RT194: Systems Engineering Experience Accelerator Tools

Sponsor: DASD(SE)

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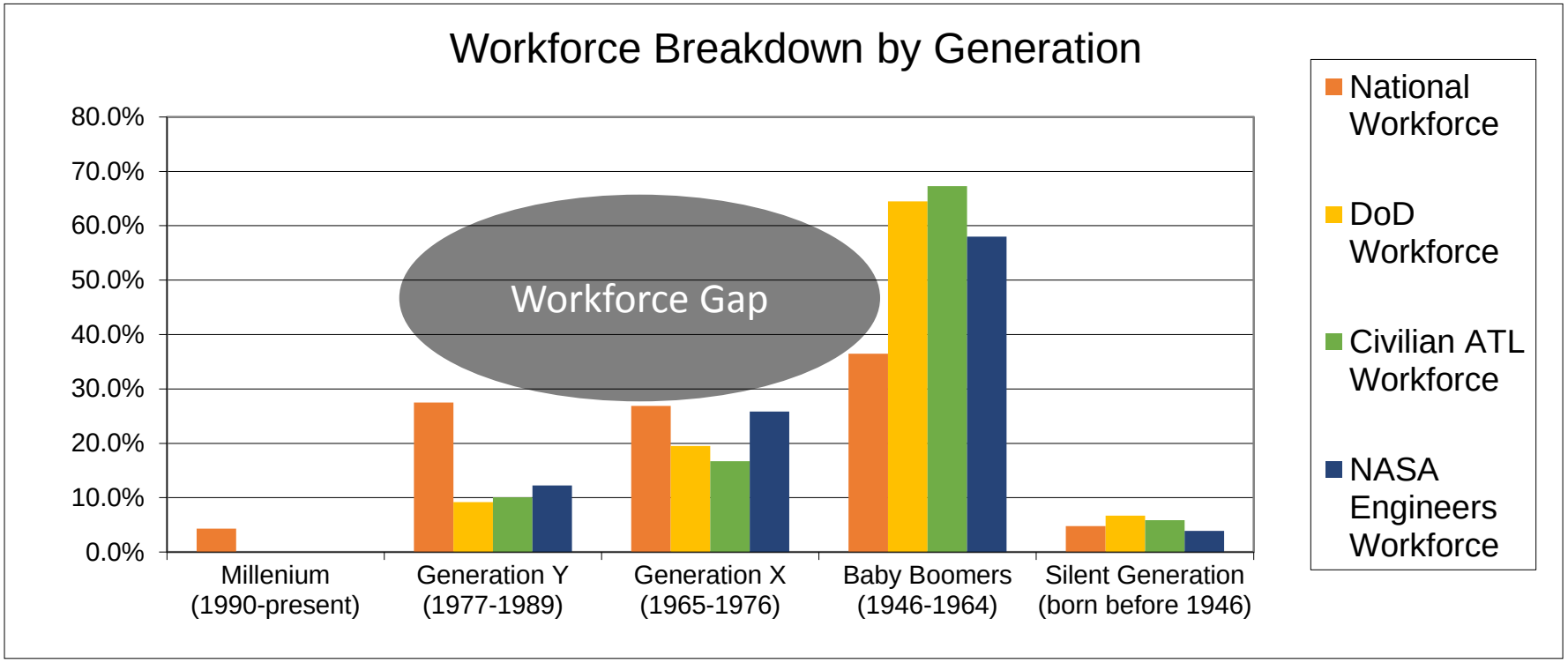
www.sercuarc.org

Outline

- **Background**
- New EA Experiences
- New Tool Features & Capabilities
- Additional Activities
- Future Work

Problem Statement

- A widening gap in industry between the need and the availability of systems engineering practitioners with the necessary experience to address these challenges
- Systems engineering educators are struggling to meet the growing educational demands for a workforce able to solve problems driven by accelerating technology, rapidly evolving needs, and increasing systems complexity



Hypothesis & Goals

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.*

Goals: 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

The Learning Experience

- An UAV acquisition program
- Learner assumes the role of lead program systems engineer
- Focused on developing the systems thinking, problem solving and recovery skills

UAV System:

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

UAV KPMs:

- Schedule
- Quality
- Range
- Cost

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 7 (P7): Reflection
- Each session = 1 day

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New EA DAU Features & Capabilities

Development of "Vignette" Experiences

- Engage learning objectives team (user institutions) and experience concept team (SMEs)
- Select targeted set of experiences from list
- Identify learning objectives
- Storyboard experience concepts
- Develop experiences
- Test and validate experiences

Experience Learning Objectives

- **Wright Brothers Experience**
  - Manage risks and options
  - Trade study between different benefits and c
- **Systems Thinking Game**
  - N/A
- **UK MoD Experience**
  - Familiarize mission critical communication
  - Conduct individual investigation through communication to find underlying issues
  - Prepare investigation report to supervisor with discoveries to backup claims
- **Robot Game**
  - Conduct trade study on different options
  - Use systems thinking

Extracted from Existing UAV Experience:

- **EA: Readiness for CDR**
  - Understand critical design review
  - Familiarize the CDR process
  - Manage KPP and schedule for CDR preparation
- **EA: Trade Study**
  - Conduct trade study on UAV actuators
  - Develop trade study matrix
  - Determine the best option
- **EA: TPM**
  - Understand total productive maintenance
  - Develop TPM plan

