Developing the Systems Engineering Experience Accelerator (SEEA) Prototype and Roadmap


27 July 2015

Principal Investigator:
Dr. Jon Wade - Stevens Institute of Technology

Co-Principal Investigator:
Dr. Douglas Bodner – Co-PI, Georgia Tech

Research Team:
Dr. Richard Turner, Stevens Institute of Technology
Dr. William Watson – Purdue University
Peizhu Zhang, Stevens Institute of Technology
Hao Kang, Stevens Institute of Technology
Gopi Namibar, Georgia Tech

With Contributions by Subject Matter Experts
Chris Robinson & John Snoderly, DAU

Period of Performance: 30 June 2014 to 29 June 2015
Copyright © 2015 Stevens Institute of Technology

The Systems Engineering Research Center (SERC) is a federally funded University Affiliated Research Center managed by Stevens Institute of Technology.

This material is based upon work supported, in whole or in part, by the U.S. Department of Defense through the Office of the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) under Contract HQ0034-13-D-0004.

Any views, opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the United States Department of Defense nor ASD(R&E).

No Warranty.
This Stevens Institute of Technology and Systems Engineering Research Center Material is furnished on an “as-is” basis. Stevens Institute of Technology makes no warranties of any kind, either expressed or implied, as to any matter including, but not limited to, warranty of fitness for purpose or merchantability, exclusivity, or results obtained from use of the material. Stevens Institute of Technology does not make any warranty of any kind with respect to freedom from patent, trademark, or copyright infringement.

This material has been approved for public release and unlimited distribution.
Executive Summary

This document is a summary of the work that was completed in the second increment year of the SERC Research Topic DO1/TTO2/0016 “Developing Systems Engineering Experience Accelerator (SEEA) Prototype and Roadmap” supported by the Defense Acquisition University (DAU). The purpose of the research project is to test the feasibility of a simulated approach for accelerating systems engineering competency development in the learner. The SEEA research project hypothesis is:

*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.*

The major research activities in Increment 3 were the enhancement of EA capabilities as noted below:

- The contractor shall develop, test, and pilot a stable multi-player capability. This capability shall allow experienced instructors to provide feedback to the student teams, such as explaining the outcomes of the teams’ decisions, and helping the students understand the impact of their recommendations.
- The contractor shall add a predictive capability to the SEEA to improve the students’ decision-making capabilities and produce better recommendations.
- The contractor shall develop the capability to provide dialog based on the students’ past recommendations. Currently the SEEA provides dialog based only on the current state of the simulation.
- The contractor shall make improvements to the user interface to allow students to quickly find information through status charts. Such improvements shall be compliant with Section 508 user interface requirements.

The Experience Accelerator has continued to mature and now has a variety of compatibilities that should support experiences in numerous domains and several different single and multi-player modes. Future research for the EA may include:

- efforts to ensure a successful DAU experience deployment,
- the extension of the scope and capabilities of the current DAU experience,
- the creation of Multi-Player Acquisition Mission Support,
- a number of potential experiences that leverage the capabilities of the SE to train and evaluate the performance of SERC MPTs, to provide a laboratory for learning assessment,
- updates and evolution of EA tools
- updates to the EA infrastructure
- and building of the EA community
# Table of Contents

Executive Summary........................................................................................................................................... iii

Table of Contents................................................................................................................................................ iv

List of Figures....................................................................................................................................................... vi

Preface .................................................................................................................................................................... vii

1 Introduction ........................................................................................................................................................ 1
  1.1 Background and Motivation ......................................................................................................................... 2
  1.2 Project Goals and Success Metrics ............................................................................................................ 2
    1.2.1 Purpose ........................................................................................................................................ 3
    1.2.2 Hypothesis .................................................................................................................................... 3
    1.2.3 Program Goals ............................................................................................................................... 3
    1.2.4 Target Audience ............................................................................................................................. 4
    1.2.5 Success Metrics ............................................................................................................................... 4
  1.3 Management Plan/Technical Overview ...................................................................................................... 4
    1.3.1 Research Activities ....................................................................................................................... 4
    1.3.2 Risk Management ......................................................................................................................... 8

2 Prototype Development .................................................................................................................................. 9
  2.1 Instructor Support Materials .................................................................................................................... 9
  2.2 Experience Design and Development ..................................................................................................... 10
    2.2.1 Overview .................................................................................................................................... 10
    2.2.2 Artifacts ...................................................................................................................................... 11
    2.2.3 Dialog ......................................................................................................................................... 11
    2.2.4 Experience Flow ......................................................................................................................... 12
    2.2.5 Trade Study Experience Design ................................................................................................. 13
  2.3 Technology Development ......................................................................................................................... 25
    2.3.1 Background .................................................................................................................................... 25
    2.3.2 Stabilization and Performance Enhancements ............................................................................... 27
    2.3.3 Complete full Multi-Player Mode ................................................................................................. 31
    2.3.4 Learner Interface Enhancements ................................................................................................. 31
    2.3.5 Tools Infrastructure Support ...................................................................................................... 32
  2.4 Simulation .................................................................................................................................................... 32
    2.4.1 Effects of Test Reviews .................................................................................................................. 32
    2.4.2 High-Resolution Charts ................................................................................................................ 33
    2.4.4 Learner Input Value Errors .......................................................................................................... 34
    2.4.5 Thrust Specification ....................................................................................................................... 34
    2.4.6 Relaxation of Range KPP ............................................................................................................. 35
    2.4.7 TPM Relationships ....................................................................................................................... 35
    2.4.8 Status Chart Rebaseline .............................................................................................................. 35

3 Future Research ................................................................................................................................................. 37
  3.1 DAU Experience Deployment .................................................................................................................... 37
  3.2 Extend Current DAU Experience Scope and Capabilities ....................................................................... 38
  3.3 Multi-player Acquisition Mission Support .............................................................................................. 39
  3.4 New Experiences Leveraging SERC MPTs ............................................................................................. 40
List of Figures

Figure 1: Notional Diagram of the SEEA Prototype Simulator .................................................. 1
Figure 2: A Day in the Life of a LSE ......................................................................................... 10
Figure 3 - Global Hawk Hydraulic System Block Diagram ........................................................ 17
Figure 4 - Master Actuator Trade Matrix .................................................................................. 18
Figure 5 - Trade Study Introduction Flowchart ....................................................................... 20
Figure 6 - Dialogue Talking Points - Per Architecture ............................................................... 22
Figure 7 - Dialogue Talking Points - Per Criteria ....................................................................... 23
Figure 8 - Trade Study Recommendation Form ......................................................................... 24
Figure 9: Experience Accelerator Logical Block Diagram ......................................................... 26
Figure 10: Total simulation time in seconds .............................................................................. 28
Figure 11: Estimated total execution time of 30 concurrent simulations .................................... 29
Figure 12: CPU Utilization Breakdown ..................................................................................... 30
Figure 13: Concurrent execution ............................................................................................... 31
Figure 14: Sequential execution ............................................................................................... 31
Figure 15: Partially concurrent execution .................................................................................. 31
Figure 16: Range Behavior without Learner Action .................................................................. 33
Figure 17: Color Contrast in Charts ......................................................................................... 34
Figure 18: Learner Behind Schedule, No CDR Delay ................................................................. 36
Figure 19: Learner Behind Schedule, Delays CDR by Three Months ......................................... 36
Figure 20: Workshop Participants’ assessment of SEEA Potential ........................................... 52
Figure 21: Workshop Participants’ assessment of Areas of Importance ..................................... 53
Figure 22: Workshop Participants’ assessment of SEEA Level of Support ................................ 53
Figure 23: Workshop Participants’ Interest in Participation ....................................................... 54

List of Tables

Table 1 - Potential Trade Study Concepts ................................................................................... 14
Table 2 - Trade Study Concept Selection Criteria ....................................................................... 15
Table 3 - Trade Study Selection Matrix ..................................................................................... 16
Table 4 - Actuation System Rearchitecture Rankings and Rationale .......................................... 16
Table 5 - Criteria Weighting Talking Points ............................................................................... 22
Preface

This document is a summary of the work that was completed in the Increment 3 of the SERC Research Topic DO1/TTO2/0016 “Developing Systems Engineering Experience Accelerator (SEEA) Prototype and Roadmap” supported by the Defense Acquisition University (DAU). This summary focuses on each of the work items noted in the proposal.

The following are the documents that were produced by this research and may be referenced in this document:

Experience Accelerator RT16 Project documents:
- RT16 Project Goals and Success Metrics (A013)
- RT16 Technical and Management Work Plan (A009)
- RT16 Monthly Status Reports (A008)
- Experience Accelerator Concept of Operations (A013)
- Experience Accelerator System Architecture and Design Specification (A013)
- Experience Accelerator Systems Specification (A013)
- Experience Accelerator: Experience Design Document
- Experience Accelerator White Paper
- Developing Systems Engineering Experience Accelerator (SEEA) Prototype and Roadmap, Increment 1 proposal
- Developing Systems Engineering Experience Accelerator (SEEA) Prototype and Roadmap, Increment 2 proposal
- Developing Logistics Experience Accelerator (EA) Prototype, 5/15/2012.
- Technical Leadership Development Experience Accelerator Prototype, 8/22/2012.

Publications:


1 INTRODUCTION

Systems engineering educators are struggling to address workforce development needs required to meet the emerging challenges posed by increasing systems complexity (Bagg, et. al, 2003) and the widening gap in systems engineering expertise in the workforce (Charette, 2008). The Systems Engineering Experience Accelerator (SEEA) research project was conceived as a critical response to these needs and challenges. The project was initiated to validate the use of technology to potentially create an experiential, emotional state in the learner coupled with reflective learning so that time is effectively compressed and the learning process of a systems engineer (SE) is significantly accelerated as compared to the rate at which learning would occur naturally on the job. The purpose of the research project is to test the feasibility of a simulated approach for accelerating systems engineering competency development in the learner. An example of how the various concepts developed for the SEEA are related is shown in Figure 1.

Figure 1: Notional Diagram of the SEEA Prototype Simulator

As shown, the development team had a threefold challenge to balance the development of the simulator technology that supports displayed content (shown in green) that, in turn, supports the developed concepts (shown in purple). The goal was to effectively create challenges and
landmines that support the learner’s experience of the necessary “Aha” moment. The intent was that by experiencing the “Aha” moment, the learner transitions to a more advanced level of understanding in the targeted competency, in this case “Problem Solving and Recovery Approach”.

The testing of the prototype will support evaluation of the theoretical capabilities of the developed system and provide guidance for the continuing development of the SEEA simulator going forward.

1.1 BACKGROUND AND MOTIVATION

In The Art and Science of Systems Engineering, Mr. Harold Bell, Director Advanced Planning and Analysis Division, NASA Office of Chief Engineer, is quoted as saying: “A great systems engineer completely understands and applies the art of leadership and has the experience and scar tissue from trying to earn the badge of leader from his or her team” (Ryschkewitsch, et. al, 2009, p. 2). Historically, competent systems engineers have developed their “scar tissue” by gaining the necessary insights and wisdom through both failures and successes, in an integrated real world environment. In the workplace, however, the learning events that result in the development of “scar tissue” are distributed, sometimes sparsely, over time. In addition, a common benchmark time for the development of a competent SE is a minimum of about 10-15 years (Dubey, 2006). Given there is a shortfall of SEs in the global workforce today (NDIA SE Division, 2010) and no readily available source of SEs to replace the top SEs in the retiring baby boomer generation, the time to develop competent SEs needs to be significantly shortened.

The primary goal of the SEEA, once it is developed, is to accelerate the maturation of SEs in the workforce by providing the opportunities to earn “scar tissue” through realistic, engaging simulation. These tailored experiences will allow the learner to feel the consequences of success and failure in a simulated environment so they can gain the necessary insights and wisdoms to mature as a SE, and yet not jeopardize the lives of others or compromise their careers. The initial target audience of the SEEA program is lead program SEs in the acquisition workforce who are required to effectively manage complex systems throughout their lifecycle from an acquisition/acquirer viewpoint in a typical program office. The initial focus is on maturing these leads to prepare them for executive assignments.

1.2 PROJECT GOALS AND SUCCESS METRICS

Based on SEEA research team meetings and feedback provided by the sponsors, the team set specific goals and success metrics as summarized in the following sections.
1.2.1 PURPOSE
The ultimate purpose of the SEEA is to leverage technology to create an experiential, emotional state in the learner so that time is effectively compressed and the learning process of a systems engineer accelerated as compared to the rate at which learning would occur naturally on the job.

