Rapid Intelligent Systems Engineering

AI4SE & SE4AI Workshop 2024

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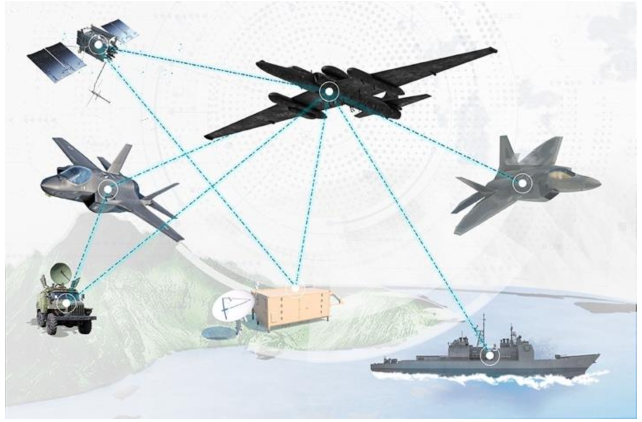
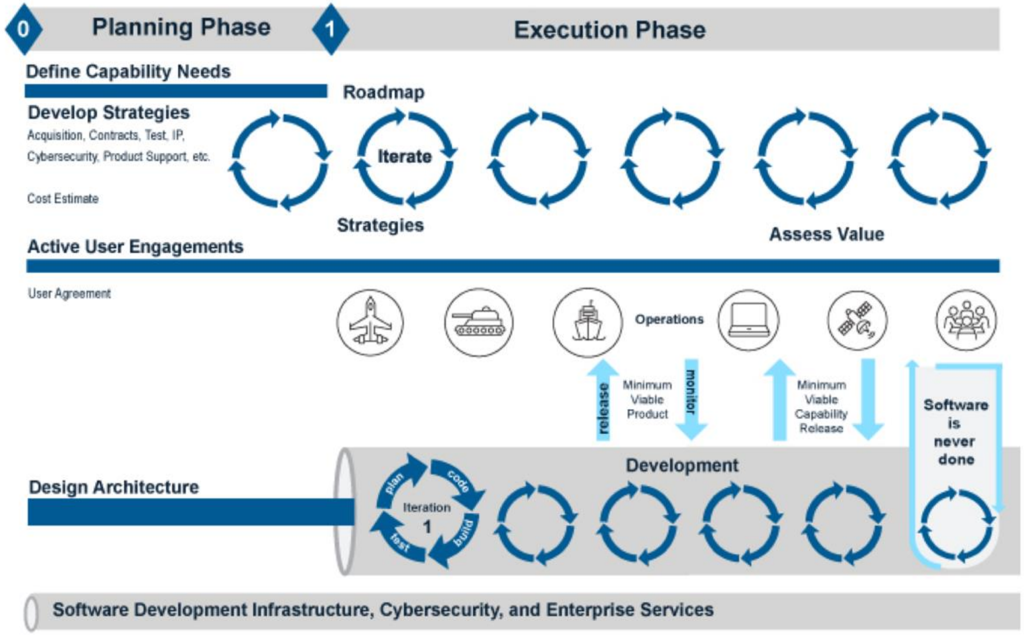
Why “Rapid”?

- System acquisition is becoming agile
- Capabilities will be assembled **just-in-time** and **at the edge** to address specific mission needs
- Capabilities are added and weaknesses addressed continually
- Stakeholders need to make risk-informed decisions and use the information obtained from SE activities
- Transition from traditional waterfall V-model systems engineering to Dev*Ops transforms the view of assurance from compliance to value-driven



LM Project Hydra



From DoD instruction 5000.87: OPERATION OF THE SOFTWARE ACQUISITION PATHWAY

New acquisition regimes are characterized by **complexity** and **agility**. Can Generative AI help?

