Trusted Artificial Intelligence Challenge for Systems Engineering: Results and Insights

Overview for the SE4AI/AI4SE Workshop

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Background and Motivation

- Rapid AI advancements can introduce both performance improvements and risks for mission-critical systems, particularly in uncertain/evolving conditions
  - *Under-utilization* → reduced mission effectiveness
  - *Over-reliance* → misplaced confidence & inadequate oversight

- **Trusted AI Challenge for Armaments Systems Engineering** (SE) aimed to develop SE methods capable of enhancing trustworthiness of AI-enabled systems (AIES), particularly in life-critical operational settings
  - **Trustworthiness** = intrinsic system property, demonstrated through attributes like verifiability, reliability, safety, & transparency
  - Build/operate systems with trustworthy behaviors using less trustworthy components

Primary Research Questions:

1. What SE activities and artifacts are best suited to build trust in AIES?
2. What infrastructure is needed to validate trust of AIES?
3. What workforce skills & abilities are required for integrated product teams to develop and manage these systems?

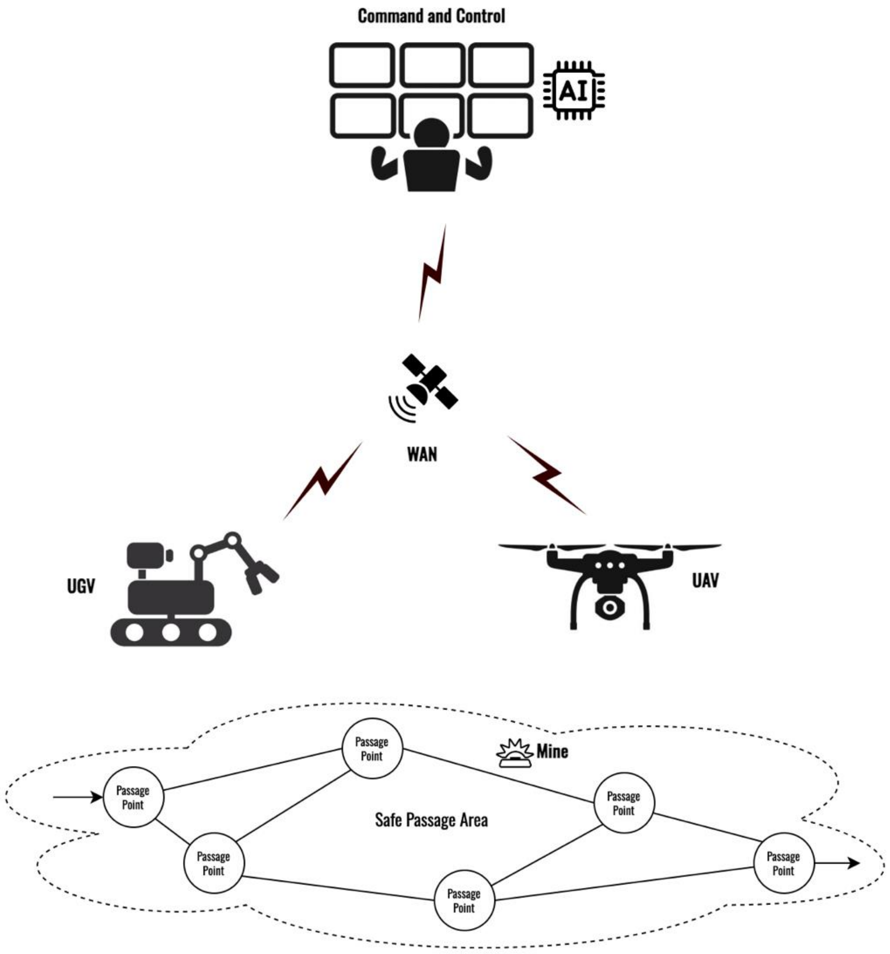
Mission – Operation Safe Passage

Goal: design trusted AI-enabled control system capable of guiding troops through mine-laden terrain

- Determine optimal routing and detection policies that balanced speed, safety, and trustworthiness

Three agents:

- **Unmanned Aerial Vehicles (UAVs)** providing aerial reconnaissance and forwarding mine detection estimates based on environmental scans
- **Mine Detection Systems** with AI-enabled estimator and human SME with varying reliability
- **Unmanned Ground Vehicles** navigating terrain to defuse mines and create path for human troops



Trust integrated by providing mine detection systems ***as-is***

Competition Phases

- **Heat 1: Concept Development**
  - Proposed initial system designs
  - Documented trust assumptions
  - Produced foundational SE artifacts
- **Heat 2: Prototype Demonstration**
  - Developed & deployed prototypes
  - Translated theoretical trust frameworks into operational architectures
- **Heat 3: Lethality Integration**
  - Refined systems to include realistic operational challenges (e.g. complex environmental conditions, additional agents, explicit lethality)

AI Performance Table (% Accuracy)

	Row Index									
Column Index	1	2	3	4	5	6	7	8	9	10
1	0.95	0.95	0.95	0.73	0.95	0.95	0.73	0.94	0.95	0.96
2	0.95	0.95	0.95	0.70	0.95	0.73	0.73	0.95	0.96	0.96
3	0.95	0.95	0.94	0.72	0.70	0.72	0.56	0.95	0.96	0.96
4	0.95	0.56	0.95	0.70	0.68	0.56	0.57	0.95	0.95	0.96
5	0.56	0.57	0.68	0.62	0.94	0.57	0.95	0.96	0.94	0.96
6	0.57	0.57	0.68	0.64	0.94	0.57	0.95	0.96	0.95	0.96
7	0.96	0.57	0.70	0.65	0.94	0.56	0.57	0.95	0.95	0.96
8	0.96	0.96	0.68	0.65	0.94	0.56	0.57	0.94	0.96	0.96
9	0.96	0.96	0.69	0.67	0.70	0.56	0.56	0.96	0.96	0.95
10	0.96	0.96	0.72	0.95	0.72	0.56	0.56	0.96	0.96	0.95

Human Performance Table (% Accuracy)

	Row Index									
Column Index	1	2	3	4	5	6	7	8	9	10
1	0.90	0.90	0.90	0.85	0.90	0.90	0.75	0.90	0.90	0.90
2	0.90	0.90	0.90	0.85	0.90	0.75	0.75	0.90	0.90	0.90
3	0.90	0.90	0.90	0.85	0.85	0.75	0.75	0.90	0.90	0.90
4	0.90	0.56	0.90	0.85	0.70	0.75	0.75	0.90	0.90	0.90
5	0.75	0.75	0.75	0.75	0.90	0.75	0.95	0.90	0.90	0.90
6	0.57	0.75	0.75	0.75	0.90	0.75	0.95	0.90	0.90	0.90
7	0.90	0.75	0.85	0.75	0.90	0.75	0.75	0.90	0.90	0.90
8	0.90	0.90	0.75	0.75	0.90	0.75	0.75	0.90	0.90	0.90
9	0.90	0.90	0.75	0.75	0.85	0.75	0.75	0.90	0.90	0.90
10	0.90	0.90	0.85	0.90	0.85	0.75	0.75	0.90	0.90	0.90

Surface Type Table

	Row Index									
Column Index	1	2	3	4	5	6	7	8	9	10
1	Grassy	Grassy	Grassy	Rocky	Sandy	Sandy	Rocky	Sandy	Sandy	Swampy
2	Grassy	Grassy	Grassy	Rocky	Sandy	Rocky	Rocky	Sandy	Swampy	Swampy
3	Grassy	Grassy	Grassy	Rocky	Rocky	Rocky	Wooded	Sandy	Swampy	Swampy
4	Grassy	Wooded	Grassy	Rocky	Rocky	Wooded	Wooded	Grassy	Grassy	Swampy
5	Wooded	Wooded	Rocky	Rocky	Sandy	Wooded	Grassy	Grassy	Grassy	Grassy
6	Wooded	Wooded	Rocky	Rocky	Sandy	Wooded	Grassy	Grassy	Grassy	Grassy
7	Swampy	Wooded	Rocky	Rocky	Sandy	Wooded	Wooded	Grassy	Grassy	Grassy
8	Grassy	Swampy	Rocky	Rocky	Sandy	Wooded	Wooded	Grassy	Grassy	Grassy
9	Swampy	Swampy	Rocky	Rocky	Rocky	Wooded	Wooded	Swampy	Swampy	Grassy
10	Swampy	Swampy	Rocky	Sandy	Rocky	Wooded	Wooded	Swampy	Swampy	Grassy