The purpose of this project is to develop a prototype of the SEEA that is focused on a small set of competencies, in order to evaluate the theoretical capabilities of that technology.

1.2.2 HYPOTHESIS
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.

1.2.3 PROGRAM GOALS
The primary goal of the SEEA is to transform the development of systems engineers by creating a new paradigm capable of significantly reducing the time to mature and sustain a senior systems engineer while providing the skills necessary to address emerging systems challenges in an economically attractive manner.

The approach is to build insights and “wisdom” and hone decision making skills by:

- Creating a “safe”, but realistic environment for decision making where decisions have programmatic and technical consequences
- Exposing the participants to job-relevant scenarios and problems
- Providing rapid feedback by accelerating time and experiencing the downstream consequences of the decisions made

Outcomes needed to achieve this goal include:

1. Moving the systems engineer to the next level of proficiency in one or more SE competencies as listed in the Systems Planning, Research Development, and Engineering (SPRDE) Systems Engineering (SE) and Lead Systems Engineer (LSE) competency model, known as the SPRDE-SE/LSE.
2. Developing and maturing systems thinking skills.
3. Developing and maturing leadership skills.
1.2.4 TARGET AUDIENCE
The initial focus is on the Systems Engineering Executive Level skills of a DoD Lead Systems Engineer necessary to effectively manage complex systems throughout their lifecycle from an acquisition/acquirer viewpoint in a typical Project Management Office (PMO). The skills addressed may well complement or support those taught in senior program management courses. The SEEA targets the entire life-long learning of the Systems Engineer.

1.2.5 SUCCESS METRICS
Success of the Experience Accelerator prototype will be indicated with a positive result in the following areas:

• Experienced Lead Program Systems Engineers authenticate the EA and provide useful feedback on areas of improvement.
• Learners express general satisfaction with the learning experience.
• The potential for learners who successfully complete the training to be able to immediately implement lessons learned from the training experience to the job, assuming the culture allows this.

1.3 MANAGEMENT PLAN/TECHNICAL OVERVIEW
The RT16 work plan is summarized in the next section, with the detail in the Technical and Management Work Plan (A009). Program risks, addressed in the following section, were also reported on in the latter half of the project in the Monthly Status Reports (A008).

1.3.1 RESEARCH ACTIVITIES
The top priorities for this increment are in the following areas:

1. EA Capabilities:
   A. Develop, test and pilot stable multi-player capability. This will also include features that allow experienced instructors to provide feedback to the team, to convey whether the decisions made by the team made were appropriate and the resulting consequences.

   B. Provide the basis for learners to understand the impact of their recommendations. This should include the means by which the learner to have some appropriate predictive capabilities.

   C. Provide dialog that is synchronized not only to the state of the simulation (e.g., project status), but also to the history of recommendations made by the learners.
D. Provide an improved user interface such that they can quick find through an appropriate status chart, especially those not linked to the virtual desktop dashboard.

2. **Support Instructor and Student Pilots:** Provide support to DAU instructor and student pilots with EA application, materials and staff. Collection feedback and update EA application and materials as deemed appropriate. (None were conducted due to scheduling difficulties.)

3. **DAU Deployment:** Specification of the concrete deliverables so that the EA can be used in the DAU on a long-term basis. This includes criteria, requirements, sustaining support, technical details of the hosting requirements. (This was deferred due to delays in pilots and deployment.)
   
   A. Determine Hosting Solution(s) for DAU: Options include commercial support (external network), DAU support (DAU network) and/or support on a laptop within the classroom (classroom network).
   
   B. Migrate Development to 3\textsuperscript{rd} Party Support: This includes identifying support staff and cost, and determining process and procedures for ticket creation and processing.
   
   C. Update EA documentation: This includes the concept of operations, system and support specifications, architecture and design document, and experience tools and development document.

4. **Section 508 Compliance:** These issues will be addressed in a separate RT proposal on a parallel path. (This activity was deferred.)

5. **Tools for DAU customization:** This will be addressed in a separate RT supported by SERC core funds. The DAU will be offered to the option to test and pilot the tools that are developed in this research effort. (This work was initiated and reported in SERC Technical Report No. SERC 2015-TR-016-4, RT 123: Design and Development Tools for the Systems Engineering Experience Accelerator - Part I.)

The major research activities that were completed in Increment 3 are as follows:

1. **Lecture/Student Materials**
   
   a. Update Instructor User Guide: This includes additional information on the multi-player roles. In addition, this work addressed additional issues and/or requests that arose from subsequent reviews of the materials. This included information on the range calculations, systems dynamics models, etc. The DAU provided a mark-up of the guide used for the student pilots to facilitate this work.

2. **Stabilization and Performance Enhancements**
a. Stabilized system in Single- & Multi-Player mode: This work completed any additional items discovered for single-player mode, and was done for multi-player mode.

b. Performance Enhancements: This work implemented a number of the potential performance enhancements noted in the EA Increment 2 Final Report to reduce the server system requirements.

3. Complete full Multi-Player Mode – Stevens
   a. Ensured that current communication and decision making features work correctly. E.g., resolved potential common folder issues.
   b. Prevented students from proceeding to CDR until instructor is ready.
   c. Supported ability for instructor to create teams.

4. Update Phases 3-5 – entire EA team
   a. Updated simulation, dialog and artifacts to be consistent with the pre-integration phase.

5. EA Enhancements: The following are enhancements were identified and prioritized during this research period.

   a. Artifacts: Stevens <items highlighted in yellow not completed>
      i. Placed cost and critical defect feedback in emails
      ii. Provided Information in email on effects of recommendations
      iii. On critical software error charts, y-axis units took on integer values
      iv. Showed test defect correction rate on dashboard.
      v. Provided the ability to print out learner reports for the instructor.
      vi. Improved readability of colors in status charts.
      vii. Update IMS if CDR is moved out. (determined not to be necessary)
      viii. Phase charts (dashboard charts) should display full delay past CDR (deferred)

   b. Dialog: Stevens
      i. Enhanced dialog to establish risk tolerance, opinions on achieving CDR and other clues.
      ii. Merged some background material into simulation dialog.
      iii. Made dialog to be in sync with both recommendations and project status.
      iv. Moved some information from PM to other NPCs.
      v. Made the dialog change if the learner moves weight from one subsystem to another.
      vi. Added more hints about Command & Control capabilities in the dialog.
      vii. Showed question and answer together in a single screen.
viii. Make NPC unavailable for calls after he/she has been called during a phase. (deferred)
ix. Ensure that PM dialog is correct past CDR (deferred)
x. Add dialogs with test NPC. (deferred)

c. **Flow: Stevens**
i. Tested case of delay in schedule beyond 6 months. If delay too long, indicate experience is over.
ii. Ensured that CDR pass/fail and learner dismissal are consistent with the simulation results.
iii. Include a test readiness review prior to flight readiness review. (determined not to be necessary)
iv. If mandatory survey is completed once, there is no need to complete it again even after aborting. (deferred)
v. Initiate a call from the PM if the LSE recommends a change in schedule. (deferred)

d. **Interface: Stevens**
i. Fixed date and time issues
ii. Eliminated issue of certain artifacts being larger than the virtual desktop.
iii. Made it easier to find recommendation form (put link on desktop).
iv. Created a numerical score for each experience. Use a weighted combination of performance measures, and other metrics to calculate a normalized score.
v. Improved paging within documents, particularly status charts that are not accessed through the dashboard.
vi. Made folders more user friendly. Investigate use of a “details” like view for folders/directories.
vii. Update help videos for current dashboard.
viii. Add reference material information to the Help system. DAU to provide a list of references relevant to the scenario. (deferred)
x. Label EA phases to align with DAU terminology. DAU to review this and generate a list of recommendations. (deferred)

e. **Simulation: Georgia Tech**
i. Simulated the effect of having test reviews impact progress on creating software. Positive impact on long-term quality. Negative impact on short term productivity.
ii. Ensured that weight and range are issues if no steps are taken by the learner to address it.
iii. Created high-resolution status charts.
iv. Send an error message when the learner inputs a quantity for a variable that is not feasible/cannot be handled by the simulation.
v. Changed thrust specification to a thrust/weight ratio or similar for jet engine performance.
v. Investigated having the ability to relax the range KPP and keep it consistent with other parameters.

vii. Reviewed the TPMs to ensure that they obey the proper relationships.

1.3.2 Risk Management

In addition to the work activities, five top program risks were identified and tracked throughout the first year of the program in the following areas:

1. Effectiveness of Experience
2. Deficiencies of Functionality/Capability
3. Difficulties in Learning Measurement
4. Delayed Funding
5. Challenges in DAU Hosting Solution

Mitigation strategies were put in place as described below.

1. Effective and Authentic Learning Experience Challenges

Risk: Inability to produce a prototype that provides a compelling experience, supports the desired learning and is seen to be authentic.

Mitigation: Develop and review a design experience document which is used to guide the development process. This experience document will be improved to ensure that it contains the specific information necessary to facilitate configuration management. Unfortunately, due to the instability of the implementation in Increment 1, it was difficult to iteratively develop dialogue and feedback. However, the Experience Accelerator is now sufficiently robust that this iterative approach can be taken. Additional tools will be explored that could improve this situation by providing the ability to quickly see the ramifications of specific learner behaviors.

2. Functionality and Capability Deficiencies

Risk: Upon testing with actual students, a number of deficiencies in functionality and capability are discovered with the prototype. The major risk area is in multi-player capabilities.

Mitigation strategy: The EA has already been piloted with DAU instructors and students, so it is less likely that major issues will be discovered in subsequent pilots. Also, the multi-player capabilities have been designed and mainly require debug and updates. Regardless, a prioritized list of desired enhancements will be maintained and updated on a weekly basis, using an agile development process to implement the highest valued features.

3. Learning Measurement Difficulties

Risk: It is extremely difficult to find appropriate measures for learning in the selected areas.

Mitigation strategy: Review and model research on measuring learning outcomes in constructivist-based learning environments, such as those developed with case-based learning, problem-based learning, project-based learning, and discovery learning methodologies, in order
to determine how best to measure critical thinking, problem-solving, and professional skills and competencies, measure learner perceptions of learning in these areas, and capture the EA experience of some learners in order to capture qualitative evidence of learning, as exhibited through user actions and strategies within the simulation.

4. Funding Delay
Risk: Funding is delayed to the point where we lose the current students at Stevens who are most familiar with the technology. Their departure would delay the program.
Mitigation strategy: Ensure funding as rapidly as possible through this RT and the Tools RT which is supported by SERC core funding at the level necessary to support our students. Have students work on both the EA tools and infrastructure to broaden the learning base. Have self-funded doctoral students use the EA for their research.

5. DAU Hosting Solution Challenges
Risk: It is difficult to find a hosting solution that works for all of DAU.
Mitigation strategy: There are at least three different approaches that will be used, so that a solution can be potentially customized for each DAU site. This includes a global DAU solution (hosted in house), an external commercial solution or a laptop with the application server. The second two of these solutions has already been shown to work.

2 PROTOTYPE DEVELOPMENT

The following describes the development of the Experience Accelerator prototype in RT16 Increment 3.

2.1 INSTRUCTOR SUPPORT MATERIALS

The objective during this increment was to update the Instructor User Guide which includes providing additional information on the multi-player roles. This work also addressed additional issues and/or requests that arose from subsequent reviews of the materials. This included information on the range calculations, systems dynamics models, etc. The DAU provided a mark-up of the guide used for the student pilots to facilitate this work.

The Instructor User Guide was reviewed by DAU and updated accordingly. The latest version of the instructor guide is included in Appendix A. A Student Guide was also created which is a subset of the Instructor User Guide, namely EA Recommendation Dashboard scratch sheets, a Student Reflection questionnaire and an Overview of the EA.
2.2 EXPERIENCE DESIGN AND DEVELOPMENT

The following section describes the research done on the artifacts, dialog, experience flow and the development of a trade-study experience module.