Experience Selection

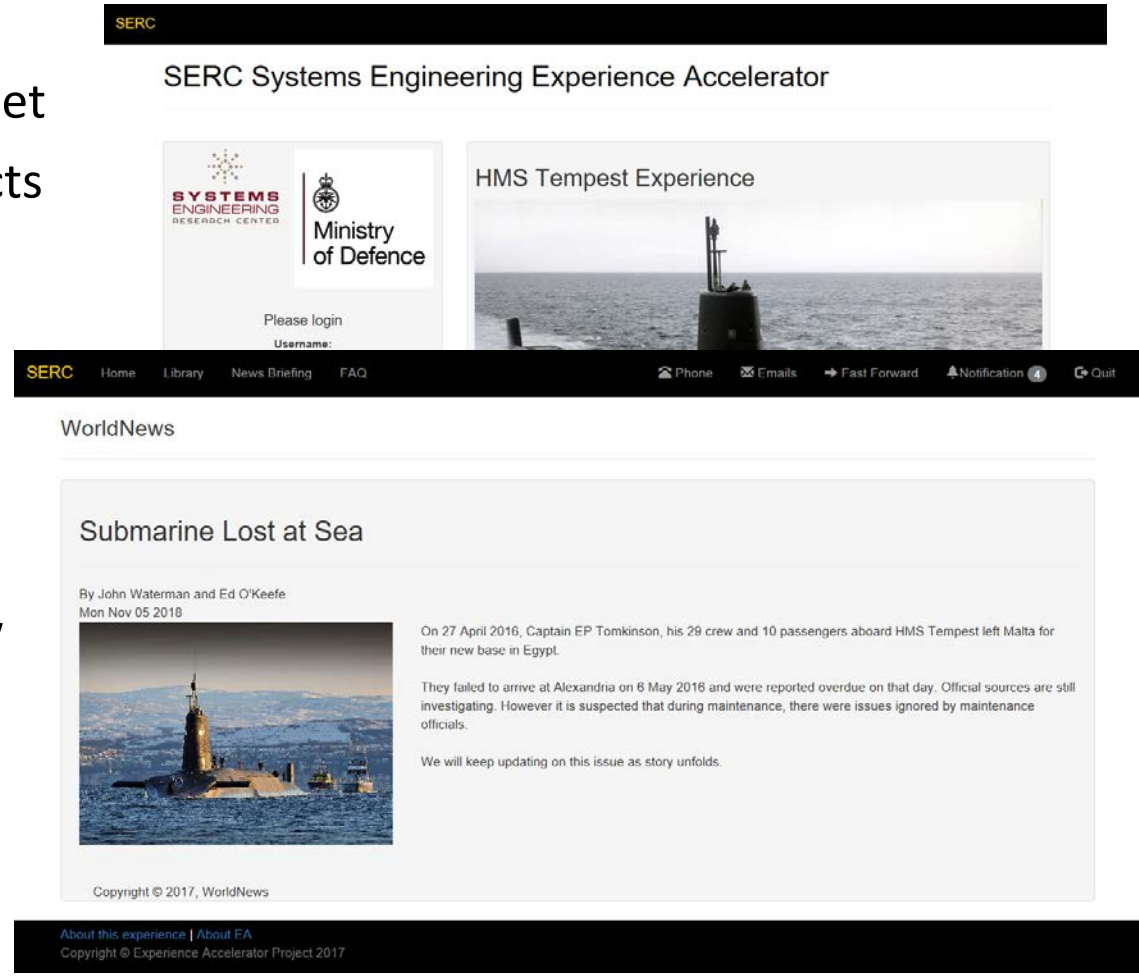
	Audience	Learning Value	Time Efficient	Realistic	Fun Factor	Ease of Implement	Average	Weighted Total
Wright Bros	5	4	4	5	4	3	4.17	204
UK MoD	4	3	5	4	4	5	4.17	195
Systems Thinking	5	NA	5	NA	3	3	4.00	193.5
Robot Game	4	4	3	2	5	2	3.33	168
EA: Readiness for CDR	4	5	1	5	3	2	3.33	167
EA: Trade-Study	2	4	4	4	2	4	3.33	156
EA: TPM	1	2	2	3	2	2	2.00	93

The weightings for each factor are as follows:

Factor	Audience	Learning Value	Time Efficient	Realistic	Fun Factor	Ease of Implement
Weight	10	10	8	7	8	5

UK MoD Experience

- Prior work
  - Utilized the integrated toolset
  - Imported PDF files as artifacts
  - Made changes to phases
  - Created new events
- Recent work
  - Converted to HTML5
  - Completed thorough review
    - 14 improvements
    - 2 experience flow items
  - Target completion and deployment in January



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Wright Brothers

Planning the Technical Baseline

- Exercise 1: Planning the Technical Baseline
  - 1.a (Step 1: Define the Work: Scope)
  - 1.b (Define the Work) Identify set of potential TPMs and develop TPM Progress Plan.
  - 1.c (Define the Work) Identify and Manage Risk
- Exercise 2: Scheduling the Work
  - Wilbur's Time-Phased Budget
  - Orville's Time-Phased Budget

US Army 1907 Advertisement

SIGNAL CORPS SPECIFICATION NO. 486.

ADVERTISEMENT AND SPECIFICATION FOR A HEAVIER THAN-AIR FLYING MACHINE.

To The Public:

Sealed proposals, in duplicate, will be received at this office until 12 o'clock noon on February 1, 1908, on behalf of the Board of Ordnance and Fortification for furnishing the Signal Corps with a heavier-than-air flying machine. All proposals received will be turned over to the Board of Ordnance and Fortification at its first meeting after February 1 for its official action.

Persons wishing to submit proposals under this specification can obtain the necessary forms and envelopes by application to the Chief Signal Officer, United States Army, War Department, Washington, D. C. The United States reserves the right to reject any and all proposals.

Unless the bidders are also the manufacturers of the flying machine they must state the name and place of the maker.

Preliminary. - This specification cavers the construction of a Flying machine supported entirety by the dynamic reaction of the atmosphere and having no gas bag.

Acceptance. - The flying machine will be accepted only after a successful trial flight, during which it will comply with all requirements of this specification. No payments on account will be made until after the trial flight and acceptance.

Inspection. — The Government reserves the right to inspect any and all processes of manufacture.

