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Systems Engineering Experience Accelerator

Accelerated Learning & Learning Assessment for Systems Engineering Education

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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
- Providing tools to facilitate experience development and tailoring

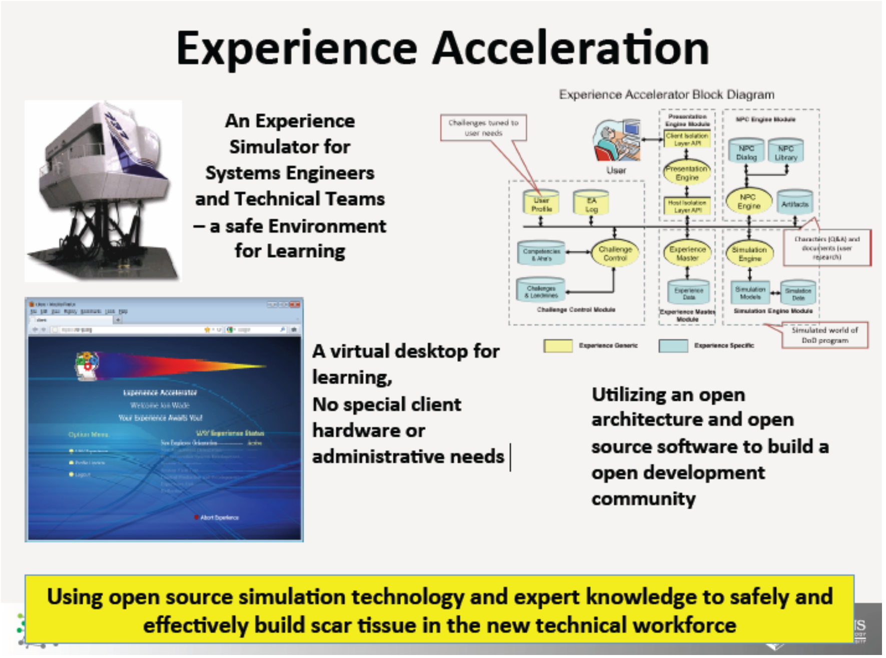
Program Plan 2016-17

Work plan for RT-167	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Deliverable ◇
Task 1. New Experience Capabilities														
T1.1: Trade study						◇								Trade study demo
T1.2: Reliability KPP & tech debt						◇								REL KPP/technical debt demo
Task 2. Experience Improvements														
T2.1: UAV full life-cycle.									◇					Complete UAS (all phases)
T2.2: Tune simulation														Incremental updates
T2.3: Complete mentor role				◇										Mentor dialogues
T2.4: Update class materials												◇		Updated materials
Task 3. Section 508 Compliance														
T3.1: Section 508 methods														Methods/changes for 508
T3.2:Section 508 changes			◇											report
T3.3: Translation of EA screens														All screens and artifacts
T3.4: Translation of EA artifacts										◇				translated
T3.5: Evaluation of 508 compliance												◇		508 conformance certification
Task 4. Validate Research Hypothesis - Learning Evaluation														
T4.1: Provide support to DAU staff														None
T4.2: Support pilot uses of the EA														None
T4.3: Design learning evaluation; collect data						◇								Evaluation plan
T4.4: Analyze learning effectiveness data													◇	Effectiveness report
Task 5. Support DAU EA Deployment														
T5.1: Specification of hosting deliverables					◇									Deliverable descriptions
T5.2: Hosting solution(s) for DAU								◇						Hosting solution report
T5.3: Migrate to 3rd Party Support												◇		3rd party support demo
T5.4: Update EA documentation												◇		Updated documentation
T5.5: Support of Deployment Plan														None

Introduction

- 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

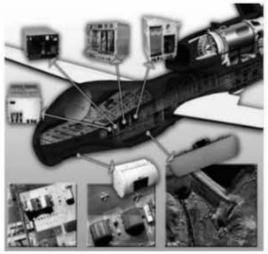


The Learning Experience

- 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

Phases of the XZ-5 UAV Experience

Phase	Phase Description		
	Phase Activity Focus	Ending Event	Activities
0	SEEA Introduction	Survey completion	The learner is introduced to the SEEA
1	Assignment to UAV Program	Submission of likely problems and actions	Introduction to the experience
2	System Pre-integration	Critical Design Review	Acts as LSE
3	System Integration	Flight Readiness Review	Acts as LSE
4	Flight Test	Production Readiness Review	Acts as LSE
5	Limited Production	Integrated System Review	Acts as LSE
6	End of Project	Success or Failure	Results are presented.
7	Reflection	End of experience	Receive information about their decisions and reflect on learning objectives.