2.2.1 OVERVIEW

It is believed that accelerating the learning and maturation of Systems Engineers requires:

- Viewing a program through the entire lifecycle
- Seeing the relationships between elements of the system, and the system developing the system
- Encountering the challenges faced in a complex system development
- Being able to navigate through the “gray” zone
- Creating mental templates which can be applied to similar future situations

### UAV System:
- S0 – System (UAV)
- S1 – Airframe and Propulsion (A&P)
- S2 – Command and Control (C&C)
- S3 – Ground Support (GS)

### Phases:
- **EA Introduction**
  - Phase 0 (P0): New Employee Orientation
- **Experience Introduction**
  - Phase 1 (P1): New Assignment Orientation
- **Experience Body**
  - Phase 2 (P2): Pre-integration system development -> CDR
  - Phase 3 (P3): Integration -> FRR
  - Phase 4 (P4): System Field Test -> PRR
  - Phase 5 (P5): Limited Production and Deployment
  - Phase 6 (P6): Experience End
- **Experience Conclusion**
  - Phase 6 (P6): Reflection

Each session = 1 day

*Figure 2: A Day in the Life of a LSE*

The SE Experience initially developed in the baseline year focused on developing the systems thinking, and problem solving and recovery skills of a DoD Lead Systems Engineer. As shown in Figure 2, the SE Experience is designed to provide this learning by simulating the lifecycle of a UAV in which the learner is brought into the program after the Preliminary Design Review and is responsible for discovering the issues in the program and making the appropriate recommendations to correct the situation. The UAV system consists of three major subsystems of which the Airframe and Propulsion is primarily electro-mechanical, the Command and Control system is mainly software, and the Ground Support system is mainly human based. The
major key performance measures (KPMs) are schedule, quality, range and cost. Each of the learner’s sessions in the Experience represent a single day in the program and are estimated to take approximately one hour to complete, although the learner is free to login and out any number of times during a session.

2.2.2 ARTIFACTS

Information contained in the artifacts was updated to reflect DAU nomenclature and to clarify the information consistent with feedback from the learners. Additionally, the following were completed:

- Placed cost and critical defect feedback in emails
- Provided Information in email on effects of the previous cycles recommendations, filling out the rationale behind the resulting status
- On critical software error charts, y-axis units took on integer values
- Showed test defect correction rate on dashboard.
- Provided the ability to print out learner reports for the instructor.
- Improved readability of colors in status charts.
- Status charts (accessed via the files menu) are adjusted if CDR is moved out.
- Phase charts (dashboard charts) should display full delay past CDR.
- A more thorough description of the dashboard values and their interpretations was drafted but not included.

2.2.3 DIALOG

The initial dialogues tended to be based on a single thread of actions on the part of the learner, and only varied slightly from cycle to cycle. As the experience evolved, and learners navigated the experience, it became obvious that the dialogues needed to be richer and more responsive, reflecting both the project status as simulated and the learner’s recommendations. Additional information was provided through new dialogs and the Mentor role (such as the specific status of the artifacts required for CDR).

Temporality

The dialogues had primarily been developed on a cycle basis rather than a sub-cycle basis. However, it was soon apparent that each sub-cycle, with the learner’s recommendations and the simulation results based on those recommendations, was the de facto cadence. To maintain the information flow to support the learner, dialogues were developed for each subcycle. This involved tracking the current subcycle status and providing different conversation tree branches based solely on the temporal subcycle. This allowed dialogues to be based on time-critical issues and to reflect and comment on recommendations. It also allowed insertion of challenges based on external events (such as unexpected changes to requirements, resources or schedules).
Relevance
The dialogues needed to better track the information that was provided in the recommendations of the learner and the results they generated in the simulation. To support this, dialogue variables were provided for conditional branching in dialogues. This allowed the dialogue to change based on the recommendations and simulation results. The NPCs can now provide additional information based on the simulation as well as the story line. The dialogues also display subject values to the learner during the conversation. While not necessary because of the new dashboard and recommendations interfaces, being able to use values in the conversation adds to its verisimilitude. It also can support or warn against a decision. The addition of the mentor to explain underlying rationale also improved the relevance of the dialogs.

The following were completed:
• To counter the reluctance of learners to interact with the PM, a required conversation was established that allowed the PM to answer questions about risk tolerance, opinions on achieving CDR, and other clues.
• Fleshed out the Mentor role to provide information both from the available artifact documents but also from external resources where appropriate.
• Enabled dialog to be in sync with both recommendations and project status.
• Merged some background material into simulation dialog.
• Moved some information from PM to other NPCs.
• Made the dialog change if the learner moves weight from one subsystem to another.
• Added more hints about Command & Control capabilities in the dialog.
• Showed question and answer together in a single screen.
• Make NPC unavailable for calls after he/she has been called during a cycle.
• Ensured that PM dialog is correct past CDR.

2.2.4 Experience Flow
The flow of the experience was enhanced in several ways. The dialogue enhances the learner’s concept of time passing and of the lag time for some decisions. Readiness for CDR is clarified through an algorithm that is adjustable by the instructor and is shown to the learner in an opportunity to proceed or delay offered after the cycle just prior to CDR. Overall multi-phase flow has not been adjusted significantly due to the focus on the one phase between PDR and CDR.

The following areas were completed:
• Tested case of delay in schedule beyond 6 months. If delay too long, indicate experience is over.
• Ensured that CDR pass/fail and learner dismissal are consistent with the simulation results.
• Significant reaction from NPCs, particularly the PM if the Learner recommends a change in CDR schedule.

The following areas were completed:
  ▪ Placed cost and critical defect feedback in emails
  ▪ Provided information in email on effects of recommendations
  ▪ On critical software error charts, y-axis units took on integer values
  ▪ Showed test defect correction rate on dashboard.
  ▪ Provided the ability to print out learner reports for the instructor.
  ▪ Improved readability of colors in status charts.

2.2.5 TRADE STUDY EXPERIENCE DESIGN

One of the most crucial skills for a seasoned systems engineer is the ability to make well-reasoned technical decisions, balancing often conflicting criteria to arrive at an optimal solution. In a typical tradeoff analysis, multiple competing design alternatives are assessed against defined criteria, often using weightings established through stakeholder consensus.

Given the importance of this skill, its inclusion in the Systems Engineering Experience Accelerator (SEEA), or EA for short, was considered to be an early priority in the prototype learning content.

2.2.5.1 Methodology

The approach to developing the trade study content for the prototype EA consisted of the following high-level steps:

1. Perform trade study concept selection
2. Perform background research in selected trade area
3. Define trade alternatives and a set of appropriate weighting criteria
4. Lay out the high-level trade experience flow
5. Populate the established trade framework with draft content
6. Update the Experience Design Document (EDD)
7. Identify and document future work required to complete implementation

In order to develop an effective trade study simulation, an appropriate trade concept first had to be identified. The complexity of a large UAV offered numerous design areas that could serve as suitable topics for a design trade. However, it was important to select a concept that would balance a number of criteria, such as technical relevance, learning value, and ease of integration into the EA. As this is the very nature of a trade study, it seemed appropriate to start the project with a trade study of trade study concepts. In this case, after comparison of a number of competing options, rearchitecture of the UAV’s actuation systems proved to be the top choice, as detailed below.
Once the concept was identified, the next step was to perform background research in the appropriate decision space – i.e. UAV actuation systems. This was to ensure the chosen trade topic would be realistic, technically relevant, and supported by relevant real-world data. Having gained an understanding of the decision space, the next step focused on bounding the scope of the trade. This included identifying the actuation system architectures that would serve as the trade candidates and defining what criteria would be used to rank the alternatives.

At this point, with the options and criteria established, it was time to define underlying “design” values for the criteria weightings, the ranking scale, the option-criteria rankings themselves, and the expected trade outcome. This represented a critical step; it guided the development of dialogues and other artifacts to inform the Learner’s decision making, and it provided a basis upon which the Learner’s performance could be gauged.

A high-level flow of the trade study experience was then developed to serve as a storyboard upon which the simulation events, interactions, and recommendations could be built. This included analyzing the chosen design values for the criteria weightings and the option-criteria rankings to develop some notional dialogue themes. With the bulk of the trade study experience “roughed out”, the Experience Design Document (EDD) was updated to reflect this new content.

Note that this project concluded prior to any integration work. A discussion of the effort required to complete implementation is described below.

2.2.5.2 Results
The following sections describe in detail the results of the activities outlined above.

a. Trade Study Concept Selection
The approach of performing a trade study to select the trade study concept worked quite well. The complexity of a HALE UAV provided a wide range of technical challenge areas suitable for a design trade. A set of five potential trades were selected, based on major functional areas. The descriptions of each conceptual trade are provided in Table 1 below.

<table>
<thead>
<tr>
<th>Trade Concept</th>
<th>A trade between:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Fairing Opt.</td>
<td>Three different fairing designs - the baseline design, one lighter but with a higher drag coefficient, and one heavier but more streamlined</td>
</tr>
<tr>
<td>COTS GNC/Avionics</td>
<td>Lower-cost Commercial-Off-the Shelf (COTS) avionics, COTS with a packaging redesign, or a custom design</td>
</tr>
<tr>
<td>Engine Technology</td>
<td>Alternative propulsion sources, including the baseline turbine engine, a fuel cell, or some alternative power source</td>
</tr>
</tbody>
</table>
Electrical Power System Optimization

Four different electrical system architectures – the baseline turbine driven generator, a separate Auxiliary Power Unit (APU), a fuel cell power source, or some composite of those options

Actuation System Rearchitecture

Four different actuation system configurations – the baseline hydraulic actuators, electrohydrostatic actuators, a mix of hydraulic and electromechanical actuators, or entirely electromechanical

With a number of trade study concepts identified, the next task was to identify appropriate criteria on which to evaluate the options. It was considered a high priority to have a trade study concept that could be easily implemented. Likewise, the trade should provide an opportunity for additional learning value. For example, could certain “ilities” aspects, such as Supportability or Reliability, be introduced? Of lesser importance, the trade study should represent a realistic and technically relevant area of investigation. It was considered of moderate importance to have a suitable level of technical depth necessary to make the trade. Lastly, to the extent possible, the trade should be an interesting problem area. With these factors in mind, criteria weightings were assigned, as in Table 2.

Table 2 - Trade Study Concept Selection Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
<th>Weighting (1-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Implementation</td>
<td>How easily can the idea be incorporated into the existing experience?</td>
<td>10</td>
</tr>
<tr>
<td>Learning Value</td>
<td>How well does it teach trade techniques? Does it impart other learning?</td>
<td>10</td>
</tr>
<tr>
<td>Realism</td>
<td>How technically relevant is the trade? Is it realistic?</td>
<td>5</td>
</tr>
<tr>
<td>Depth of Trade Content</td>
<td>Is the trade either too superficial or excessively detailed? (Looking for middle ground.)</td>
<td>5</td>
</tr>
<tr>
<td>Fun Factor</td>
<td>How interesting is the trade from the student’s perspective?</td>
<td>3</td>
</tr>
</tbody>
</table>

Each of the trade concepts was then examined to identify potential alternatives and rating criteria. For example, the Engine Technology trade was framed as a trade-off of the baseline turbine engine vs. a reciprocating engine vs. a fuel cell propulsion source, scored against criteria of Reliability, Cost, Weight, Maturity, Supportability, and Technical Risk.

With a general outline of each of the five trade concepts, it was then possible to rank them against the criteria in Table 2. The results of this ranking are shown in Table 3 below. The Payload Fairing Optimization and COTS GNC/Avionics options received poor scores in depth of trade and learning value. Engine Technology and Electrical Power System Optimization were
stronger contenders, but were challenged with respect to ease of implementation. In the end, when the scores were tallied, the Actuation System Rearchitecture option rose to the top on the basis of strong rankings in all categories, as noted in Table 4 below.

**Table 3 - Trade Study Selection Matrix**

<table>
<thead>
<tr>
<th>Option</th>
<th>Realism</th>
<th>Ease of Implementation</th>
<th>Learning Value</th>
<th>Depth of Trade Content</th>
<th>Fun Factor</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Fairing Opt.</td>
<td>25</td>
<td>75</td>
<td>40</td>
<td>50</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>COTS GNC/Avionics</td>
<td>75</td>
<td>75</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>61</td>
</tr>
<tr>
<td>Engine Technology</td>
<td>25</td>
<td>40</td>
<td>75</td>
<td>25</td>
<td>75</td>
<td>49</td>
</tr>
<tr>
<td>Electrical Power System Optim</td>
<td>75</td>
<td>50</td>
<td>75</td>
<td>40</td>
<td>75</td>
<td>62</td>
</tr>
<tr>
<td>Actuation System Rearchitecture</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>60</td>
<td>74</td>
</tr>
</tbody>
</table>

The results of the trade study were reviewed with the core EA development team. After some sensitivity analysis, by varying weightings and ratings, the consensus was that the selection of the actuation system trade concept was the most appropriate; it “felt right”.