The general dimensions of the flying machine will be determined by the manufacturer, subject to the following conditions:

1. Bidders must submit with their proposals the following:

(a) Drawings to scale showing the general dimensions and shape of the flying machine which they propose to build under this specification.
(b) Statement of the speed for which it is designed.
(c) Statement of the total surface area of the supporting planes.
(d) Statement of the total weight.
(e) Description of the engine which will be used for motive power.
(f) The material of which the frame, planes, and propellers will be constructed. Plans received will not be shown to other bidders.

2. It is desirable that the flying machine should be designed so that it may be quickly and easily assembled and taken apart and packed for transportation in army wagons. It should be capable of being assembled and put in operating condition in about one hour.

3. The flying machine must be designed to carry two persons having a combined weight of about 350 pounds, also sufficient fuel for a flight of 125 miles.

14. Bidders must state the time which will be required for delivery after receipt of order.

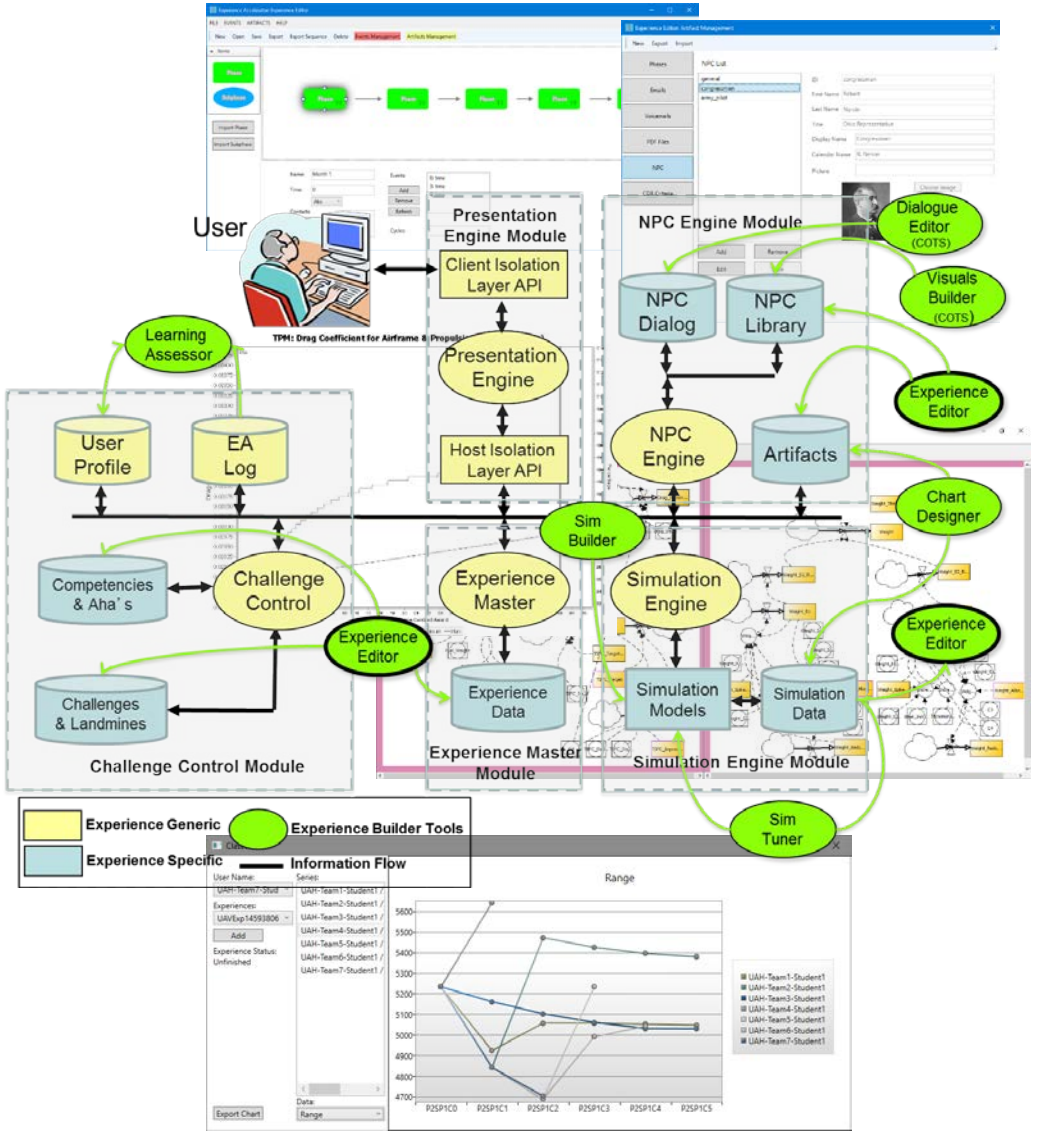
JAMES ALLEN, *Brigadier General, Chief Signal Officer of the Army*
SIGNAL OFFICE
WASHINGTON, D. C. *December 23, 1907*

Outline

- Background
- New EA Experiences
- **Tool Features & Capabilities**
- Additional Activities
- Future Work

EA Tools

- Experience Building Tools
  - Phase Editor
  - Event Editor
  - Artifact Integrator
- Simulation Tools
  - Sim Builder
  - Sim Tuner
  - Chart Designer
- Learning Assessment Tools

