting Flash
- Single-learner supporting all other roles with non-player characters (NPCs)
- Support for lifecycle phases of development, integration, field test and deployment
- Support for reflection session with NPC mentor
- Simulated outcomes using systems dynamics models for system with multiple subsystems through lifecycle phases
- Support for phase design reviews
- Ability to dial up or down skill levels
- No “right” answers
- Scoring based relative to difficulty level

1.2. Targeted Competency

The year one prototype experience focuses on addressing a systems engineering competency in the broad professional skills category: “Problem Solving and Recovery Approach”. The various elements of this competency are noted in (Squires, et. al., 2011a):

- Identifying the actual/root cause problems amid often conflicting information.
- Marshalling the resources needed to solve problems.
- Recognizing the problems that have the most impact to the overall system and appropriately prioritizing plans for solving them.
- Making recommendations, using technical knowledge and experience, by developing a clear understanding of the system.
- Identifying and analyzing problems using a systems approach, weighing the relevance and accuracy of information, accounting for interdependencies, and evaluating alternative solutions.

The project is described in more detail in Squires, et. al. (2011b).
2. Operation

Initially, the learner performs the following steps:
1. The Learner logs into the system.
2. The Learner is presented with the control screen as shown in Figure 1.

![Figure 1: SEEA Welcome Screen](image)

3. The Learner is then directed to an orientation session take a set of surveys that define his or her learning style and competencies. Results are stored in the Learner’s profile. The Learner also is introduced to a mentor, who currently is a non-player character (NPC) who can provide advice.
4. The Learner selects which Experience they want to partake in. For the prototype, there is one Unmanned Aerial Vehicle (UAV) experience focused on the integration of three major subsystems.
5. The Learner then goes through a set of Phases corresponding to the phases of an acquisition program – pre-integration development, integration, flight testing, and limited production and deployment as shown in Figure 2. Within each Phase, the Learner can interact with other personnel involved in the program (NPCs), review documents and reports on project status, and then make decisions to prevent or recover from problems. Decisions should be made based on the information that the Learner has gathered from documents and NPC interaction. A simulation is executed to advance the time in the experience, and the Learner is presented with results of his or her decisions in the form of project status updates.
6. Finally, after experiencing all Phases of the acquisition program, the Learner then receives feedback on his or her performance in managing systems engineering within the acquisition program, and is then given an opportunity for reflection and associated learning and growth.

Internally, the SEAA has been designed as a set of interacting components, each of which performs a certain function.

- The Experience Master determines which Experience and the appropriate Phase that will be presented to the Learner and ensures that each of the other major modules are presented with the proper contextual information and are sequenced appropriately.
- The Challenge Control takes as inputs the Learner’s profile and the Competencies and Aha’s that have been targeted by the current Experience based on that profile and selects from the available
set of Challenges & Landmines, and Experience Scenarios for use in this Experience. A Challenge is an initial condition for one of the simulated Phases that poses a particular difficulty to be overcome during that Phase (e.g., too many inexperienced engineers are assigned to the project, thus causing delays or quality issues). A Landmine, on the other hand, is an adverse event that is scheduled dynamically based on the Learner’s progress in the experience and occurs in mid-Phase (e.g., a wind tunnel test suddenly reveals an issue with airframe drag that previously was unknown) that is designed to ensure that the experience provides the appropriate degree of difficulty. This information is then presented to the Experience Master.

- The Experience Master updates the internal Experience state appropriately.
- The Simulation Engine uses the Simulation Models and Data along with Experience state which resides in the Experience Master to create an Experience Scenario which has been optimized to meet a specific set of project goals relating to schedule, cost, capabilities and quality. These models reflect progress over time on the acquisition program as impacted by Learner decisions.

![Diagram of SEEA Learning Cycles, Phases and SubPhases](image)

In response to the information presented, the Learner needs to take corrective action. This corrective action will be based on his/her ability to discover the challenge issues. These actions will generally take the form of recommendations or actions that either affect the inputs to the Simulation Engine or reset the expectations for the program’s results. In the case where the Learner is a technical leader, the corrective actions of the role will likely focus on identification and mitigation of technical problems and risks.