**Table 4 - Actuation System Rearchitecture Rankings and Rationale**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Ranking</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realism</td>
<td>75</td>
<td>The concept of &quot;more electric aircraft&quot; has been the topic of considerable research.</td>
</tr>
<tr>
<td>Ease of Implementation</td>
<td>75</td>
<td>This should be a fairly straightforward integration into the UAV experience.</td>
</tr>
<tr>
<td>Learning Value</td>
<td>75</td>
<td>Includes safety, reliability, sizing, etc.</td>
</tr>
<tr>
<td>Depth of Trade</td>
<td>75</td>
<td>The depth of this trade could be tailored to fit.</td>
</tr>
<tr>
<td>Fun Factor</td>
<td>60</td>
<td>This should offer an interesting look into a real-world trade.</td>
</tr>
</tbody>
</table>

A discussion with the EA development team confirmed the findings of the trade study, establishing the Actuation System trade study as the go-forward concept.

**b. Background Research**

To provide perspective, the baseline requirements for size, range, payload, and endurance for the UAV in the EA prototype were compared to the specifications of the various aircraft in the US UAV fleet. The requirements of the UAV in the prototype EA align very closely with those of
the RQ-4 Global Hawk platform; both would be considered High-Altitude Long Endurance (HALE) class UAVs, with similar ranges and payloads, primarily oriented towards reconnaissance missions.

Block diagrams of the electrical and hydraulic systems, provided a sense of system complexity and identified the various hydraulic actuators in a typical platform of this type. For perspective, as noted in the hydraulic system block diagram in Figure 3, the Global Hawk airframe includes a dozen actuators for the various landing gear door, landing gear, and steering functions.

![Figure 3 - Global Hawk Hydraulic System Block Diagram - Source: (NPS, 2003)](image)

Data was then gathered on the relative strengths and weaknesses of the various types of actuators used in aircraft systems. While somewhat dated, an excellent example of a trade study of exactly this nature was found in (Boldt, 1982). This was a report on an extensive trade study by Boeing Military for the Flight Dynamics Laboratory and Aero Propulsion Laboratory at Wright-Patterson Air Force Base. As noted in the report, the primary objective was “to establish the advantages/disadvantages and life cycle cost impact for two types of 1990+ time frame airplanes, one which has hydraulically powered actuation systems (Baseline Airplane), and the other which has electrically powered actuation systems (All-Electric or Power-By-Wire Airplane).” The report indicated a number of relevant distinctions, such as a higher level of risk for all-electric actuation systems, and improved reliability metrics for a traditional hydraulic actuation architecture.
In addition, thermal management requires careful attention in an electromechanical actuation system. While a centralized hydraulic architecture uses the hydraulic oil to move heat away from components, this is not possible in the case of electrohydrostatic or electromechanical actuators. Instead, additional cooling mechanisms, such as heat sinks or increased airflow, are required. An excellent discussion of the thermal management challenges for EMAs can be found in (Lawson, 2008).

c. Trade Detail Definition

With an understanding of the advantages and disadvantages of the various actuation system architectures, it was then possible to define a set of weighted decision criteria and assign rankings for each of the options against those criteria. A scale of 1-10 was used for criteria weightings, and the rankings were indicated on a 5-point scale – Strong Negative, Negative, Neutral, Positive, and Strong Positive. These chosen design values, indicated in yellow in Figure 4 below, were assigned for consistency with the simulated UAV program priorities and the actuation system research discussed above. This ensured that the trade study maintained a sense of realism, and it provided guidance for the development of the dialogue and related artifacts, as will be discussed below. For future reference by the EA development team, the rationale for the various assignments was captured in comments in the “Trade Matrix Master” worksheet in the Actuator Trade Study Development spreadsheet file, provided with the project artifacts.

<table>
<thead>
<tr>
<th>Criteria →</th>
<th>NRE</th>
<th>Flyway Cost</th>
<th>Total Syst. Wt. Impact</th>
<th>Schedule</th>
<th>Thermal</th>
<th>EMI/EMC</th>
<th>Reliability</th>
<th>Integration Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA Designed Weighting (1-10 Relative)</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Learner Weighting (1-10 Relative)</td>
<td>13%</td>
<td>13%</td>
<td>19%</td>
<td>8%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Designed Wt. % Learner Wt. %</td>
<td>13%</td>
<td>13%</td>
<td>19%</td>
<td>8%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Options</th>
<th>NRE</th>
<th>Flyway Cost</th>
<th>Total Syst. Wt. Impact</th>
<th>Schedule</th>
<th>Thermal</th>
<th>EMI/EMC</th>
<th>Reliability</th>
<th>Integration Risk</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline hydraulic actuators</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Electrohydrostatic actuators</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>-5</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1.19</td>
</tr>
<tr>
<td>Split Electromechanical / hydraulic</td>
<td>-5</td>
<td>-1</td>
<td>5</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>-5</td>
<td>-5</td>
<td>-1.06</td>
</tr>
<tr>
<td>All Electric actuators</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-3</td>
<td>-3</td>
<td>-0.62</td>
</tr>
</tbody>
</table>

Figure 4 - Master Actuator Trade Matrix

The design values in the master trade matrix represent the “answer key”, against which the Learner’s rankings, recommendation, and rationale can be scored. Looking at the trade study scores for the various architectures, it is interesting to note that the baseline option represents the recommended approach. In other words, make no change to the actuation system architecture; the negative impacts to cost, schedule, thermal performance and integration risk of the more electric options do not justify the weight savings, given the relative priorities of the criteria.
The criteria weightings, as noted above, were assigned for consistency with the current evolution of the UAV EA simulation. However, by modifying the underlying nature of the simulation, as evidenced through the dialogues and simulation behavior, the EA program priorities could be fundamentally shifted. In this case, the criteria weightings could be quite different, resulting in an entirely different recommended solution.

**d. Trade Study Flow Development**

A high-level flow of the trade study experience was then developed to serve as a storyboard upon which the simulation events, interactions, and recommendations could be built. The major phases of the UAV actuation system trade experience were defined as follows:

- Trigger the trade experience
- Setup actuator alternatives and weighting criteria, via NPC dialogues
- Provide Learner with required data, via NPC dialogues and artifacts
- Provide a trade recommendation form, including rationale, for communication to PM
- Update the simulation based on the Learner’s recommendation
- Provide experience feedback

There was some discussion amongst the EA team regarding the best way to trigger the trade. Should it be triggered at any point in the pre-CDR phase, based on certain parameters, or should it be assigned to a fixed point in the experience? As the current EA UAV experience is still being optimized, it was decided that it would be most appropriate to lock it into a specific point in the experience, currently Phase 2A Cycle 2. This prototype will be used as a baseline for evaluating the EA’s potential as a teaching tool, so randomness in the experience, while realistic, was considered to be a detriment.

From a storyline perspective, the decision was made to trigger the trade by a significant step change in system weight, due, notionally, to a need to add shielding and filters to meet stringent shipboard electromagnetic interference (EMI) and electromagnetic compatibility (EMC) requirements. The trade would be initiated by a call from the Prime’s Project Systems Engineer (P-PSE). One option that was considered was to adjust the simulation based on how quickly, if at all, the Learner notifies the Program Manager (PM) of the weight hit. As shown in the flowchart in Figure 5, this could affect how receptive the PM character is of the issue; in a worst-case scenario, if the Learner fails to notify the PM of the weight problem, it could lead to their termination in the leadership role and the end of the experience.
Dialogue with the P-PSE would then be used to introduce the idea of rearchitecting the actuation system, to provide the alternative architectures, and to indicate some initial pros and cons of each. Dialogue with the PM would provide the trade study assessment criteria and insight into their relative importance, consistent with the criteria and EA designed weightings in Figure 4. Draft dialogue talking points for this are provided below. To be most effective, the criteria and weightings should reflect the views of a broad stakeholder base. This could be addressed by having the PM meet with those in the User and Supportability communities, returning with weightings from multiple perspectives to be consolidated into the trade study by the Learner.

At this point, the Learner would require additional data in order to evaluate the various candidate architectures across the given criteria and to provide an appropriate
recommendation. This is expected to come from additional artifacts, consistent with the background research in Section b above.

Once the Learner has all of the information needed to make an informed decision, a recommendation form would be provided to allow the Learner to submit rankings, recommendation, and rationale. A template for this has been developed and is provided in the EA team’s development work area.

As part of the integration effort, the effects of the Learner’s recommendation on the execution of the simulation would need to be determined. While this is at the EA designers’ discretion, there are some expected impacts to non-recurring engineering (NRE) cost, schedule, and Critical Design Review (CDR) criteria that should be modeled. Additional effects; including flyaway cost, reliability, and integration risk; could also be introduced as the simulation evolves. These effects will need to be identified for both the recommended “stay the course” alternative, as well as for the less favorable redesign options.

Lastly, the Learner’s recommendation needs to be evaluated against the expected response and feedback provided. Simulation variables have been identified for the various Learner entries in Figure 4. While they may not all be necessary, they provide flexibility in scoring the Learner’s response against the “design” values.

e. Trade Content Development

Trade content development included analyzing the chosen design values for the criteria weightings and the option-criteria rankings to develop some notional dialogue themes. The dialogues serve as a primary means for the Learner to gather information upon which to make their recommendation. It is, therefore, critical to ensure the dialogues are relevant, consistent, and lead the Learner in the appropriate direction. Failure to do so would result in an unrealistic experience, potentially distracting the Learner from the lessons and compromising the learning opportunity.

Due to the complexities involved, fully defining Learner and Non-Player Character (NPC) dialogues was beyond the scope of this project. Instead, key dialogue ‘talking points’ were identified, consistent with the trade experience. For example, on the topic of criteria weighting, the design places a high emphasis on weight savings, integration risk, and cost factors, while it allows for some potential for schedule relief, if it might result in a better solution. Table 5 below shows the designed criteria weightings and provides some associated PM dialogue themes; these are intended to serve as a starting point for detailed dialogue development during implementation. As noted earlier, the evaluation criteria will be given as part of the experience and will be listed on the Trade Study Recommendation Form. It will be up to the Learner to infer the program priorities from the artifacts and dialogue and to assign their own weighting factors for the criteria.
Table 5 - Criteria Weighting Talking Points

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Designed Weighting</th>
<th>Proposed PM Dialogue</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRE</td>
<td>7</td>
<td>&quot;Need to enforce that weight is king, given its impact on fuel capacity and range, but we can't lose sight of other possible impacts of the change. We need to be conscious about pricing ourselves into cancellation - now or later. If we come up with the right design, the program office could be understanding of a minor schedule hit, but we need to tread carefully there.&quot;</td>
</tr>
<tr>
<td>Flyaway Cost</td>
<td>7</td>
<td>(Learner needs to identify importance of integration risk.)</td>
</tr>
<tr>
<td>Total System Weight Impact</td>
<td>10</td>
<td>(Note: For challenge, update dialogue so that PM pushes for weight savings beyond all else.)</td>
</tr>
<tr>
<td>Schedule</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>EMI/EMC</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Integration Risk</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

A similar approach was taken with the dialogues intended to inform the Learner’s ranking decisions. To help synthesize talking points for the ranking dialogues, consistent with the designed ranking values in the master trade matrix in Figure 4 above, the trade matrix was examined in “slices”. First, each of the architecture options was analyzed across all criteria in order to develop dialogue characterizing strengths and weaknesses, as shown in Figure 6 below. Likewise, Figure 6 shows a similar analysis – this time for a single criteria across all four architecture options.