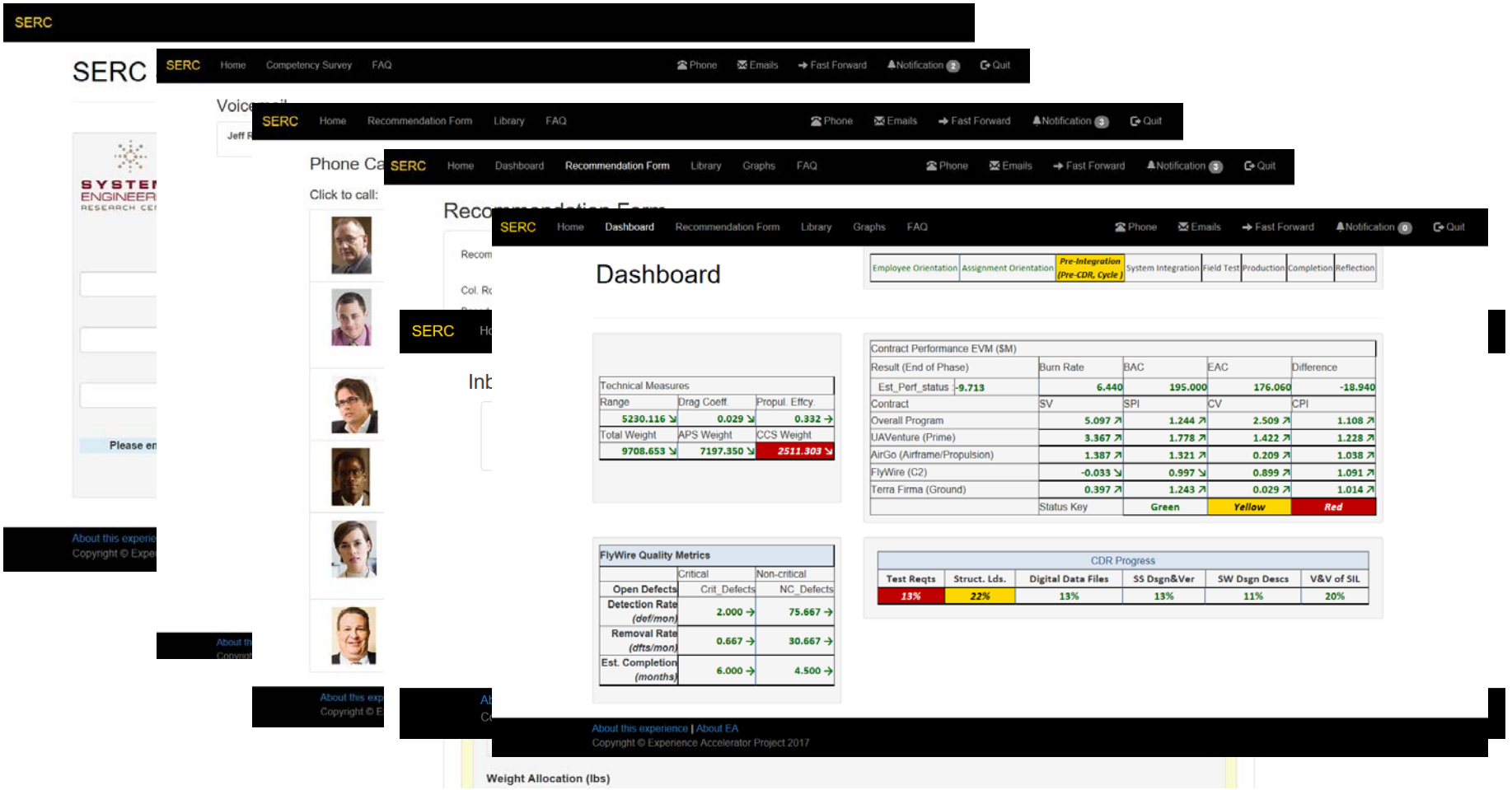


New EA Tool Features & Capabilities

Enhance existing tools:

- Extend learning assessment tool
  - —Develop a performance assessment engine which evaluates a learner's competency by comparing their performance to an experts' performance and by comparing their performance against historical data.
  - —Add a function to generate an objective score based on the experience performance and decision-making process.
- Extend simulation capability to methods beyond system dynamics
  - —Create and document an interface between the EA and generic simulators
  - —Develop a tool for specifying state-chart simulations (including XML specification for models)
  - —Provide demonstration capability for state-chart simulations in the simulation execution engine using the newly developed interface

Current Implementation of EA



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Data collected from the EA

- The EA has been instrumented to record information as a learning laboratory.
- Research will be done to determine the requisite data that needs to be recorded and the EA will be updated accordingly.
- These data has been selected and will be collected from the EA:

Participant Identification:
- Learner's Name & demographic information
- Team Name & other members
- Instruction Name & Roles played in Experience

Experience Session Information:
- Experience Name and Version
- Date of Experience Start and End
- login dates and duration of each session
- Phases/cycles covered in each login session
- Elapsed time & number of session per Phase/Cycle
- Links to past experience information

Learner Experience Inputs & Actions:
- Self-Assessment
- Initial Recommendation Input
- All subsequent Recommendation Inputs
- Workflow sequence with each action recorded with a timestamp

Instructor Input
- Feedback provided to Learners (dialog, email, etc.)
- Recommendations accepted/rejected
- Instructor's observations

Simulation Output:
- Last phase/cycle completed
- Results of schedule, cost, range and quality
- Final Status Charts
- Final score

Reflection
- Reflection feedback provided to the Learner
- Learner's reflection input

Learning Assessment Approach

- Simulation results/score
  - Simulation results showing the final project status
  - Generated score based on the project performance
- Decisions made by learner
  - Recommendations and the rhetoric behind the decisions
- Learner actions
  - Actions during the experience
- Learner self-evaluation
- Instructor evaluation
  - Instructor's evaluation of learners' performance and learning