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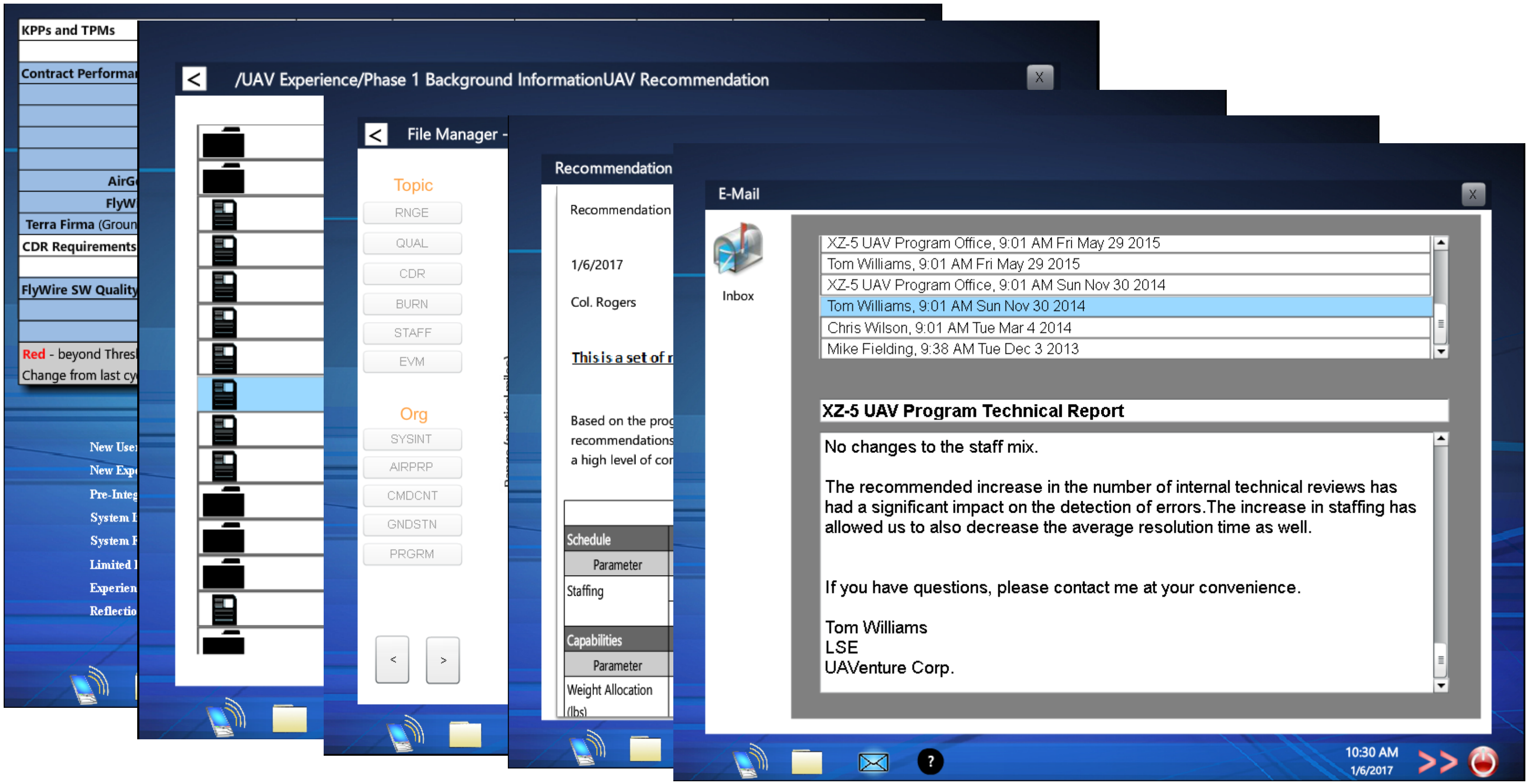
Current Implementation of SEEA



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. Prior to completing this research, these data has been selected and will be collected from the EA:

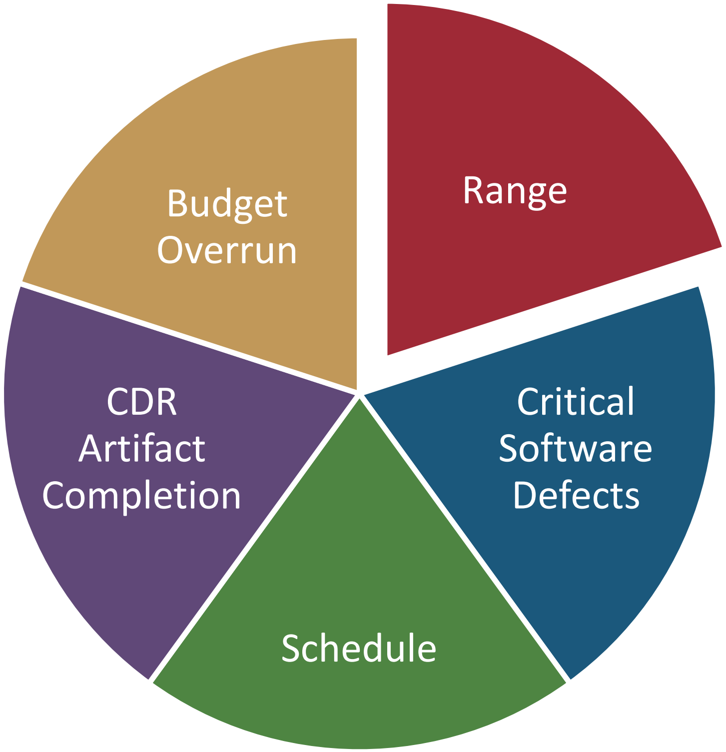
- Participant Identification:
  - Learner's Name & demographic information
  - Team Name & other members
  - Instruction Name & Roles played in Experience
- Experience Session Information:
  - Experience Name and Version
  - Date of Experience Start and End
  - login dates and duration of each session
  - 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