Figure 6 - Dialogue Talking Points - Per Architecture
<table>
<thead>
<tr>
<th></th>
<th>Baseline Electrohydraulic</th>
<th>Electrohydrostatic actuators</th>
<th>Split Electromech / Electrohydraulic</th>
<th>Fully Electromechanical</th>
<th>Suggested Dialogue</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRE</td>
<td>0</td>
<td>-1</td>
<td>-5</td>
<td>-5</td>
<td>Cheapest approach is to stay the course. May get by with converting to electric/hydraulic without too much “pain and suffering”, but anything involving electromechanical actuators is likely to get pricey, due to thermal issues.</td>
</tr>
<tr>
<td>Flyaway Cost</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>The cheapest actuators are the simplest - pure hydraulic. As soon as you involve electric motors, the hardware costs will rise.</td>
</tr>
<tr>
<td>Total System Weight Impact</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>Doing nothing gains nothing. Switching to electrohydrostatic turns out to be a wash from a weight perspective. Trading hydraulic plumbing for wiring does save a bit, but to make any real weight gains, you need to optimize the hydraulic/electric balance.</td>
</tr>
<tr>
<td>Schedule</td>
<td>0</td>
<td>-1</td>
<td>-5</td>
<td>-5</td>
<td>We might take a minor hit for introducing some electrically powered hydraulic actuators, but adding any electromechanical actuators is going to be a big disruption.</td>
</tr>
<tr>
<td>Thermal</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>-5</td>
<td>As long as the fluid is moving, it can relocate heat to a suitable location. If it’s self-contained, though, there’s no benefit in centralized dissipation.</td>
</tr>
<tr>
<td>EMI/EMC</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>Additional electrical motors/pumps will result in greater RF emissions. Could be a challenge, especially for shipboard operations.</td>
</tr>
<tr>
<td>Reliability</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>Nothing beats hydraulic fluid when it comes to reliability. As soon as electronics and wiring are involved, reliability will take a hit.</td>
</tr>
<tr>
<td>Integration Risk</td>
<td>0</td>
<td>-1</td>
<td>-5</td>
<td>-1</td>
<td>Keeping with strictly hydraulic or mechanical would be simplest. As soon as you start mixing modes, things are going to get challenging.</td>
</tr>
</tbody>
</table>

**Figure 7 - Dialogue Talking Points - Per Criteria**

A trade study recommendation form was then developed, as shown in Figure 8. The blue cells provide for input of the Learner’s criteria weightings, rankings, recommended architecture, and rationale. Based on the user entered values, the form automatically calculates the overall scores for the various architectures. It is then be up to the user to make a recommendation and to provide their rationale.
Figure 8 - Trade Study Recommendation Form

f. Experience Design Document Update

The EA Experience Design Document (EDD) was also updated as part of this project in order to capture design decisions, discussion and changes associated with the new trade study content. This included documenting the trade study flow and the associated new events, the simulation variables associated with trade, the trade study master matrix, and the new recommendation form.

This project was primarily focused on the trade study concept development and documentation. Due to other ongoing development, little time was available for incorporating such a significant change to the prototype EA.

In order to get the trade study up and running, the voicemail, email, and dialogue contents need to be fleshed out, consistent with the other existing content. The events associated with the trade need to be incorporated into the experience in Phase 2A Pre-CDR with the appropriate triggers. This could serve as a good test case for the new experience development tools. Integration must also include modeling the impacts to the various simulation development variables. Lastly, an approach for scoring the Learner’s recommendations needs to be established, along with a means of providing feedback.

2.2.5.3 Conclusions and Future Work

This project has established a cohesive trade study for incorporation into the prototype Experience Accelerator. The UAV actuation system trade study, as designed, exercises the Learner’s decision making skills, reinforcing the importance of making balanced and justified
decisions. It provides a framework and draft content upon which an interactive trade study learning experience can be built.

In addition to the items noted in Section Error! Reference source not found. above, a number of areas of potential future work have been identified. In conjunction with the other planned training verification activities, some additional effort will be required to ensure the effectiveness of this training. Does this simulated trade study have a measurable, positive effect on a Learner’s ability to make and justify sound technical decisions? As part of integrating the trade study into the baseline prototype EA, the team should consider how to validate the trade study lessons. This will likely require additional group EA sessions with appropriate ‘before and after’ skills questionnaires. Feedback from the DAU sponsors and instructors would be beneficial, as well.

Similar to the tools currently in development to aid generating new experiences, consideration should be given to developing a generic trade study capability. Trade studies are very structured, consisting of a clearly defined set of options, criteria, weightings, and rankings. A parameterized trade study tool could be developed to assist with generating new trades and incorporating them into a simulation.

2.3 TECHNOLOGY DEVELOPMENT

2.3.1 BACKGROUND

The EA game engine has two components: the runtime engine and the tools suite. The tools suite includes the Experience Development and Simulation Engine-related tools described in the Section 2.6.

In this section we will describe the EA Run Time Engine component (EARTE). As shown in Figure 9 the EARTE has a layered architecture client-server incorporating the following modules:

- **Experience Master**: contains the overall Experience state and provides control and sequencing for the other major EA modules.

- **Challenge Control**: contains the Learner profiles and Experience history logs and leverages these in conjunction with the competency taxonomy and ‘Aha’ moments to determine the appropriate challenges and landmines for each Learner.

- **Simulation Engine**: determines the future state of the system and outputs to be presented to the Learner.

- **Non-Player Characters (NPC) Engine**: represents other non-player characters in the simulation, and creates and assembles the content for Learner interactions.
• **Presentation Engine**: accepts inputs from the Learner and provides the presentation of the Experience interface to the Learner.

**Figure 9: Experience Accelerator Logical Block Diagram**

The EARTE is a multiuser architecture for internet gaming. It has light clients (currently implemented in FLASH) and a Java server which runs multiple game instances concurrently. In order to support as wide as possible range of EA games and scenarios the EARTE does not incorporate a simulation engine, but rather the NPC engine provides a framework to interface with 3d-party simulation engines. For more on the simulation see Section 2.5.

During Increment 3 the technology development team continued to refine the EARTE to achieve architecture adherence and improved runtime performance stability. The major effort in Increment 3 were the stabilization and improvement in the multi-learner capabilities, artifact and status navigation and Dashboard and Recommendation forms. The following section provides an overview of the work that arose from suggested enhancements, fixes, and multi-learner capabilities.
2.3.2 STABILIZATION AND PERFORMANCE ENHANCEMENTS

The following research was completed during Increment 3:

- Stabilized system in Single- & Multi-Player mode: This work completed any additional items discovered for single-player mode, and was done for multi-player mode.
- Performance Enhancements: This work implemented a number of the potential performance enhancements noted in the EA Increment 2 Final Report to reduce the server system requirements.
- Simulator Integration: One of the most important components of the EA is the ability of user actions to affect the state of the simulation. The ability to create variable outcomes by having an impact on the simulation and receive feedback based on simulation results is necessary for effective learning. To achieve this, the inputs and actions of the user must affect the simulation engine and the results of the simulation engine must be used by the rest of the system. Integration with the simulation engine involves:
  - Accepting user recommendations
  - Receiving simulator output
  - Making state calculations based on simulator output
  - Affecting behavior and feedback based on the output and calculations
- Networking Robustness: Because the EA is separated into a server and client is dependent on the server for most operations, a reliable means of communication between the two is a must. The EA uses the TCP protocol for its dependability. TCP guarantees packet delivery and delivery order and is used in many online games and simulations due this provided reliability. To improve the robustness and performance of networking between the server and client, communication was re-structured and enhanced by:
  - Creating a buffering system for messages
  - Grouping small messages and reducing frequency
  - Moving form synchronous pulling to asynchronous pushing

The performance of the Experience Accelerator was enhanced based on the analysis and recommendations from the Increment 2 research. This analysis and enhancements are summarized below.

2.3.2.1 Analysis

Based on a review of the response latencies, it is believed that the simulation, file update and status chart generation activities provide the greatest resource load on the Experience Accelerator server. A series of profiling experiments on independent runs of the system dynamics simulation were conducted in order to determine the system requirements necessary to support 30 simultaneous Experience Accelerator users, which is the objective for the initial DAU deployment. The results of this analysis are described in detail in Developing the Systems Engineering Experience Accelerator (SEEa) Prototype and Roadmap, Final Technical Report Increment 2, SERC-2012-TR-16-3, December 31, 2013.
The total time to complete a set of concurrent simulations was measured while varying the number of concurrent simulations. Figure 10 indicates that the total time scales linearly in the number of concurrent simulations, until the point at which simulations begin to fail due to insufficient memory (points marked by “X”).

Figure 10: Total simulation time in seconds, as the number of concurrent simulations is increased. Trials marked by “X” terminated before completion, due to insufficient memory.
Based on the linear trend seen in Figure 4, one would expect that even with sufficient RAM, the target of 30 simultaneous simulations would require as long as 6 minutes to complete. Figure 11 estimates the time required if more CPU cores were available: 4 cores would allow the simulations to complete in approximately 3 minutes, using 12 cores reduces the time to 1 minute, and 24 cores are needed to bring the worst case to 30 seconds. One can approximate the time for other scenarios with:

\[
\text{time} = 0.4 \text{ minutes} \times \text{concurrentSimulations} \div \# \text{cores}
\]

Figure 11: Estimated total execution time of 30 concurrent simulations as the number of available CPU cores is increased.

CPU utilization during the Phase-2 initialization and Phase-2 simulations is shown in Figure 12. The breakdown of CPU usage is approximately:

- 20% - startup costs (load and pre-process model XML)
- 5% - actual simulation
- 70% - rendering, encoding, and writing graph files
  - 20% reading CSV files
- 10% drawing of the graph
- 20% rasterizing the graph to an image buffer
- 20% encoding the image buffer and saving as jpeg

**Figure 12: CPU Utilization Breakdown**

### 2.3.2.2 Performance Optimizations

This section describes an approach that was taken to reduce the server resource requirements necessary to support the targeted 30 simultaneous users assuming that these users are synchronized and thus maximally stress the system.

**Implemented a work queue for simulation runs**

Limiting the number of concurrent simulation runs should reduce average wait time by between 25 and 50%, depending on the number of users. In Figure 13, three users’ simulation instances are started concurrently, and each takes approximately three time units to complete.
In Figure 13, six clients with a limit of two concurrent simulations.

<table>
<thead>
<tr>
<th>User 1 Submit</th>
<th>User 1 Start</th>
<th>User 1 Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 2 Submit</td>
<td>User 2 Start</td>
<td>User 2 Finish</td>
</tr>
<tr>
<td>User 3 Submit</td>
<td>User 3 Start</td>
<td>User 3 Finish</td>
</tr>
</tbody>
</table>

Figure 13: Concurrent execution

In Figure 14, three users’ simulation instances are started sequentially, and each takes approximately one time unit to complete. The average time to completion is two time units, instead of three.

<table>
<thead>
<tr>
<th>User 1 Submit</th>
<th>User 1 Start</th>
<th>User 1 Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 2 Submit</td>
<td>User 2 Wait</td>
<td>User 2 Start</td>
</tr>
<tr>
<td>User 3 Submit</td>
<td>User 3 Wait</td>
<td>User 3 Start</td>
</tr>
</tbody>
</table>

Figure 14: Sequential execution

If there are underutilized cores, more instances can be run concurrently. Figure 15 illustrates six clients with a limit of two concurrent simulations.

<table>
<thead>
<tr>
<th>User 1 Submit</th>
<th>User 1 Start</th>
<th>User 1 Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 2 Submit</td>
<td>User 2 Start</td>
<td>User 2 Finish</td>
</tr>
<tr>
<td>User 3 Submit</td>
<td>User 3 Wait</td>
<td>User 3 Start</td>
</tr>
<tr>
<td>User 4 Submit</td>
<td>User 4 Wait</td>
<td>User 4 Start</td>
</tr>
<tr>
<td>User 5 Submit</td>
<td>User 5 Wait</td>
<td>User 5 Start</td>
</tr>
<tr>
<td>User 6 Submit</td>
<td>User 6 Wait</td>
<td>User 6 Start</td>
</tr>
</tbody>
</table>

Figure 15: Partially concurrent execution

2.3.3 COMPLETE FULL MULTI-PLAYER MODE

Research was completed in the following areas:

- Ensured that current communication and decision making features work correctly. E.g., resolved potential common folder issues.
- Prevented students from proceeding to CDR until instructor is ready.
- Supported ability for instructor to create teams.

2.3.4 LEARNER INTERFACE ENHANCEMENTS

Research was completed in the following areas:

- Fixed date and time issues
- Eliminated issue of certain artifacts being larger than the virtual desktop.
- Made it easier to find recommendation form (put link on desktop).
- Created a numerical score for each experience. Use a weighted combination of performance measures, and other metrics to calculate a normalized score.
• Improved paging within documents, particularly status charts that are not accessed through the dashboard.
• Made folders more user friendly. Investigate use of a “details” like view for folders/directories.
• Update help videos for current dashboard.

2.3.5 TOOLS INFRASTRUCTURE SUPPORT
The EA was implemented with the UAV experience in mind and thus certain code base was written specifically for the domain. To support the development tools, current EA code base needed significant efforts to update to a more domain-independent approach. In increment 3, many efforts were made to allow development tools to alter current experience.