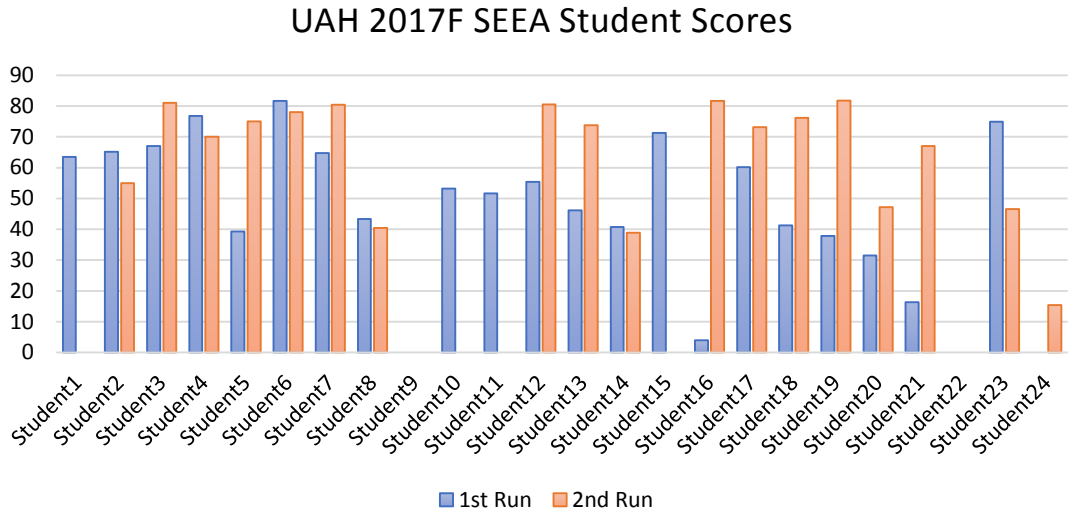
Pilot Uses of SEEA

- 2016 and 2017 academic years at University of Alabama in Huntsville (UAH)
- 2016 and 2017 summer semesters at Airforce Institute of Technology (AFIT)
- 2017 summer semester at Georgia Institute of Technology (GaTech)

Pilot Results

Pilot Use During 2017 Fall Semester in UAH

- During the 2017 fall pilot of the SEEA in UAH, twenty-four students participated in the UAV experience.
- Two separate pilot runs were conducted.
- The first experiment was performed at the beginning of the semester, and the second was performed at the end.
- Most students were able to complete the experience twice.



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Analyze the Evidence of Systems Engineering Competencies Learning Trajectories

Assessment Approach	Strengths	Limitations
Expert's review and examination	Tried and true, accepted by the industry, evaluates knowledge details and understandings	Lacks consideration of hands-on capabilities and skills. Time consuming.
Learner's project performance analysis	Reflects learner's actions in simulated environment, provide insights into decision making process and hands-on capabilities	Lacks the assessment of knowledge details. Does not provide information on learner's reflection and concept generation steps during learning.
Learner's behavior analysis	Provide insights in learner's attempts to solve problems. Demonstrate traits like communication and self-learning skills.	Lacks the causal relationship if used alone. Does not take into consideration the learner's background and capabilities level before learning.
Learner's self-evaluation analysis	Provide vital information on learner's self-reflect learning process. Provide assessment from learner's perspective. Useful for instructors to improve the learning experience.	Lacks the objective view of the learner's capabilities and skills. Results varies vastly depending on learner's personal style.

Machine Learning Approach to Learning Analysis

- Develop SEEA Behavioral Archetypes:
  - Investigator
  - Observer
  - Responder
  - Researcher
- Use supervised learning to conduct algorithm training for more accurate future classifications
- 15 experience data used for initial algorithm training

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EA Behavioral Archetypes

EA Behavioral Archetypes	Description	Counts	Avg Score
Investigator	Make no major changes early on, conduct thorough investigation, make major changes late.	6	31.71
Observer	Make no major changes early on, did not thoroughly investigage, only observe the trend and make major changes late.	2	13.24
Responder	Make major changes throughout, did not thoroughly investigate, changes respond to situations	5	19.78
Researcher	Make major changes early on, conduct thorough investigation, observe the trend	2	57.63

Classifier	APS_SR, APS_JR, APS_W, APS_TSFC, APS_DRAG, CCS_SR, CCS_JR, CCS_R, CCS_TSR, CCS_TJR, CCS_W, GLRS_SR, GLRS_JR, CDR_D
Amount of User Actions	Phone calls, Emails, Charts, Documents

New EA Tool Features & Capabilities

Enhance existing tools:

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  - —Develop a performance assessment engine which evaluates a learner's competency by comparing their performance to an experts' performance and by comparing their performance against historical data.
  - —Add a function to generate an objective score based on the experience performance and decision-making process.
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Previous Work

- Sim Builder
  - Allows an experience designer to build simulation models
  - Models reflect current experience status
  - Sim engine advances state of experience in time
  - Interaction allows learner decisions/recommendations to be incorporated into future behavior of experience
  - Uses system dynamics simulation formalism
- Sim Tuner
  - Allows experience designer to test and tune simulation models and interaction to get desired results
- Chart Designer
  - Allows the experience designer to specify output charts reflecting simulated world status

Goals of Current Work

- Specify generic interface between Experience Accelerator and simulation engines
  - —Support multiple simulation paradigms
- Develop a tool for creating state-chart based simulations
  - —Expand capability beyond system dynamics
- Demonstrate the tool