UAH Pilot Application

- More than 30 junior and senior engineering undergraduates at the university of Alabama in Huntsville (UAH) used the SEEA during the 2016 spring semester as a team project.
- The students were enrolled in the Management Systems Analysis course, which focuses primarily on project management skills. Students were asked to participate in teams of five.
- Each student in a team plays a different role in the XZ-5 UAV experience. Those roles include Lead Systems Engineer (LSE), Airframe and Propulsion System Lead (APS), Command and Control System Lead (CCS), Ground Stations Launch and Retrieval System Lead (LGLRS), and Integration Lead (Prime).
- Each team was tasked with using the SEEA in the UAV scenario given as two homework assignments – one near the beginning of the semester, and one near the end of the semester to evaluate the students’ skill advancement.

Results and Analysis

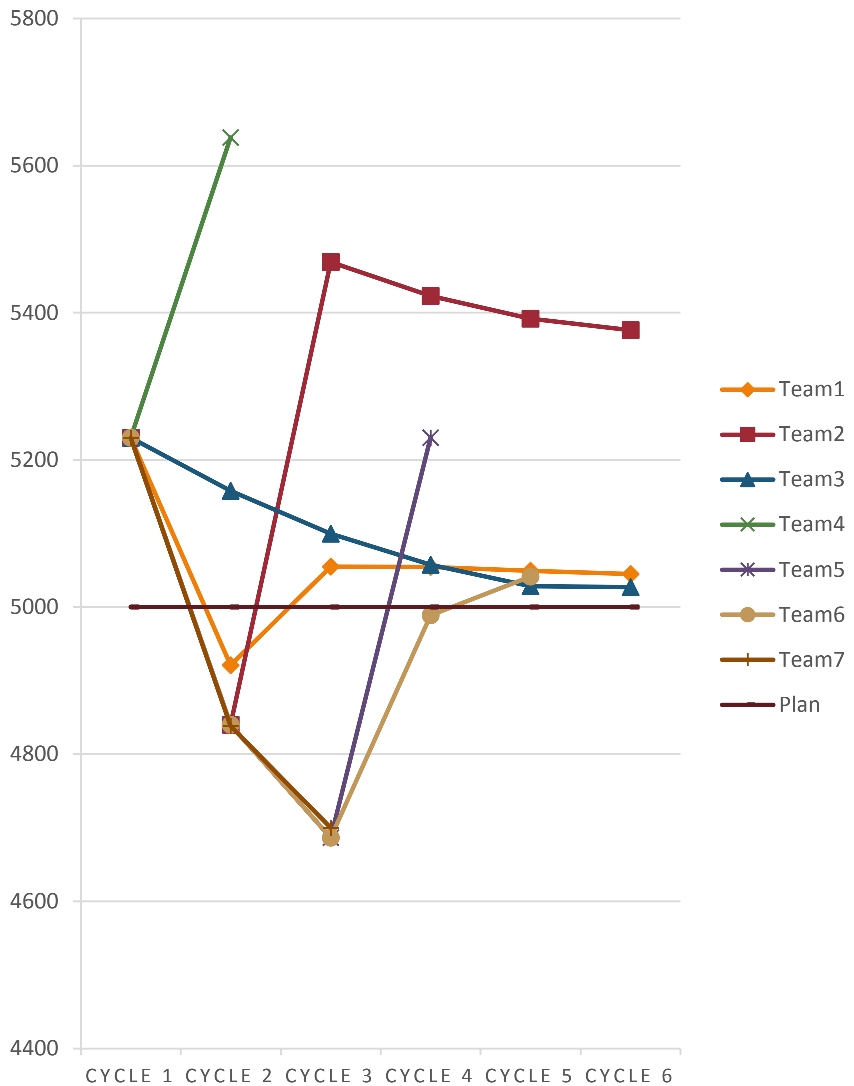
- Pilot Results
  - —Performance data of the teams gathered and compared.
  - —Performance measures include range, critical software defects, schedule, CDR artifact completion and budget overrun.
  - —Teams made different decisions resulting in a range of performances and different program results.
  - —Five of the seven teams completed the project cycle and reached phase 7 to receive performance feedbacks for the EA.