2.4 SIMULATION
The following section describes the research that was completed in the area of simulation.

2.4.1 EFFECTS OF TEST REVIEWS
The effect of having test reviews impact progress on creating software was simulated. This included the positive impact on long-term quality and the negative impact on short term productivity. The staff model for test reviews was modified so that staff FTEs are required for testing based on the frequency of the reviews. This impact productivity negatively in the short term since those staff resources are taken from the overall workforce. However, the increased test review frequency reduces the backlog of software errors that accumulate, thus reducing the staffing required to address them later on. This improves downstream productivity.

2.4.1 WEIGHT AND RANGE ISSUES
Work was performed to ensure that weight and range are issues if no steps are taken by the learner to address it. This was reviewed and verified in the Phase 2 model. If no action is taken, the weight increases substantially, to the point where the learner should notice that it is a problem. Range progresses downward and crosses the design objective, and then the requirement. If the goal of CDR is to have range above the requirement, if not above the design objective, then the learner would not succeed. See Figure 16 below.
2.4.2 **HIGH-RESOLUTION CHARTS**

High-resolution status charts were created to facilitate the learner’s ability to analyze the simulation results. The simulator was parameterized so that chart resolution is configurable. The configuration settings are in the properties file for the simulator executable. The new setting is 1000 pixels by 727 pixels. In addition, a new set/palette of colors for variables in the graphs was selected based on work on color theory ([www.stonesc.com](http://www.stonesc.com)). This palette is designed to maximize contrast between different graph colors. This source advocates light to white backgrounds for charts. Thus, the background for charts was changed from medium gray to white. See Figure 17 below.
2.4.4 Learner Input Value Errors

Support to send error messages when the learner inputs a quantity for a variable that is not feasible/cannot be handled by the simulation was developed. The simulation models have a minimum and maximum value available for each variable. These are encoded in the model XML file. During execution of the simulation, a variable cannot go above the maximum value, or below the minimum. If it attempts either, it will be held at the respective value. These maximum and minimum values can be read by the Experience Master to ensure that the learner does not enter a value outside the allowed range for a variable that is learner-decidable.

2.4.5 Thrust Specification

The thrust specification was changed to a thrust/weight ratio or similar for jet engine performance. The thrust specification was changed from specific impulse to thrust specific fuel consumption (TSFC). This is consistent with turbofan engines used in a variety of recent UAVs (e.g., Global Hawk, Northrop Grumman X-47B). The Breguet range equation, upon which the relationship between weight, drag, fuel efficiency and range relies, was updated accordingly to accommodate a turbofan.

The underlying metric was formerly propulsion efficiency (thrust per fuel consumption). TSFC is a metric denoting the inverse, i.e., fuel consumption per unit of thrust. Thus, modifications
were necessary to ensure that the learner understand that a lower TSFC is better, as opposed to a lower propulsion efficiency being better. In adjusting the Breguet range equation, the UAV payload and loiter time were also added as variables. These had not been included in the experience previously. These are now potential learner decidable variables for a trade study involving trade-offs between range, payload and loiter time. This potential trade study is an area of future work.

2.4.6 Relaxation of Range KPP

An investigation was made in having the ability to relax the range KPP and keep it consistent with other parameters. The range KPP is specified by the actuals and by a requirement. The actual obeys a proper relationship with underlying TPMs. The requirement is used as a basis for the plan. Currently, plans are specified up-front by the experience developer using hard-coded piece-wise linear continuous functions. There is not a method for a mid-experience plan update. Thus, if the range KPP requirement were modified, there is not a method to update plans that depend on it. It would be potentially useful for the learner to be able to update all plans in case of changes in requirements. This functionality would be an item of future work.

2.4.7 TPM Relationships

A review was made of the TPMs to ensure that they obey the proper relationships. The physics-based relationship between the TPMs (weight, range and drag) and the KPP (range) was reviewed. It was updated in accordance with the task of changing fuel consumption TPM to be more accommodative of a jet engine.

2.4.8 Status Chart Rebaseline

Research was done to rebaseline the plan in the status charts, which is the same effect as moving the CDR date. The dates of various review meetings had been hard-coded earlier. They were transitioned to variables that are now decidable by the learner, as with other variables associated with items in the learner recommendation form. For example, if the learner decides to delay CDR by three months on the form, the Experience Master can adjust the value of the CDR date variable to be three months later. On the next set of output charts, the line designating the CDR date will be updated accordingly. See Figures C and D below. In Figure 18, the learner has not delayed CDR and risks being well-behind schedule with respect to the software design description when the CDR date arrives. In Figure 19, the learner has delayed CDR by three months to allow a potential schedule catchup.
Figure 18: Learner Behind Schedule, No CDR Delay

Figure 19: Learner Behind Schedule, Delays CDR by Three Months
Note that if CDR is pushed back by three months, all other succeeding review dates must be pushed back by three months, as well. A set of charts graphs program performance and plans over the program life, so this is important in the Phase 2 model execution. It also is important when the learner enters succeeding phases.

3 Future Research

The Experience Accelerator has continued to mature and now has a variety of capabilities that should support experiences in numerous domains and in several different single and multi-player modes.

The following are several potential research for Increment 4 which takes the current prototype to deployment at the DAU and expands its use to other institutions:

- efforts to ensure a successful DAU experience deployment,
- the extension of the scope and capabilities of the current DAU experience,
- the creation of Multi-Player Acquisition Mission Support,
- a number of potential experiences that leverage the capabilities of the SE to train and evaluate the performance of SERC MPTs, to provide a laboratory for learning assessment,
- updates and evolution of EA tools
- updates to the EA infrastructure
- building of the EA community.

There is great potential for the EA technology, experiences and tools in a wide range of areas and domains.

3.1 DAU Experience Deployment

The following research areas: completion of selected improvements, support additional pilots and support DAU migration; are necessary to support the deployment of the current experience at the DAU.

Complete selected improvements:

- Tune simulation per sponsor and pilot feedback (opportunity for DAU faculty to use new tools).
- Complete the NPC role of mentor to better fit DAU course.
- Update Lecture/Student Materials to facilitate learning evaluation using logged data from the EA leveraging work from learning evaluations.
- Provide instructor means to set various thresholds (e.g. CDR Pass-stall-fail limits, variation from plan thresholds for Green/Yellow/Red status).
- Restrict multiple calls to NPC within one cycle so discussions won’t repeat on a subject-by-subject basis.
- Further improve chart readability.
Support additional instructor and student pilots:

- Provide support to DAU instructor (at least one) and student pilots (at least two) with EA application, materials and staff.
- Collect feedback and update EA application and materials as deemed appropriate.

Support DAU Deployment:

- Specification of the concrete deliverables so that the EA can be used in the DAU on a long-term basis. This includes criteria, requirements, sustaining support, technical details of the hosting requirements.
- Determine Hosting Solution(s) for DAU: Options include commercial support (external network), DAU support (DAU network) and/or support on a laptop within the classroom (classroom network).
- Migrate Development to 3rd Party Support: This includes identifying support staff and cost, and determining process and procedures for ticket creation and processing.
- Update EA documentation: This includes the concept of operations, system and support specifications, architecture and design document, and experience tools and development document.

3.2 EXTEND CURRENT DAU EXPERIENCE SCOPE AND CAPABILITIES

The current DAU experience can be extended in both scope and new capabilities. The experience was designed to support the UAV project from PDR to limited production. However, these additional phases have not kept up with the PDR to CDR development phase which became the focus of the DAU experience. Some possibilities are noted below.

Complete scope of intended simulation

- Update simulation, dialog and artifacts to be consistent with the current pre-integration phase throughout the complete the full life-cycle.

Add new capabilities

- Add trade study and technical decision making activities
  - Introduce and validate new Actuation System Re-architecture (Fontaine Master’s Thesis) trade study
  - Incorporate necessary artifacts, dialogs, and simulation capabilities (using new tools)
- Add technical planning activities (see Wright Flyer Experience described below)
- More detailed group support simulations
- Additional KPPs
- Technical debt accumulated in one phase to be worked in the next phase
- Individualized difficulty factors

One approach in expanding the scope of the EA would be the creation of a team building *Wright Flyer Development* experience. This experience would leverage the existing course
materials developed by the DAU, and provide a test bed for the use of the EA tools (funded by SERC core funding) in the rapid development of an experience. In addition, this experience would complement the existing one in that it is primarily focused on the front end of the system lifecycle, namely in technical planning focusing on the establishment of baselines, measures, and metrics that are used to track progress and manage risk and uncertainty. If desired, the results of this work can be ported back to the current UAV experience, expanding its scope.

Another possible area for expansion would be in supporting the Technical Leadership work that has been completed by the SERC for the DAU and Missile Defense Agency. The Technical Leadership Project has created an innovative approach to educating technical leaders through three lenses: systems, business, and enterprise. A series of three five-day courses has been prototyped, piloted and is in transition to full deployment in the classroom. The courses take the student from (a) leading systems development in the face of uncertainty and ambiguity to (b) understanding how commercial businesses or organizations accountable for multi-system and multi-customers strategize, operate and measure performance to (c) the technical leadership expectations of an enterprise senior technical leader responsible for assessing and adapting multi-nodal structural and activity-based processes within DoD or commercial enterprises. There are multiple possibilities that could be explored in the area of multi-player experience EA support for these courses.

### 3.3 Multi-player Acquisition Mission Support

DAU not only educates, but provides hands on support to programs when requested. The EA has been suggested as a possible tool for use in this acquisition mission support role. Areas where the multi-player mode and the EA tools might apply include:

- **Team Building**
  - The team could use the existing EA UAV experience, or some other experience as a multi-player team building experience
  - The team could use the EA tools to define a new, simple experience to better understand relationships between the various roles

- **Problem Solving**
  - An experience based on or similar to a current or possible program problem could be adapted from an existing experience or newly developed to provide a surrogate to focus discussion and strategy development

- **Program Familiarization and Risk Identification**
  - A front end could be provided to allow programs to load the existing EA with information based on their specific project and apply it in an expectations clarification and risk identification team exercise

The amount of new EA development required varies according to how the EA will be used. However, as the tool suite is completed, the infrastructure strengthened, and more experiences and simulations are developed, rapidly building new experiences or altering old ones will
become easier. At the same time, new ways of using the tool in mission support will be discovered by the practitioners.

### 3.4 New Experiences Leveraging SERC MPTs

There are numerous new experiences that could be developed leveraging newly developed SERC MPT and simulation capabilities interfaced to the Experience Accelerator to provide the means to teach students and professionals how to use tools, and also as a means to measure learning results to be passed back to the developers. The SERC Innovation and Demonstration Lab also can act as an integration point for this work. The following are a number of potential projects that might take this approach.

#### 3.4.1 Graphical ConOps

One potentially powerful use of the EA is for the training of teams as well as individuals. As engineering is a team-based activity, the ability of teams to work well together is critical. One proposal to support this need is the development of a group-based experience in which a newly formed team jointly develops a concept of operation. Each of the learners would take on specific roles which would provide them with certain, sometimes opposing, incentive structures. To be successful, the team would need to be able to make the necessary trades to optimize overall success. It could be quite effective if the participants are an actual new team who is taking on these same activities in real life. In this case, the learners could go through an initial experience in their own roles, and then repeat the experience taking on other roles to help them see the program through a different lens. The use of graphical ConOps technology could facilitate the rapid development of the ConOps and provide a means to automatically validate its results. This would be a multi-player experience and would require minimal development of dialog.

#### 3.4.2 DATASEM

DATASEM is a simulation generator built for experimenting with adaptive system development governance mechanisms. Several industry members have indicated an interest in this work, particularly in the area of systems of systems where capability governance approaches may differ between component systems. Having an experience based on one or more DATASEM simulations applying some of these adaptive mechanisms would provide systems engineers an excellent opportunity to learn about their value and how they change the SE environment.

#### 3.4.3 Supply Chain Integration

Systems engineering increasingly addresses the system lifecycle, as opposed to its more traditional role focusing on design and development. This new situation results in part from the recognition that upstream design and deployment decisions have potentially significant cost
and performance implications post-deployment. For military systems, the role that typically addresses post-deployment issues is the logisitician. Over the system lifecycle, it is important that the traditional roles of systems engineer and logisitician understand issues faced by one another, as well as joint cost and performance implications. A conceptual design for a role-based experiential learning environment for logisticians involved in military sustainment has been created (Bodner et al., 2013). This design leverages the generic components of the Experience Accelerator for presenting and controlling the learner experience, plus simulating program outcomes resulting from learner decisions. It also leverages the current UAV experience. In this new environment, a logisitician learner interacts with systems engineers during UAV system acquisition and sustainment, learns about systems engineering issues and their effect on logistics, tries to influence upstream systems engineering decisions, and also performs logistics functions.