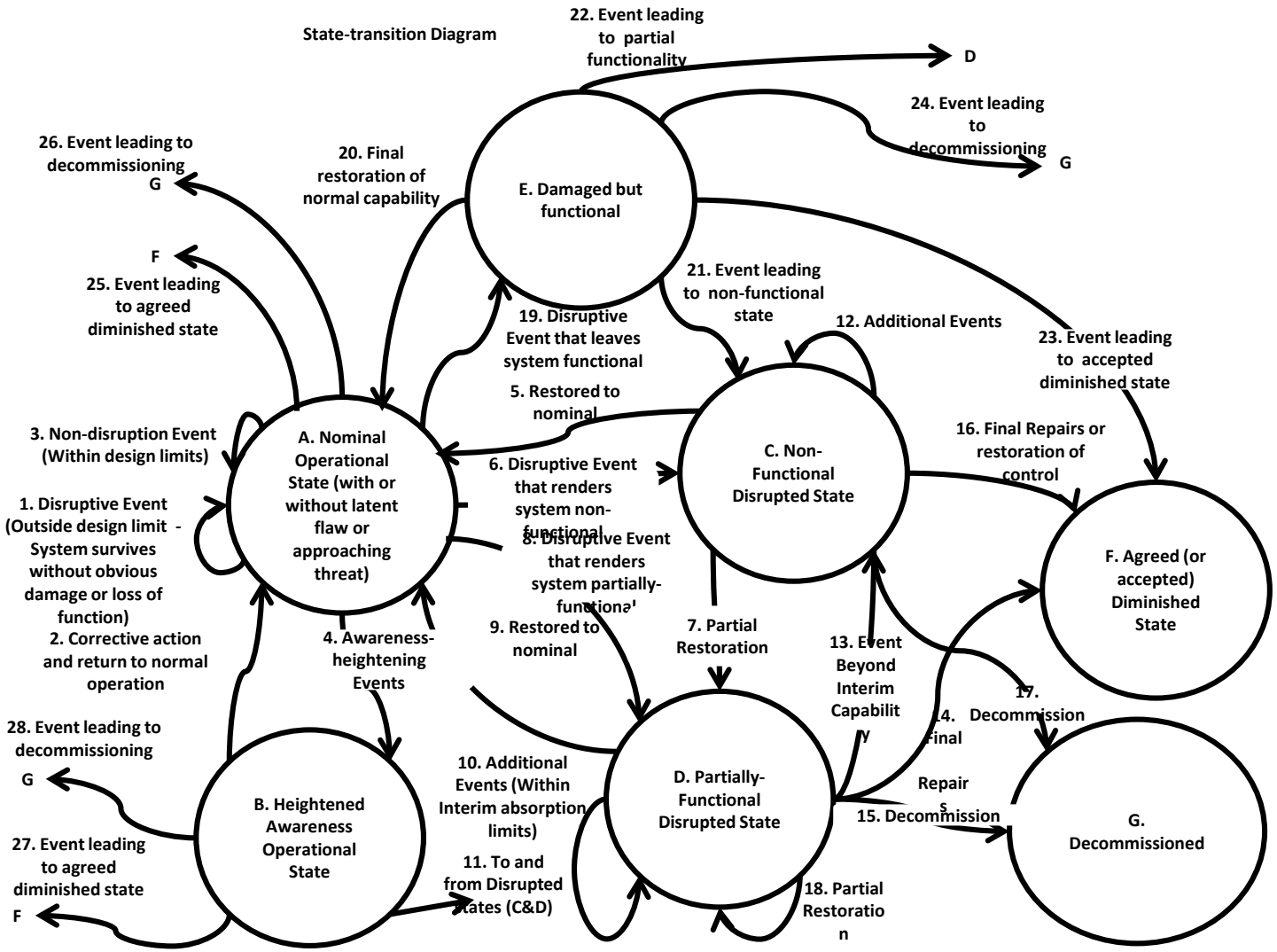
EA – Simulation Interface

- Previous work
  - —Based on system dynamics
  - —Specified run length, filenames and cycle information
  - —Also specified variables with which the learner could interact (not formally specified, though)
- Current specification
  - —Model interface contains structural information
  - —Experiment interface contains parameters that the experience designer controls to vary the experience
    - o More vs. less difficult
  - —Interaction interface contains variables with which learner interacts plus limits on learner-specified changes

State-Chart Simulation

- Current simulation based on system dynamics
  - Many useful system features modeled
  - Lags
  - Feedback loops
  - Non-linearity
- But state transitions and other discrete-event formalisms not easily modeled
  - Discrete state space
  - Modes
  - Triggers
  - Probabilistic transitions between states
  - Cascading failures
  - Used in other efforts (Enterprise Modeling and Analysis RTs)

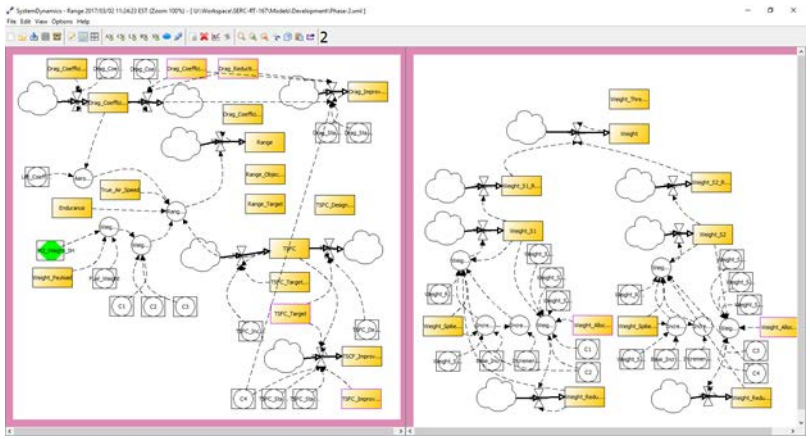
Example State Transition System



Current Work

- Designed use cases for how an experience designer would use a state-chart simulation tool
- Designed GUI for state-chart simulation tool
- Currently developing tool
  - —Using open-source state-chart class library from Apache
  - —Implementing using Java
  - —Goal to have something similar to system dynamics simulation tool

System Dynamics Tool



Demonstration Plans

- Using a generic acquisition program as the demonstration system
- Features
  - State transitions between acquisition phases
  - Triggers that cause problems in the program
  - Probabilistic transitions and transition times
  - Modes such as normal operation versus crisis model
- Fleshing out detailed model
- Designer could use tool to aid with experience flow

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Modes of Operation

- **Synchronous Instructor**: Instructors are available to provide an introduction to the students, and lead them through the experience in a class room setting, with synchronous interaction with the students in the classroom along with one on one evaluation and discussion.

- **Asynchronous Instructor:** This is similar to the synchronous version except that travel is not required for the instructor and there is freedom with respect to the scheduling of the experience.