Results and Analysis

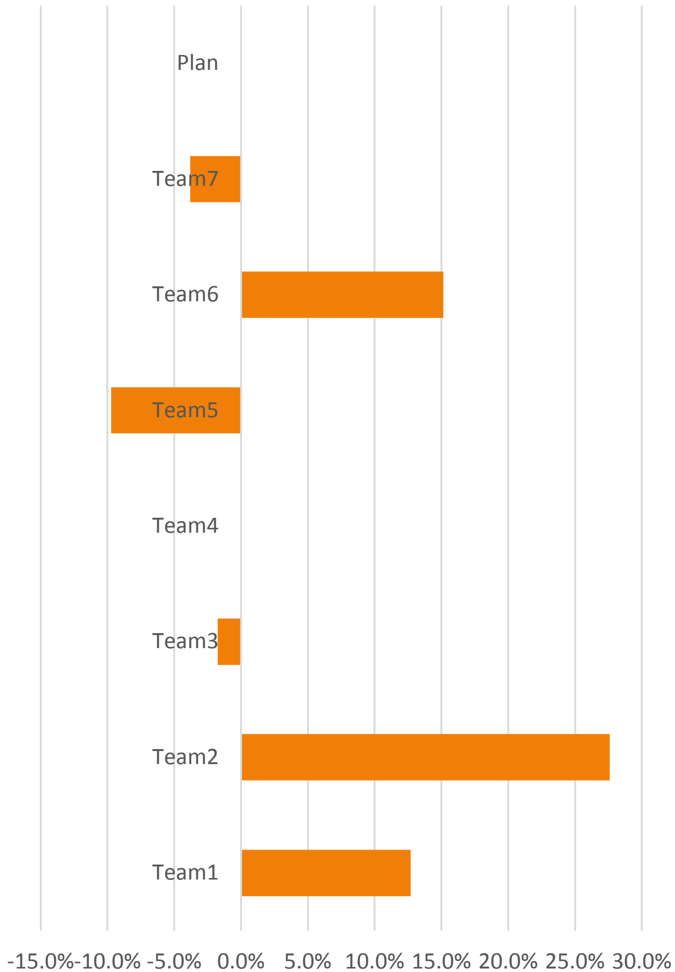
Team1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7
Experience Finished	Experience Finished	Experience Finished	Experience not Finished	Experience Finished	Experience Finished	Experience Not Finished
Score: 83	Score: 58	Score: 77		Score: 44	Score 86	
Program Completed Successfully	Program Canceled	Program Terminated		Program Terminated	Program Completed Successfully	

Range Performance



- Range of the UAV is affected by weight, drag coefficient and thrust specific fuel consumption (TSFC).
- There were early signs of a range problem caused by weight issues.
- Team 2 performed very well with range, team 1, 5, 6 achieved the requirement.
- Most of the teams reacted to the weight issues by reallocating the weight balance and adding more workforce to the airframe and propulsion team.

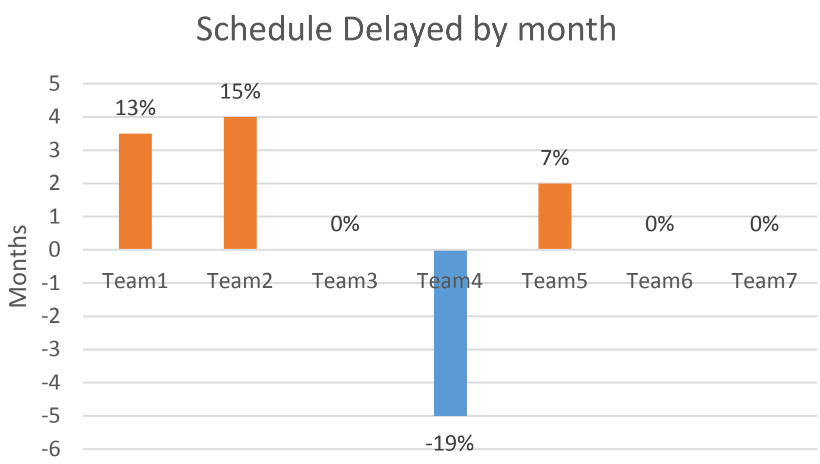
Budget Overrun

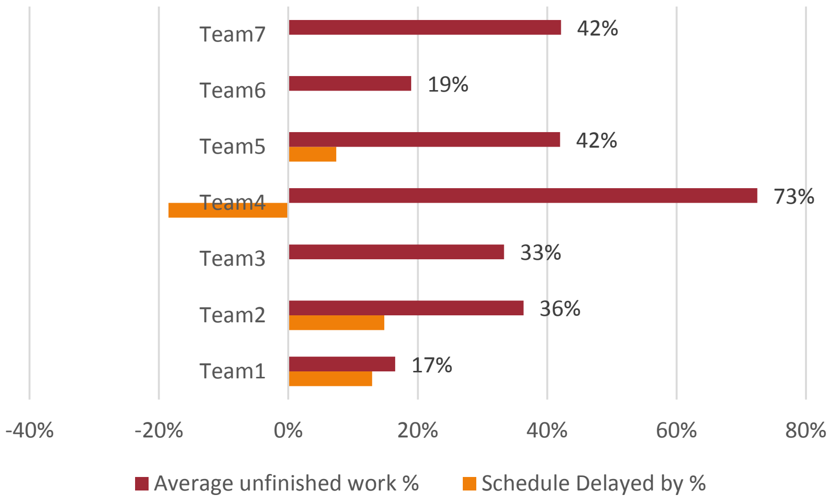


	Team1	Team2	Team3	Team4	Team5	Team6	Team7	Plan
Budget Overrun	12.702%	27.589%	-1.735%	-0.026%	-9.713%	15.141%	-3.808%	0.000%

- Budget is an important measure to the success of the UAV program. Teams need to control the budget to be successful in the experience.
- Team 2 performed well in range, the recommendations they made caused significant budget overrun.
- All the successful teams managed the budget and had a budget overrun of less than 15 percent.