### 3.4.4 ENTERPRISE MODELING

The enterprise modeling RT has developed an interactive simulation to mitigate the intrusion of counterfeit parts into the defense supply chain (Bodner, 2014). It accounts for multiple stakeholder agencies that manage different parts of the problem and serves as a policy flight simulator to test the effectiveness of different policies and multi-jurisdictional interactions. As an experience, it could operate in single-player mode with NPCSS representing different policy actors, or in multi-player mode with conversations and negotiations among players representing different roles.

### 3.4.5 OTHER SERC MPT TRANSITION SUPPORT

There are numerous other MPTs being developed in SERC research programs that constitute SERC’s technology. The EA can be used as a transition vehicle for these MPTs, effectively serving as a demonstration and training vehicle. One initial target for this could be the application integration currently being developed for the SERC Innovation and Demonstration Lab. This demonstration will integrate the capabilities of the SoS Analytic Workbench (AWB) tools to generate an optimal architecture to be used in negotiation, Flexible Intelligent Learning Architectures for Systems of Systems (FILA-SoS) models to negotiate the optimal architecture and provide a new architecture to be simulated, and finally, a Counterfeit Parts simulation to assess the performance risks of the negotiated architecture. The EA can provide a platform and front end to this work to facilitate the ability of new learners to engage in this experience and provide learning assessment back to the learners and the developers of the simulations and tools.

### 3.5 LEARNING ASSESSMENT

Learning assessment is a critical component of accelerated learning. It is imperative to understand individual learning and the efficacy of various learning experiences. This is critical both in determining the capabilities of the learner, but also to continually improve the capabilities of the learning experience. The EA has the potential to serve as a learning
laboratory to support both of these objectives. Some ongoing activities are described below. Tools development to support this work is described in Section 3.6.

### 3.5.1 Systems Engineering Capstone Assessment

INCOSE’s Academic Council has made strides in promoting the cause of ensuring that all engineers have systems engineering skills. A series of INCOSE Academic Forum workshops in May and June of 2015 have resulted in initiating the development of foundational work for this. As engineering undergraduate curricula are already overloaded, the additional systems engineering learning will likely take the form of introducing SE skills through undergraduate engineering cornerstone and capstone experiences. There is a great opportunity to marry the SERC Capstone program with the Experience Accelerator to support the mission of pre- and post-Capstone experience testing of SE skills. In addition, a learning laboratory environment can be created which will provide the ability for data capture and analysis through these capstone experiences nationwide.

### 3.5.2 Systems Thinking

As noted in the Systems Engineering Vision 2025, systems thinking constitutes a critical capability for all systems decision makers. While there are currently methods used to teach systems thinking, there is no proven means by which the efficacy of this teaching can be measured as a whole. To address this challenge, research is being conducted by a doctoral candidate, Ross Arnold, at Stevens. Mr. Arnold’s research is being supported by his employer at the U. S. Army Armament Research, Development, and Engineering Center (ARDEC). He was the co-winner in the Experience Accelerator competition held at Stevens in 2010. Ross’ research approach is to define systems thinking, create a taxonomy for assessment, and propose a standard by which to measure systems thinking called Systems Thinking Maturity. He will then create an assessment method that incorporates the EA as its support platform. Many different systems thinking assessment methods have been attempted before, with varying degrees of success. Simulation is not one of those methods. Mr. Arnold proposes that simulation as an assessment method will resolve a number of key issues highlighted in prior systems thinking measurement attempts. As a result of this research, simulation as an effective method of systems thinking assessment will be explored and the proposed systems thinking capabilities will be evaluated for validity.

This research will result in a new systems thinking evaluation experience and tools. It will also result in the improvement of general EA learning evaluation tools and provide the base for a systems thinking learning experience that will be targeted for use in the Stevens Systems Thinking course.
3.6 Tools Development

There are a number of tools being developed in a multi-part program funded by SERC core funds.

The tools include:

1. Simulation:
   a. Sim Builder – This tool provides the ability for non-technical staff to build systems dynamics models based on existing templates in a GUI environment.
   b. Sim Tuner – This tool provides the ability to analyze the system, determine the sensitivity of various parameters, and aid in the tuning of the system to achieve desired behaviors.

2. Experience:
   a. Phase Editor – This tool provides the ability to change the finite state machine that changes the phases within an EA experience. For example, the project phases can be customized to new domains and environments and can be constructed to represent state changes that are not affiliated with formal project states.
   b. Event Editor – This tool provides the capability to create and edit events during an experience and the activities that may trigger them. For example, a phone call from the learner’s supervisor can be triggered based on a decision made by the learner or the state of the project.
   c. Artifact Integrator – This tool allows an experience builder the ability to quickly upload an experience change, be it a new artifact such as a new dialog or report, or a changed phase and or event, and test the results without having to do any programming.

3. Learning Assessment:
   a. Learning Assessor – This tool will analyze the subject’s activities, decisions, project performance and self-assessments to determine the learning level achieved. This work will involve developing the logging ability to collect the necessary information, and an analysis tool for making the final predictions.

Additional tools are being developed that facilitate the ability of the instructor to easily tune the experience to provide the desired learning objectives.

Finally, there is a need to develop a top-level tool that integrates these tools into a single environment. One example of this is noted in the Multi-player Acquisition Mission Support Version where a front end is provided to allow programs to load the existing EA with information based on their specific project and apply it to the experience. This would support rapid customization of existing experiences. Another approach is to update and extend multi-player capabilities to provide additional formats and support rapid experience development through “paper-based” play. This would enable the rapid evaluation of new paper-based game prototypes before their full implementation into the EA.
3.7 **Update Experience Accelerator Infrastructure**

There are a number of areas in which the EA infrastructure can be enhanced to improve the current software for enhanced reliability, flexibility, and quality of experience. Some of these are noted below.

- Improve integration between user interface and experience-building tools:
  - Evaluate effort to migrate to HTML5
  - Improve interface with ChatMapper for easier dialog development
  - Improve internal data architecture to simplify status reporting
  - Generalize simulator-EA interface to facilitate use of other simulations
- Installation and Support:
  - Improve accessibility of tool in secure or other special IT environments

While many of these will be completed through ongoing experience development and deployment, the migration to HTML5 is a major effort and will likely require targeted support.

3.8 **Building the Experience Accelerator Community**

For the EA to reach its full potential, there needs to be an active community of users, supporters and developers. Having an accessible application, experiences, tools and supporting documentation are critical to this. The previous sections describe some of the activities necessary for this. However, additional efforts are necessary to create the community. These include numerous private presentations to interested organizations, presentations at conferences including ASEE, CSER, IEEE, and INCOSE, EA User Group Web meetings, and a future workshop at INCOSE IS 2015. The following additional activities are necessary to support this work:

- Website Development – a dedicated website that contains in EA publications, presentations, technical data, User Group information, and blogs. Will leverage the SERC Virtual Innovation and Demonstration Lab (IDL).
- Distribution Support – a download and bug tracking facility that is linked to the website. Will leverage the SERC IDL.
- Community Building – outreach to government, academic and industry organizations who might have interest in the EA.
- User Group Activities - meetings and workshops designed to increase the value of the EA to its ecosystem.
- Licensing support – facilitate the ability of developers, administrators and users to access the EA technology and experiences.

4 **Lessons Learned & Conclusion**
4.1 Lessons Learned

The following is a summary of the lessons learned by the RT16 team through Increments 1, 2 and 3. The lessons are divided into the following four categories:

1. Competencies, Learning and Content
2. Complexity/Effort vs. Authenticity/Learning
3. Technology
4. R&D Processes & Tools

Lessons learned in each of these areas are described below along with an approach to mitigate negative impacts in the future. These lessons learned have impacted the nature of the future work, the processes used, and the identified risk factors moving forward.

4.1.1 Competencies, Learning and Content

LL1.1: Systems Thinking Evaluation - It is very difficult to evaluate capabilities in systems thinking. After an extensive literature search, very little was found in how to test system thinking and technical problem identification and resolution skills. Additional research will need to be done to develop a means of testing these capabilities. Our approach has been to use a Delphi approach in which subject matter experts review behavior and grade them with respect to competency levels. Doctoral research will be pursued in this area by Ross Arnold at Stevens Institute.

LL1.2: Learning and Concept Capability Evaluation – It is difficult to determine if the learner has actually learned and can apply the identified concepts. Even if the learner goes through the Experience more than once and shows improvement, it is not clear whether they have just learned how to best this particular experience or if they have learned the concept and how to apply it in future situations. It would be desired to develop and exam in a different medium which could be used for pre- and post-testing to assess the results. Doctoral research will be pursued in this area by Ross Arnold for Systems Thinking and Peizhu Zhang for Systems Engineering, both at Stevens Institute.

LL1.3: Use of Subject Matter Experts - The project has relied on subject matter experts to help authenticate and validate the experience. The subject matter experts have extensive experience in aircraft systems design and development. On the other hand, the experience is intended for use in a current “state-of-the-art” course in systems engineering at Defense Acquisition University. The intent is this course is to teach the most up-to-date methods for systems engineering in DoD acquisition. There were several instances where input from SMEs conflicted with methods taught at DAU, particularly in the presentation of TPMs for the redesign of the legacy airframe used for the UAV. In the future, it is advisable that experience be developed with simultaneous SME and DAU/instructor feedback. In addition, subject matter experts will be recruited from a number of sources.
**LL1.4: User Interface** - Learners expect a smooth, relatively rapidly updated user interface that is similar to their other tools. We have updated the EA interface with Chart navigation and files. A more modern interface will likely require moving to HTML5.

**LL1.5: Importance of Understanding Lags** - Learners need to understand the lag between changing something and the actual evidence the change had the appropriate result. Research will be done to review the work of Dietrich Dorner and his “Logic of Failure” results.

**LL1.6: Importance of Background Information** – Learners require more background information to make decisions than was originally anticipated.

**LL1.7: Technical vs. Programmatic Issues** – The current experience focuses more on the programmatic than on the technical issues in a program. It is an open question on how this can be addressed while still working within the restricted amount of time that is available for the experience while being flexible with the level of domain knowledge possessed by the learner. A trade study module has been developed to expand the learning experience more broadly to technical issues.

**LL1.8: Role Adaptation** – It is desired to have the ability to adapt scenarios for different SE roles (PSE on gov’t side very different from PSE on developer side). Future work will involve adapting the current experience and developing new experiences that are relevant to a wide range of roles.

**LL1.9: Impact of Non-Player Characters (NPCs) Roles** – NPCs are valuable, but their role title may impact usefulness (learners did not want to communicate with the senior Program Manager). However, this real world behavior with respect to NPCs provides the opportunity for additional learning.

**LL1.10: Decision Making Tools** – Learners desire “what-if” tools to help with decision making. Is this helpful or is failure resulting from trial and error a better educational method? Some exploration should be done in this area to determine the optimal mix.

**LL1.11: Importance of Understanding Impact of Decisions** – Additional feedback has been added in the experience to provide learners with insights on the impact of their recommendations. The efficacy of this will need to be reviewed and validated.

**LL1.12: Dialog Dependencies on Experience State** – Initially dialogs were wholly dependent on the particular experience phase. However, this was very limiting and led to dialog that was rightly perceived to be “canned”. Significant work has been done to create dialog that is dependent on the learner’s actions and the state of the experience.
4.1.2 Technology

**LL2.1: Client Graphic Technology Migration** - While Flash is currently has the most productive environments in which to develop graphical content and is free on the client, the development licensing can be expensive (approximately $200 for individual educational licenses, and $700 for individual commercial licenses) and Flash does not work on iPads which represent a major client technology base. Once the open competing technology, HTML5, has development environments which provide the same level of productivity of Flash, it would be advantageous to migrate to the new technology.

**LL2.2: Client/Server Interface Reliability** - We had a number of problems getting the EA client/server interface reliably in the presence of an unreliable network. While the system now works well, getting it to this state required a significant amount of debug and redesign work. We reviewed the design and updated it to a stable and reliable interface.

**LL2.3: UI Look and Feel** - Creating a professional look and feel for a virtual desktop continues to be a non-trivial undertaking. We received feedback from the subject matter experts on the difficulties that they faced in using the browser and virtual desktop. We have added a text based support online, but we may need to create an overall experience training video as well. The file system structure UI has been updated to a tree style interface which is much easier for users to find specific files. Also an icon has been created on the taskbar for easy access to the recommendation form.