Judging Criteria and Scores

Judges used 7-pt Likert Scale to indicate extent of agreement with twelve positively worded statements

- Highest & lowest scores eliminated
- Scores calculated based only on sponsor & industry judges to remove academic bias

Rank your agreement with the following sentences:

1. This team's deliverables described the **<u>systems engineering activities and artifacts</u>** best suited to build trust in AI-enabled systems.

Strongly Disagree	Disagree	Mildly Disagree	Neutral	Mildly Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

Score:__________

Notes:

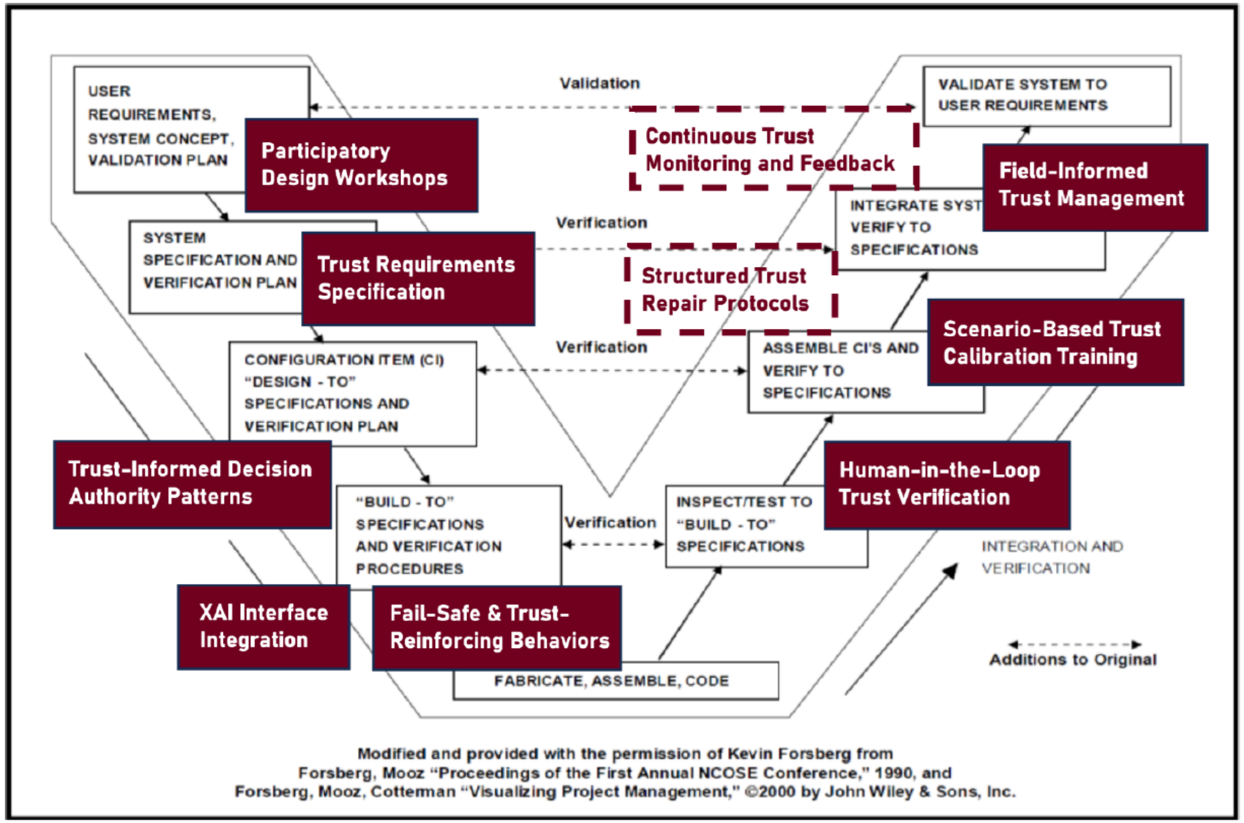
Statements included statements related to research questions as well as design patterns, risk-based monitoring, best practices & novel approaches