Schedule & CDR Readiness





- The XZ-5 UAV program has an original plan of 27 months between PDR and CDR. Any significant delay will potentially undermine the success of the program.
- It is recommended by the experts that the schedule shall not be delayed over 20 while the delay within 10% of the period is considered good.
- Team 3, 5, 6 and 7 managed the schedule well. Team 4 recommended to advance the CDR time by 5 months which resulted in incomplete work. Team 1 and 2 performed within acceptable range.
- Teams that manages the schedule well are likely to pass CDR proceed with low risk.

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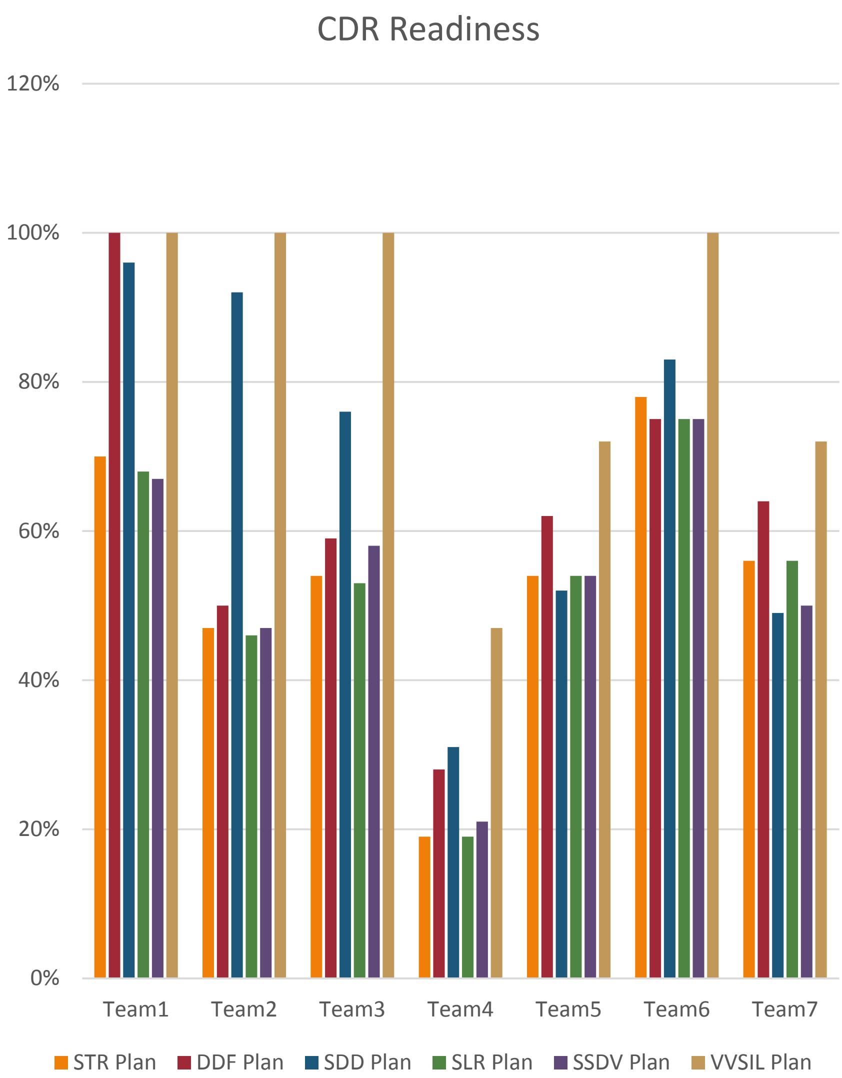
CDR Artifacts Completion



- The CDR Readiness is affected by the staff mix, as well as the number of design and test plan reviews.
- Includes STR, DDF, SDD, SLR, SSDV and VVSIL plans.
- Team 1 and 6 did very well. While Team 2, 3 and 5 did ok.