- **Off-line Mentoring:** Instructors provide off-line mentoring to each of the individuals who have completed the experience. Approximately 15 minutes will be dedicated per student, plus approximately 15 minutes of preparation time for each. The learning assessment tools will assist in these efforts.

- **Independent:** This option does not include any direct interaction between the instructors and the students. However, support will be provided for the interpretation of the students' results. This would be useful for a very large-scale training exercise with an organization on a short time scale.

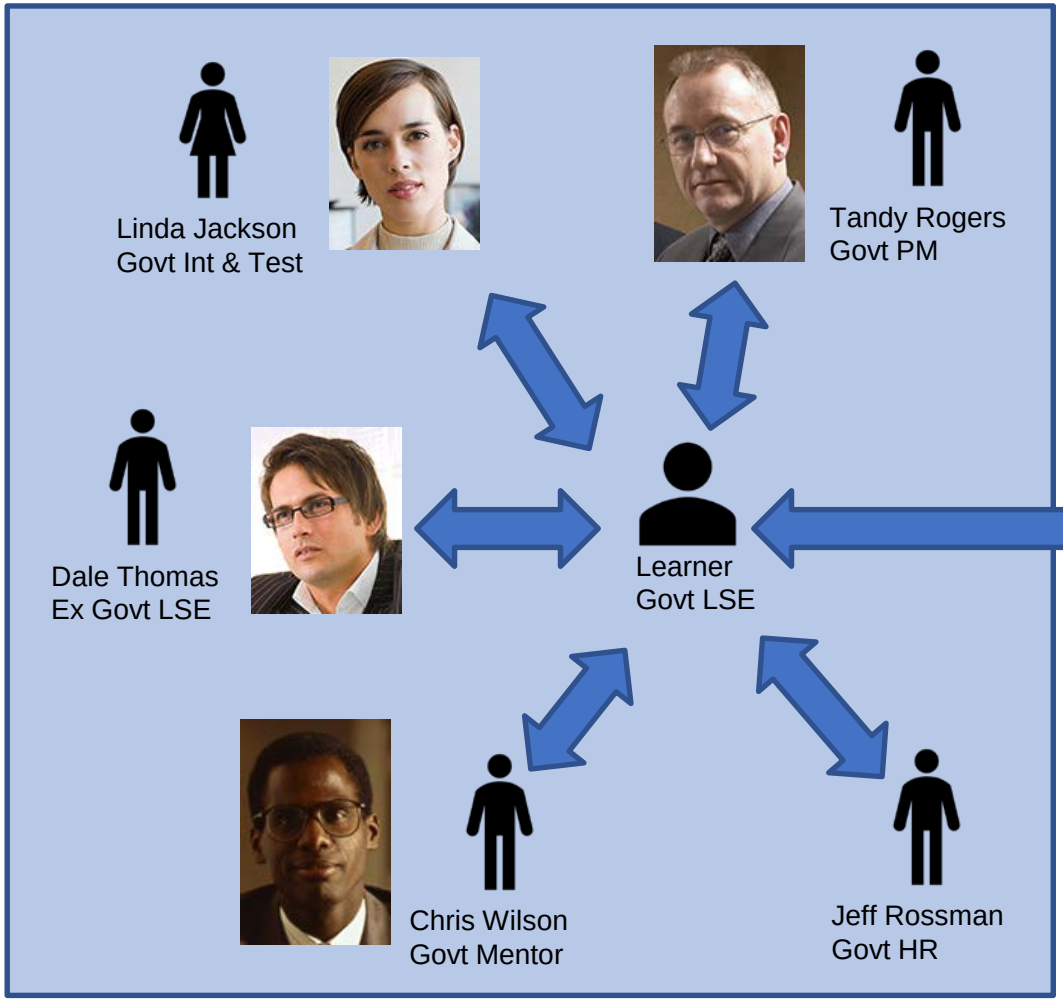
Major Changes for Industry Experience

1. **Challenge Areas:**
   - 1.1 Understanding customer's needs and managing them
   - 1.2 Management of contractors
   - 1.3 Unclear objectives