	Team 1								Team 2							
Factor	Judge 1	Judge 2	Judge 3	Judge 4	Judge 5	Judge 6	Judge 7	Judge 8	Judge 1	Judge 2	Judge 3	Judge 4	Judge 5	Judge 6	Judge 7	Judge 8
SE activities	6	4	6	6	6	7	1	4	4	4	7	6	3	4	1	1
Trust infrastructure	7	6	7	7	4	6	3	4	4	4	7	7	3	6	3	3
Key workforce skills/abilities	6	4	6	4	3	6	6	2	4	4	7	6	6	7	6	6
Added sensing	5	2	5	5	4	2	2	6	5	2	4	4	5	2	6	5
Lethality	6	2	4	5	6	2	3	6	5	2	6	5	3	2	4	3
Design patterns	5	7	7	6	6	5	7	4	6	7	6	6	6	7	7	4
Risk-based monitoring/mgmt	6	5	7	5	3	6	7	3	5	4	6	6	5	2	6	3
Quantitative methods	6	6	7	5	6	6	3	6	5	6	6	7	6	7	4	5
Best practices	5	6	6	5	5	6	4	3	4	7	6	6	4	6	6	3
Novel approaches	6	5	5	6	4	7	5	4	4	6	4	6	6	7	3	4
Future plans	6	4	4	5	4	2	6	2	4	4	4	5	4	5	3	2
Transition	6	5	7	6	5	6	1	4	4	4	7	6	4	6	1	3
Total	89	70	90	82	69	80	58	58	66	66	91	89	67	78	60	52

Final Approaches and Results

Approaches:

- **GWU** – Established structured framework to evaluate human-AI collaboration architectures
- **Purdue** – Extended aspects of the GWU framework, and utilized RL to explore human-AI interaction scenarios
- **Old Dominion** – Developed a modular, transparent simulation framework
- **Stevens** – Employed robust statistical analyses & Monte Carlo simulations
- 2 **Virginia Tech** – Integrated trust into SE V-model with rigorous human-systems integration activities
- 1 **UVA** – Combined RL with explainable statistical methods & risk monitoring and outlined workforce capability requirements
- **Arizona** – *Did not participate in final heat due to unforeseen circumstances*



VT V-Model Definition

Insights and Recommendations

	Near-Term	Intermediate	Future
Systems Engineering (SE) Activities and Artifacts	• Clearly document explicit trust requirements & trust calibration steps • Organize rigorous participatory design sessions, targeting modularization	• Iterate on human-systems integration artifacts • Establish iterative testing cadence and systematic refinement • Structure V& V workflows	• Incorporate comprehensive SE frameworks with explicit trust requirements, iterative validation, and stakeholder engagement
Trust Validation Infrastructure	• Develop human-in-the-loop simulation frameworks • Engineer clear visualization tools	• Employ large-scale modular simulation validated under variety of conditions for operational robustness • Test operational visualization tools	• Establish resilience pipelines and methods integrated in the mission context • Incorporate operational visualization tools into workflows and pipelines
Workforce Skills & Team Competencies	• Prioritize technical proficiency foundational to interdisciplinary skills in hiring and team-building decisions	• Instantiate evaluations and continuous feedback mechanisms • Evaluate cognitive agility and real-time risk assessment skills for operational effectiveness	• Promote continuous learning through training exercises and workshops to stay current with evolving technologies, threats, and best practices

Future Work

- **Human-AI teaming**, emphasizing human-in-the-loop participation in decision-making vs. fully autonomous systems.
- **Operational resilience testing**, including how to identify system failures under disturbance and how to assess trust degradation and recovery capabilities.
- **Systematic risk management** approaches, involving articulating risk indicators for AI subsystem failure or human-AI communication breakdowns.
- Assessing impact of accessing underlying detection methods and **modifying system components on trustworthiness** to enhance system interoperability and adaptability across various operational contexts.

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