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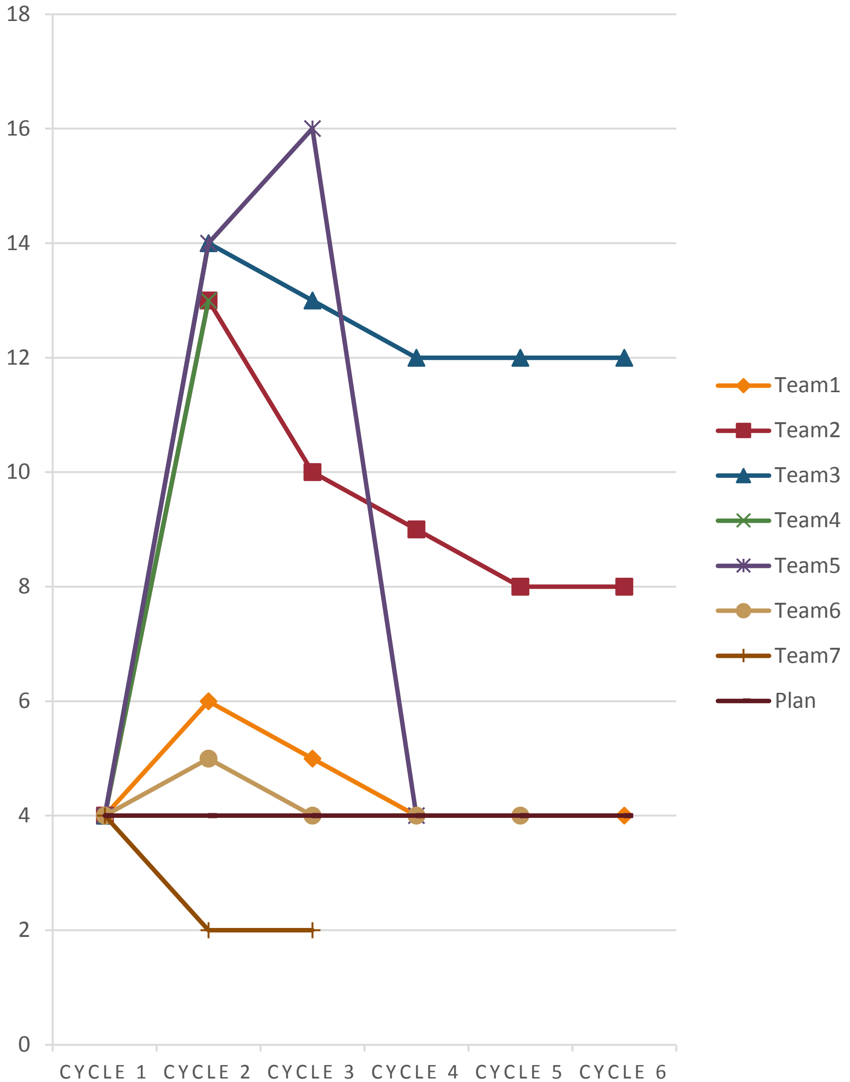
Software Critical Defects



- Software critical defects are affected by the mix of senior junior staff and the number of software reviews.
- It is recommended to have less than eight critical defects to pass CDR proceed with low risk.
- Team 1, 5, 6 and 7 kept the critical defects quite low, while Team 2 and Team 3 kept them within an acceptable range.

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Pilot Analysis

Teams	Simulation Result & Score	Presentation Results	Decision and Actions throughout the Experience
Team 1	Finished the experience, entered CDR with low risks. Program completed successfully. Score 83	Decisions that would be changed in hindsight: Command and Control weight would have been decreased more significantly More junior staff would have been hired and less senior staff to avoid costs Overall, the project was overrun by 13% at the end of Phase 2, so more questions would have been asked to stakeholders to make better decisions	Increased the CCS weight allocation. Increased senior staff and decreased junior staff. Increased the drag coefficient target
Team 2	Finished the experience, entered CDR with high risks. Program canceled. Score 58	N/A	Increased the CCS weight allocation, and hired more junior staff. More junior staff and increased the drag coefficient target significantly. Decreased CCS weight allocation and hired even more junior staff. Changed senior/junior staff mix.
Team 3	Finished the experience, entered CDR with medium risks. Program terminated. Score 77	Entry criteria for CDR was not achieved due to personnel disbursement error. After hiring and training new personnel, it was decided to move forward in the hopes of achieving at least 80% effectiveness. In hindsight, the team would ensure the correct amount of personnel per department is hired and trained efficiently and effectively to meet guidelines and quality metrics for the success of the program	Decreased CCS weight allocation and increased both senior and junior staff. Decreased CCS weight allocation. Further increased senior and junior staff. Increased drag coefficient target. Further increase senior and junior staff.
Team 4	Didn't finish the experience. Score N/A	Most likely would not have been ready for the CDR because of the issues with scheduling and project progress, but there seems to be improvement compared to our previous run. We were more willing to make changes this time, which seemed to improve the project overall.	Increased senior staff in APS and CCS, change weight allocations. Added more senior staff and less junior staff.
Team 5	Finished the experience. Entered CDR with medium risks. Program terminated. Score 44	Our CDR was delayed by 2 months because the range wasn't where we wanted it to be. After delay, CDR criteria was achieved and we proceeded to the next phase. CDR completed and mission accomplished.	Increased senior and junior staff. More senior staff and less junior staff. Increase drag coefficient target. Increased senior and junior staff.
Team 6	Finished the experience. Entered CDR with low risks. Program completed successfully. Score 86	Adding quality engineers was very successful in our simulation.	Increased senior and junior staff. Decrease senior staff slightly. Increase weight allocation for CCS. Increased target of drag coefficient. Reduced junior staff number.
Team 7	Didn't finish the experience. Score N/A	Would do differently: Add more staff to APS at the beginning to reduce the drag. Not hire as much staff for the CCS. Try to find different ways to reduce the drag coefficient. Try to find different ways to increase the range.	Reduced the total weight allocation of APS, increased both senior and junior staff for CCS, increased the GS junior staff, increased APS. Added more senior and junior staff. Increased software review frequency.