**LL2.4: Domain-specific Code Base and Implementation** – The EA was implemented with the UAV experience in mind and thus certain code base was written specifically for the domain. To support the development tools, current EA code base needed significant efforts to update to a more domain-independent approach. In Increment 3, we made efforts to allow development tools to alter current experience.

4.1.3 Complexity/Effort vs. Authenticity/Learning

**LL3.1: Challenges & Landmines** - There are an almost infinite number of ways in which a program can fail; combinatorial explosion is a major challenge. This is not so much of a challenge for the simulator, but this continues to be a major issue for the creation of artifacts and dialog which can support these to allow the Learner to make sense of the situation. While we created a catalog of a large number of frequently encountered Challenges and Landmines, for the prototype we implemented just a few of the most likely ones in the areas of aviation hardware and software. During this past year we have added challenges in the area of budget management.

**LL3.2: TPMs** - TPMs drive the amount of information that needs to be simulated, the amount of artifacts for background information, dialog and Learner recommendations. During Increment
1 we have added cost to the existing TPMs of schedule, quality and capabilities (range) which has required the development of a plausible cost model and supporting artifacts and dialog. While we have implemented a relatively simple EVM system, it is clear that developing one similar to what would be found in a DoD program office would be very challenging. We will have to see if what we developed has sufficient authenticity to provide the desired learning. In addition, new KPPs could be developed.

LL3.3: Feedback to/from Learner – In Increments 2 and 3 we increased the amount of feedback to the learner in the form of a confirmation of the actions which were taken as a result of the recommendations that the learner made throughout the experience, and in the feedback that the learner received at the end of the experience. While the recommendation form of feedback was fairly straightforward in its implementation as it represented objective fact, the reflection feedback was more complicated in that it was both subjective in nature and the multiple actions that the learner has taken are inter-related. The process that was used involved noted the decisions that were deemed appropriate, inappropriate and neutral and feedback on each decision was made independently. Understanding the interactions between these is far more complex. One possibility for future work is to record how the learner’s behave and determine if there are specific patterns of behavior which can be identified and feedback given to the learner which is most appropriate to the pattern of behavior. The quantity and quality of feedback will continue to increase, coming in the form of dialogs, reports, reflection and a final score.

LL3.4: Balance of Complexity and Authenticity in Defense Acquisition - Defense acquisition is a very complex enterprise, with many processes, actors and organizations. Selecting a subset of these to represent in the Experience Accelerator involves numerous design trade-offs to address the interests of (i) the learner community, that wants a realistic but not overwhelming experience, (ii) the education community, that wants realism in support of learning objectives, (iii) the acquisition community, that wants its various aspects represented faithfully, and (iv) the developer community, that wants to provide a useful product while managing complexity, schedule and cost. One of the biggest challenges was to create an authentic, learning experience while managing complexity and the amount of content that needed to be created. During this past year we have continued to learn in these areas.

LL3.5: Extending the Learner’s Role to Improve Learning - One of the recommendations that the learner can make is to change the labor resources assigned to sub-system development. Since the learner is the government’s lead systems engineer, it was pointed out by DAU faculty that this recommendation choice is not realistic. The government PSE cannot make staffing recommendations for contractors, although he or she can have a discussion with the prime contractor LSE about current deficiencies and alternatives (and costs) to remedy them, including the contractor deciding to change staffing. The decision was made to keep the PSE’s ability to recommend staffing changes as a surrogate for the more complex discussions that he or she might have with the prime’s PSE. This might be revisited in the future with richer NPC interactions.
**LL3.6: User Interface for Data Navigation** - The number of simulation output charts tends to increase with the number of stakeholders involved in review and usage, since each stakeholder has potentially a different perspective on important metrics to track. This makes navigating the chart set difficult for a user. The interface for such navigation has been incrementally improved in Increments 2 and 3.

**4.1.4 R&D Processes & Tools**

At the outset of this project, given the exploratory nature of the research, open communication was established between all of the team members through the use of a Wiki site. However, it was discovered that the overhead in learning how to use and navigate through the site outweighed its advantages so we migrated to the use of a simple Dropbox technology for documents and development code, and Webex for group meetings which were held once a week. As the team more than doubled in size and became more specialized, this mode of communication became a bit cumbersome. We eventually migrated to a weekly meeting with the SMEs for content, a weekly team meeting and technology meetings on an as needed basis. While the intention was for the team to develop technology and content using an agile software development process on a single server site at Purdue, it was more difficult than expected to set up an iterative development environment and workflow. During the Increment 1, we moved the development to Stevens and used a set of technologies for bug tracking and version control that are standard in the open source software world. The following are some of the lessons that were learned in Increment 1, 2 and 3 after moving to this new environment.

**LL4.1: Change Management** - In Increment 1 we started using a formalized ticketing system and process. Due to the instability of the design, we quickly created a huge number of tickets for the developers. Due to this large backlog, we slowly moved away from this system, and started contacting the developers directly on our needs. In retrospect, this was a mistake as it created challenges in tracking the work in queue, in process and completed. Now that the design and implementation has stabilized, we intend to move back to the more formal approach that should prepare for open source distribution and should help us with our challenges in configuration management (see LL4.2).

**LL4.2: Configuration Management** - Due to the large number of design files, artifacts, simulation parameters and the like, configuration management has become a great challenge. One of the issues is that the Experience Design document is overly generalized and it is sometimes difficult to know exactly what has been implemented. Another issue is that we do not have a centralized place that is a source for all of the files. The issue goes beyond the software build and reflects all of the artifacts and code. To address this issue we have created a single design document that will be used with a work tracking tool to provide configuration management for the program. Reconciliation and updates in these two sources of data is done on a regular basis to ensure that control is maintained over the design.
LL4.3: Verification and Validation - The system that we are developing has become very complex making it quite difficult to test. In addition, resources are quite limited such that the testing that we do is ad hoc and carried out by the person who is implementing the code. One possible solution to this problem is to develop an automated tool for verification. There are simulation packages available that have the ability to automate tests that provide the ability to run a suite of simulations and then check all of the results in parallel. In addition, we should create a pool of people who are outside the implementation team who can test the overall Experience Accelerator system. During increment 3, a stable version of EA has been made available online to a number of interested parties. In the near future, a website will be created to gather tester feedbacks.

LL4.4: Configuration Dependency Testing - There are a number of implementation issues that are configuration dependent, yet may not be discovered through our normal testing procedures which are limited in their configuration variations. Addressing this will require automated test beds and the prerequisite software and hardware support.

LL4.5: Content Creation - It is quite difficult to create content, particularly dialog, without actually going through the experience to see what it is like. Unfortunately, this was not possible during much of increment 1 due to instabilities in the code base and the recent development of the EVM features. In addition, as a content creator you need the ability to see the effects of the experience from the beginning to the end. It would be quite useful to have a developer mode in which one could quickly see the projected results of an entire Experience based on some scripted learner behaviors. These behaviors could be based on recorded behaviors of actual learners. This information could also be useful in the identification of classes of behavior types, how to identify them, and how to improve their performance.

LL4.6: Architectural Conformance - There was a lack of conformance between the implementation, heavy client, and the architecture, thin client, that was developed in the base line year. As a result, there was a good deal of rework that had to be completed by the Stevens development team. It was clear that we needed someone with a computer science and game design background to manage the development team. This action was taken and the issues have been remedied.

LL4.7: Academic Software Development - Software is difficult in an academic setting as the workforce is largely composed of students who quickly come and go. In addition, since the development team is so small, consisting of 2-3 member, transitions are particularly difficult as the loss of a single member is a large fraction of the team, there is little overlap with other members, and it is not easy to quickly recruit and bring up to speed new members. It is clear that there needs to be at least one member of the team who understands the entire design and is there long term to provide continuity to the team. This has been accomplished on the technology, simulation and experience design teams through continuity of technically capable faculty researchers. In addition, longer term support is also in place with a graduate student in system engineering.
**LL4.8: Automation of Repetitive Tasks** - There are a number of repetitive tasks that consume a great deal of our developers’ time and effort. One example is the conversion of documents from one format to another which then need to be placed in the appropriate design file. There is a strong need for the development of tools to automate these tedious processes. There is a need for tools to automate tedious processes. A conceptual design has been created for this tool. In increment 3, an Artifact Integrator tool has been implemented. This new tool provides capability to convert PDF files to SWF files which specifically resolved this issue.

**LL4.9: System Interfaces and Partitioning** - Another lesson learned in the baseline year and repeated in Increment 1 is the importance of partitioning in the system and creating interfaces such that artifacts and dialog can be created without the involvement of developers. This was increasingly successful in Increment 1 as tools were created to allow the simulation team to create graphs and charts that could be automatically incorporated into the system.

**LL4.10: Simulation Tuning** - For the DAU pilot, the difficulty of the experience was called back somewhat so that the learner could succeed with a 20% cost overrun and three month schedule slip in Phase 2 if the correct decisions are made. While the difficulty level can be controlled by manually tuning the simulator, this approach will not scale up to handle numerous difficulty levels targeting different experience aspects. A more automated approach is needed. This is being addressed via the Sim Tuner in the EA tools development.

### 4.2 CONCLUSION

An Experience Accelerator workshop was held at the 2015 INCOSE International Symposium on July 11th. The following is the abstract for this workshop:

**Short Abstract:** Industry, government and academia are struggling to address workforce development needs required to meet the emerging challenges posed by increasing systems complexity and the widening gap in systems engineering expertise in the workforce. In response to this challenge, the Systems Engineering Experience Accelerator (SEEA) research project was initiated to test the feasibility of a simulated approach for accelerating systems engineering competency development in the learner. For this workshop, we will demonstrate the SEEA and customization tools, and solicit feedback on the effectiveness of the prototype from the audience. We will first provide a brief overview of the SEEA and demonstrate its use. Then we will describe and demonstrate a number of tools that have been developed to tailor and create new experiences. A discussion will follow to assist in future developments.
The Experience Accelerator work was also presented at the 2015 INCOSE IS Corporate Advisory Board (CAB) meeting. Unfortunately, the INCASE CAB meeting conflicted with the EA Workshop which limited participation in the workshop. Of the six participating participants, four completed a questionnaire concerning their evaluation of the workshop. As shown in Figure 20, all of the responding participants strongly agreed (75%) or agreed (25%) that the SEEA has the potential to be useful for their organization. This is not surprising since this is what likely motivated their attendance at the workshop. The same proportions also strongly agreed or agreed that the prototype effectively demonstrates the concept.

As shown in Figure 21, all of the responding participants believed that technical realism, technical content, the learner interface, experience design and learning assessment were very important or important. All believed that design tools, and modeling and simulation, were very important, important or somewhat important.
With regard to the support of these areas in the SEEA, as shown in Figure 22, all of the responding participants believed that the SEEA strongly supported or supported effective learner interface, experience design, design tools and learning assessment. All but one of the responding participants believed that the SEEA strongly supported or supported effective technical realism, technical content, and modeling and simulation.

The following are the participants’ responses to the question, “If I could change one thing about the SEEA, I would”:

- “Ensure putting experiences in the tool would be easy and relatively fast.”
- “I would also add the ability to develop (for) other industries, than aerospace/defense.”
- “More graphical aids - more visuals along with metrics.”
- “A ‘menu’ of experiences or lessons learned to bring into and tailor for my organization.”

The following are the participants’ responses to the question, “The best thing about the SEEA prototype is”:

- It gives students a chance to experience failure and understand why they failed.
- The great level of thinking & multidisciplinary application to a difficult problem.

Finally, as shown in Figure 23, all of the responding participants are interested in participating in an SEEA Pilot and SEEA open source development. All but one responding participant is interested in contributing tools and/or technology to the SEEA.
Figure 23: Workshop Participants’ Interest in Participation

There is a great level of interest in the Experience Accelerator in a number of organizations, many of whom were not able to attend the 2015 INCOSE IS EA Workshop. The Experience Accelerator and its supporting tools have now reached a level of maturity where there is great value in expanding its use for a number of different experiences in various domains. There are many opportunities this coming year for the Experience Accelerator to begin to achieve its potential to accelerate the learning of systems engineers and technical leaders.

References


NDIA SE Division (2010, July). “Top systems engineering issues in department of defense and defense industry (Final 9a-7/15/10).”