Significant communication, facilitation and coordination skills are required, especially for programmatic changes that must be agreed upon by various program personnel and stakeholders and
approved by the program manager. In this case, the Learner’s information gathering, decision-making and actions can take the following forms:

- Identification:
  - Which meetings should be attended?
  - Which people should be consulted and what questions should be asked of them?
  - How should the results be interpreted and what actions should be taken as a result?

- Decisions:
  - How should decisions be made in the presence of incomplete and conflicting information?
  - How should risks be quantified and what criteria should be established to mitigate risks?
  - What actions should take place to respond to budget turbulence and schedule compression?

- Possible actions:
  - Changing the system requirements/desirements
  - Changing the system feature set
  - Replacing or reshuffling personnel
  - Changing the project plan schedule, internal activities/capabilities/timing, resource allocation
  - Changing the budget (allocation or request for more)

The Learner uses artifacts such as written documents (e.g., project status), emails received, and voicemail and interacts with NPCs using text-messages and phone calls.

In general, the Learner will make corrective changes through written recommendations to the relevant decision-maker or interacting with the decision-maker NPC. There will also be some ambiguity in communication back to these NPCs such that all of the desired changes may or may not be made. Again, the Challenge Control will determine the number and amount of deviation that is input to the Simulator for the next session. Note that the Learner also has access to their profile, has access to their SEEA log through artifacts that were created on previous experiences and has the ability to restart previous experience simulations. This can be used to help the Learner understand the connection between his/her actions and the resultant responses in the simulation.

3. Research Contribution

While the prototype SEEA is focused on proving a theoretical concept - that technology can be leveraged to accelerate the time it takes to reach higher levels of proficiency in systems engineering competencies - there are other contributions as well. The effort to develop the prototype provides guidance on the following:

- What are the right requirements for future efforts focused in this area? These include technology requirements, experience design requirements, single and multiple player capability, etc.
- Can systems engineering issues be represented effectively using a system dynamics framework and what extensions/modifications would be needed?
- How well do current DoD project status reports, data presentations and data visualizations provide effective decision support and training for program-level systems engineers in DoD acquisition? What improvements to these artifacts would provide better decision support?
- Is it better to let the learner learn from failing or to provide the learner with proactive tools that let him/her see and avoid problems (even though such tools are not present in real programs)?
- How do you balance the size of the experience state space, time and effort on dialogue creation, technology development, and authenticity to create the desired learning?

4. Future Research

In the first year of this project, evaluation of the prototype was largely incorporated through sponsor and expert review. Future work will involve an informal evaluation process with actual students and a
limited number of practitioners testing the SEEA during this development process. In addition, planning will be done for the more formal evaluations. This activity will consist of the development of a set of evaluation metrics and the design of the evaluation experiments. This work will require developing the means of pre- and post-testing the participants to determine not only their perception of the value of the experience, but also to determine the level at which the targeted lessons were learned. Post-experience competency assessments will also be developed, along with additional pre- and post-test formal assessments to capture user perception of the prototype and measure experience impacts. Research is also targeted in the areas necessary to support the SEEA and content in a collaborative open source environment. This work will include any necessary architectural and design modifications, the development of tools to increase the efficiency of content creation, the migration of the code base to a source controlled environment, and the creation of the necessary documentation set to support this work.

5. Summary

The International Council on Systems Engineering (INCOSE) Technical Operations publication *Systems Engineering Vision 2020* predicted that the “Use of technologies such as simulation, visualization, and gaming will lead to innovations in systems engineering education.” (p. 6) This vision is critical for addressing the current shortfall of experienced SEs. A benefit of the research to date is the development of an approach that can potentially be used to accelerate learning through real life simulation. Research contributions to date include empirical data on the use of systems dynamics to simulate systems engineering; the use of DoD-like artifacts to support the PSE in the experience; the balance act between helping the user versus allowing the user to fail; and the required tradeoffs in the development to find the best value add strategy to enable learning.

Acknowledgements

This material is based upon work supported, in whole or in part, by the Systems Engineering Research Center (SERC). SERC is a federally funded University Affiliated Research Center managed by Stevens Institute of Technology. We are grateful to all the members of the Experience Accelerator team including members of participating universities, sponsor members, and subject matter experts.

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