Summary

- Discussed the use of Systems Engineering Experience Accelerator in the domain of Systems Engineering Education, its use for SE education and learning assessment.
- During the pilot application of the technology, data was gathered from seven teams of students who participated the XZ-5 UAV learning experience.
- The technical difficulties encountered in the first run of this pilot have been resolved and for future pilot applications will conduct multiple runs of the SEEA.

Future Works

- More pilot applications with multiple runs and data gathering.
- Compare students' behavior data and decision-making process with experts'.
- Continue the development of the Learning Assessment Tools.
- New presentation engine.

Acknowledgement

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Thanks

Questions?

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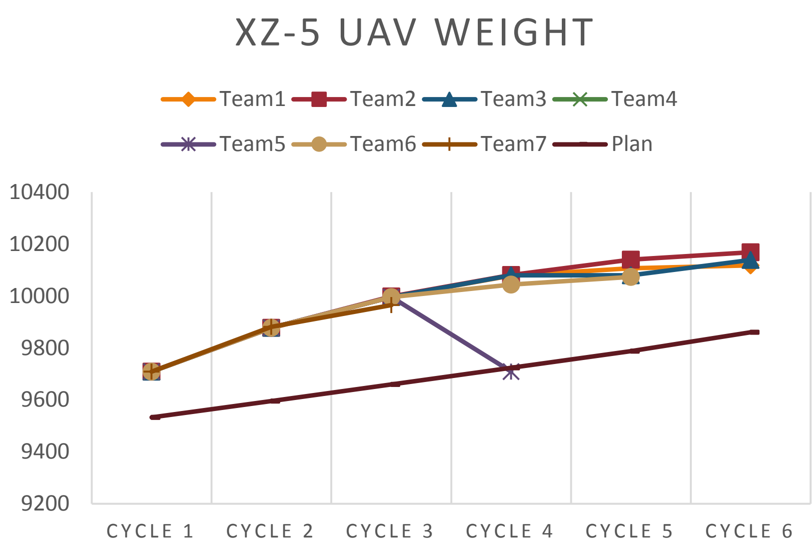
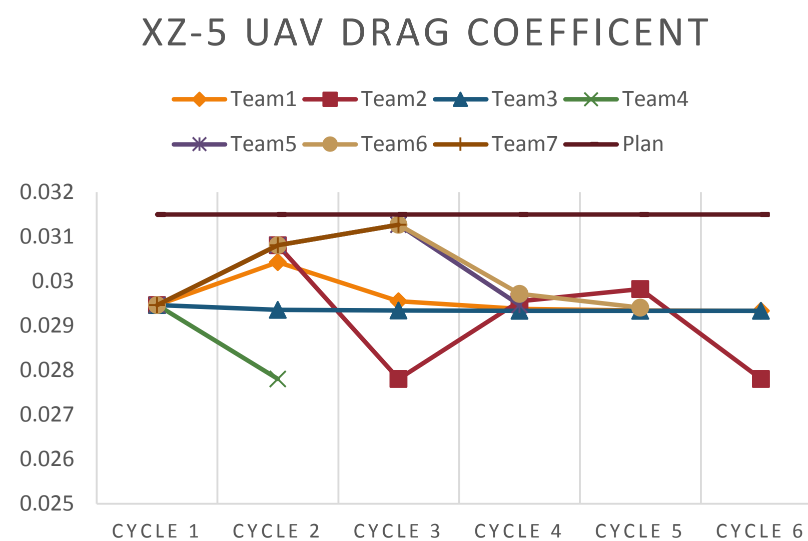
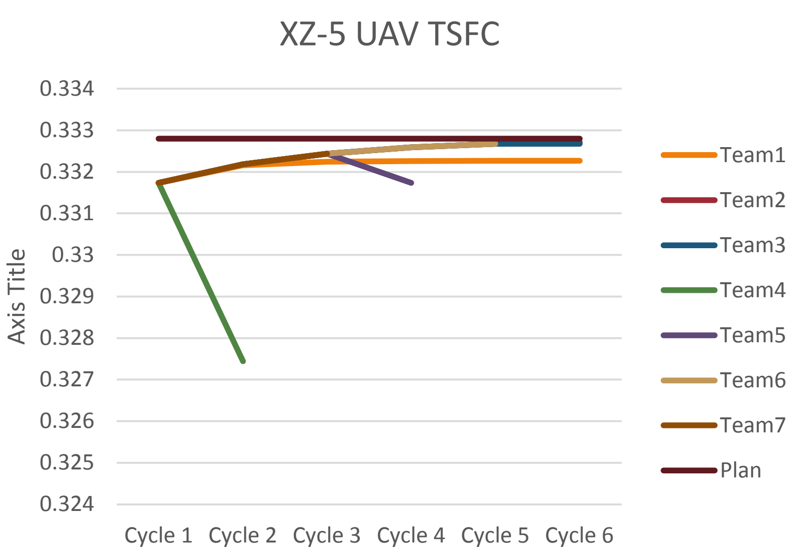
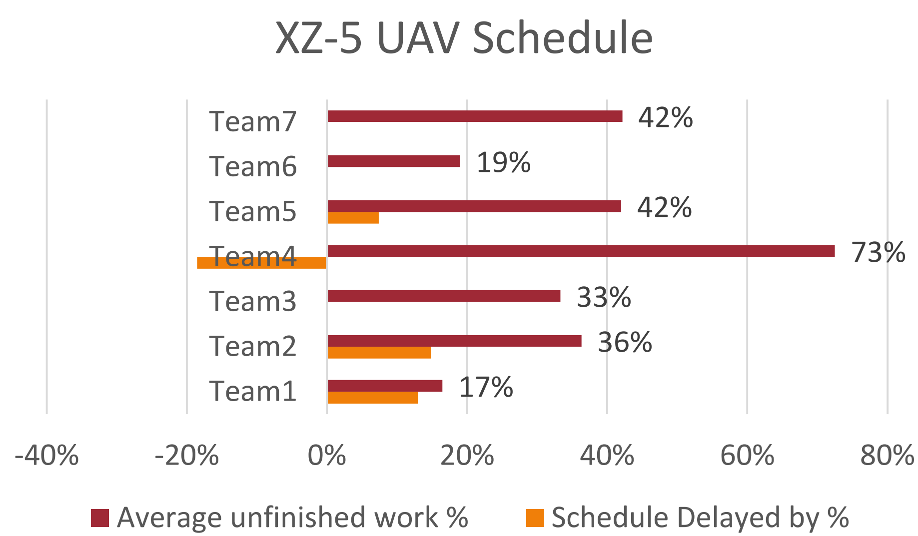
Other data gathered