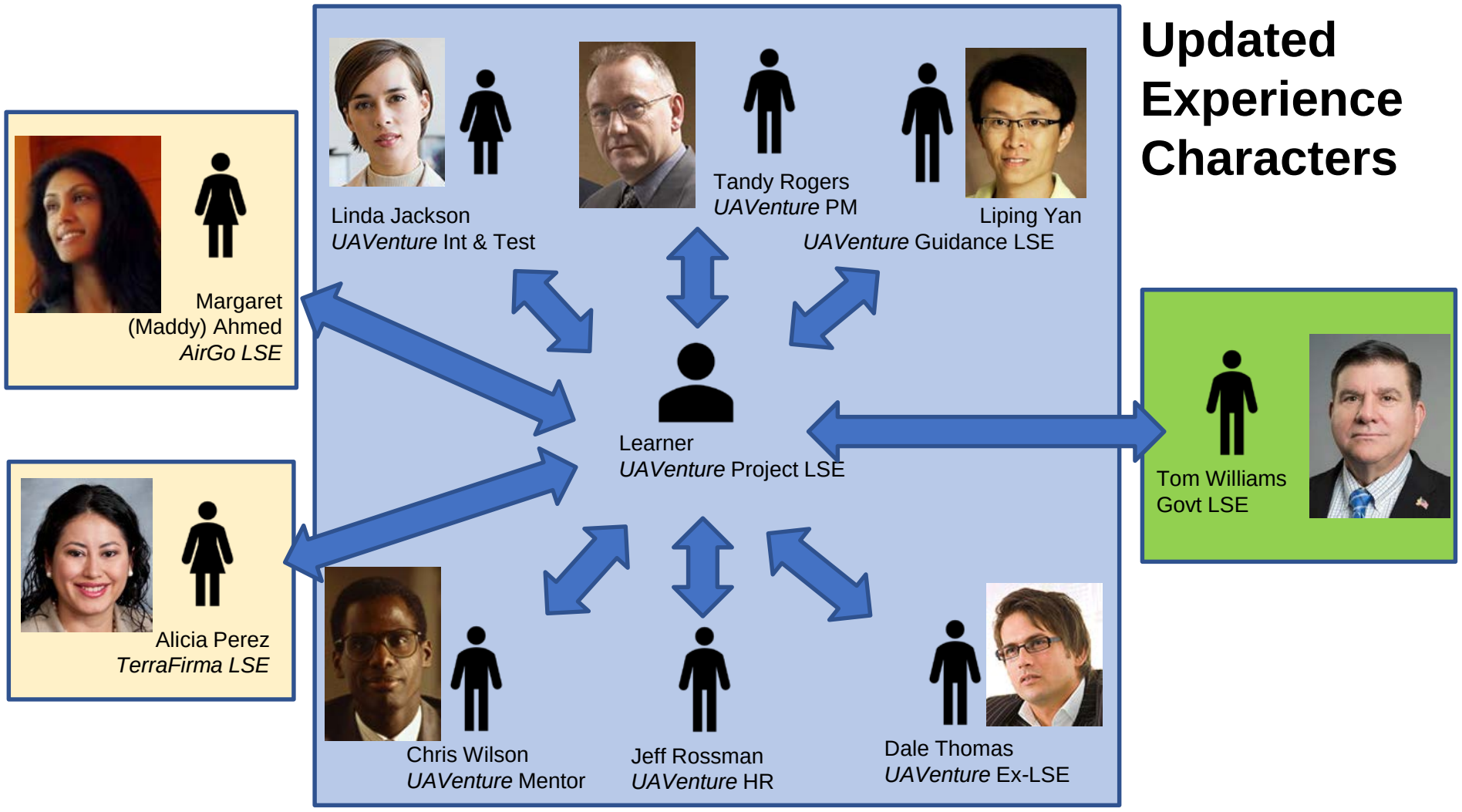
2. **Roles:** Change of learner role from lead system engineer for the government to lead system engineer for the prime contractor. This involves the creation of several new NPC roles including three subcontractor technical leads, and a prime contractor Program Manager

3. **Artifacts:** Format changes made based on review with sponsor.

Current UAV Experience Characters



Updated Experience Characters



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Future Work

- Experience Development
  - Complete and deploy UK MoD Experience
  - Complete and deply industry Experience
  - Complete Wright Bros Experience

- Learning Evaluation
  - Gather performance data through pilot application with a number of systems engineering experts
  - Calibrate the experience and scoring mechanism using data gathered from expert pilot usage
  - Comparing students' behavioral data and decision-making process with experts'
  - Improving the stability of the system using feedback
  - Finish training of the machine learning algorithm

- Simulation Capabilities
  - Complete generic interface between Experience Accelerator and simulation engines
  - Support multiple simulation paradigms
  - Develop and use tool for creating state-chart based simulations

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Acknowledgement

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Systems Engineering Experience Accelerator

10 YEARS of SERC

US Army 1907 Advertisement

4. The flying machine should he designed to have a speed of at least forty miles per hour in still air, but bidders must submit quotations in their proposals for cost depending upon the speed attained during the trial flight, according to the following scale:

40 miles per hour, 100 per cent.
39 miles per hour, 90 per cent.
38 miles per hour, 80 per cent.
37 miles per hour. 70 per cent.
36 miles per hour, 50 percent;
Less than 36 miles per hour rejected.
41 miles per hour, 110 per cent.
42 miles per hour. 120 percent.
43 miles per hour, 130 per cent.
44 miles per hour. 140 per cent.

5. The speed accomplished during the trial flight will be determined by taking an average of the time over a measured course of more than five miles against and with the wind. The time will be taken by a flying start, passing the starting point at full speed at both ends of the course. This test subject to such additional details as the Chief Signal Officer of the Army may prescribe at the lime.

6. Before acceptance a trial endurance flight will be required of at least one hour during which time the flying, machine must remain continuously in the air without landing. It shall return to the starting point and land without any damage that would prevent it immediately starting upon another flight. During this trial flight of one hour it must be steered in all directions without difficulty and at all times under perfect control and equilibrium.

7. Three trials will be allowed for speed as provided for in paragraphs 4 and 5. Three trials for endurance as provided for in paragraph 6. and both tests must be completed within a period of thirty days from the dale of delivery. The expense of the tests to be borne by the manufacturer. The place of delivery to the Government and trial flights will be at Fort Myer, Virginia.

8. It should be so designed as to ascend in any country which may be encountered in field service. The starting device must be simple and transportable. It should also land in a field without requiring a specially prepared spot and without damaging its structure.

9. It should be provided with some device to permit of a safe descent in case of an accident to the propelling machinery.

10. It should be sufficiently simple in its construction and operation to permit an intelligent man to become proficient in its use within a reasonable length of time.

11. Bidders must furnish evidence that the Government of the United States has the lawful right to use all patented devices or appurtenances which may be a part of the flying machine, and that the manufacturers of the flying machine are authorized to convey the same to the Government. This refers to the unrestricted right to use the flying machine sold to the Government, but does not contemplate the exclusive purchase of patent rights for duplicating the flying machine.

US Army 1907 Advertisement

12. Bidders will be required to furnish with their proposal a certified check amounting to ten per cent of the price stated for the 40-mile speed. Upon making the award for the flying machine these certified checks will be returned to the bidders and the successful bidder will be required to furnish a bond, according to Army Regulations, of the amount equal to the price stated for the 40-mile speed.

13. The price quoted in proposals must be understood to include the instruction of two men in the handling and operation of this flying machine. No extra charge for this service will be allowed.

14. Bidders must state the time which will be required for delivery after receipt of order.

JAMES ALLEN, *Brigadier General, Chief Signal Officer of the Army*
SIGNAL OFFICE
WASHINGTON, D. C. *December 23, 1907.*