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CDR Status Evaluation

Simulator Status @ CDR	
Range	5376
SW Qual (Crit. Defects)	8
Actual Budget ($M)	248
Actual Schedule (Months)	31
CDR Artifact Completion	
System Test Reqts	47%
Digital Design Files	50%
Software Design Desc.	92%
Structural Loads Released	46%
Sub-System Design/Ver	47%
V&V of System Integ. Lab	100%
Overall Concern Points	7
Risk of Proceeding Based on CDR Results	**High!**

CDR Status Determination	7
Max Concern Points for Low	3
Max Concern Points for Medium	4

	PTs		Values	CDR Concern Points
KPP				
Range		5376		
Range Plan		5000		
Green %		95%	4750	
Yellow %	1	85%	4250	
Red %	3	<85%		
SW Quality				
Defects Remaining		8		
Green Max		8		
Yellow Max	1	12		
Red Min	2	>12		
Overall Artifact Status		11		
Green Max ACPs		4		
Yellow Max ACPs	2	6		
Red Min ACPs	4	>7		4
Budget				
Actual		248		
Plan		195		
Green <=% over		15%	224.25	
Yellow <= % over	1	20%	234	
Red > % over	2	>20%		2
Schedule				
Actual		31		
Plan		27		
Green <=% over		10%	29.7	
Yellow <= % over	1	20%	32.4	1
Red > % over	2	>20%		

	PTs		Artifact Concern Points
Documentation			
System Test Reqts		47%	
STR Plan		100%	
Green % complete		95%	
Yellow % complete	1	80%	
Red <% complete	2	<80%	2
Digital Design Files		50%	
DDF Plan		100%	
Green % complete		95%	
Yellow % complete	2	80%	
Red % complete	4	<80%	4
Software Design Desc.		92%	
SDD Plan		95%	
Green % complete		95%	
Yellow % complete	1	80%	1
Red % complete	2	<80%	
Structural Loads Released		46%	
SLR Plan		100%	
Green % complete		95%	
Yellow % complete	1	80%	
Red % complete	2	<80%	2
Sub-System Design/Ver		47%	
SSDV Plan		100%	
Green % complete		90%	
Yellow % complete	1	90%	
Red % complete	2	<80%	2
V&V of System Integ. Lab		100%	
VVSIL Plan		100%	
Green % complete		95%	
Yellow % complete	1	90%	
Red % complete	2	<90%	
Total Artifact Concern Pts			11

EA Experience Score

Area Scores		Weight	Base	loss per % work not complete	loss per month of delay
Schedule	100	25%	100	2.5	15
		Weight	Base	Loss per % of range shortfall	
Range	100	25%	100	5	
		Weight	Base	Loss per critical defect	
Quality	92	25%	100	2	
		Weight	Base	Loss per $1M overrun	
Cost	52	25%	100	2	

- Calculated based on schedule, range, quality and cost. Raw score scaled based on the no nothing scenario and the best possible scenario.
- Final score calibrated to be between 0-100.