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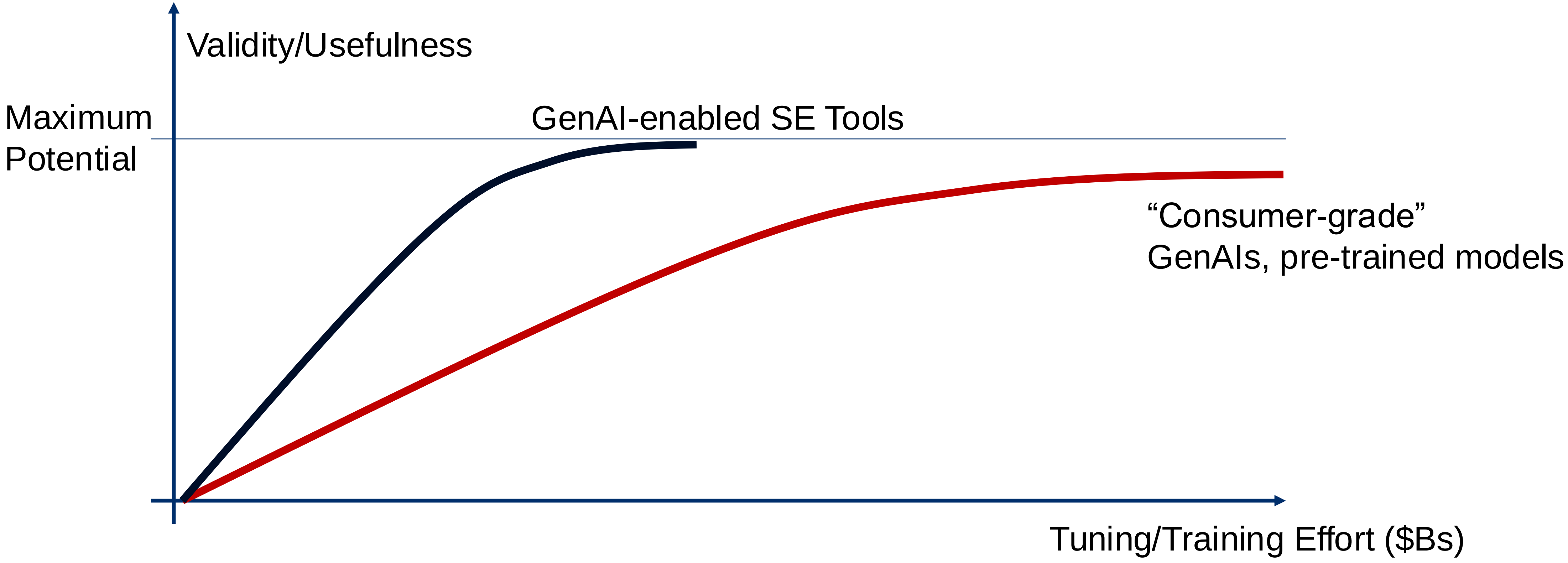
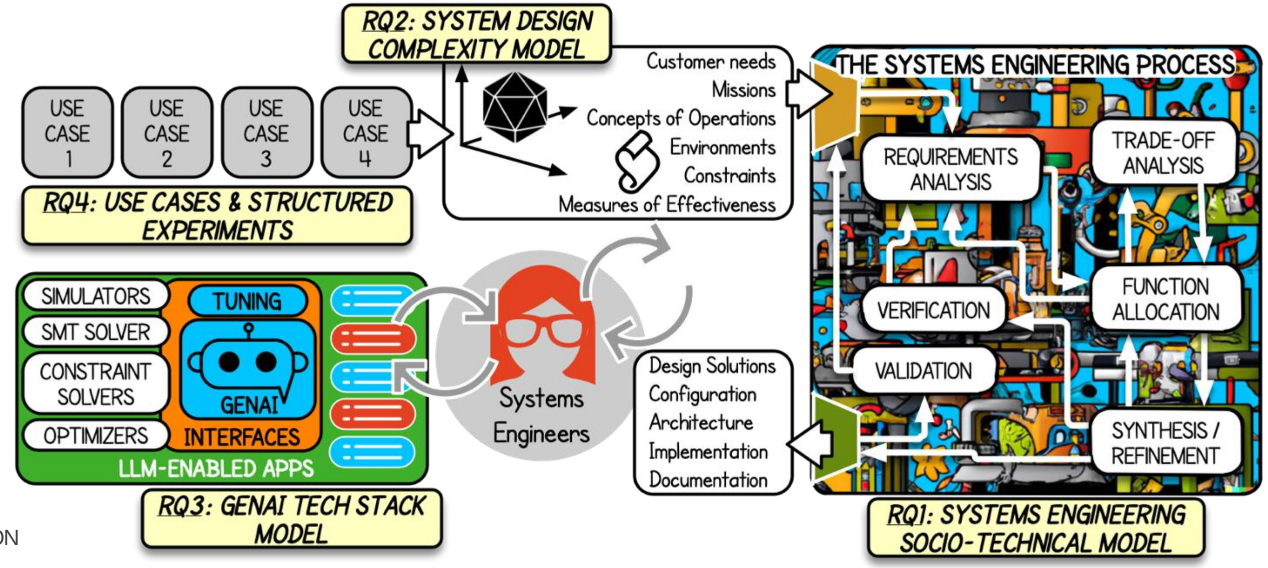
Hypothesis



Can we build useful capabilities for SE solely on pre-trained models?
Note: Usefulness does not imply validity or truthfulness

High-level Research Questions

- RQ1: If we want to introduce GenAI, how do we know what SE activities are most promising/suitable?
  - What does the sociotechnical Systems Engineering process look like today? We need to create a “map” of SE activities, tasks, and roles and where AI has the best chances to help.
- RQ2: How would we measure improvements?
  - Intuitively: feed system with and without AI the same task, define acceptance criteria for generated outputs
  - Prerequisite: Qualify/quantify SE tasks by their “size” and complexity. Define what is a “big” task and what is a “hard” task.
- RQ3: What are possible GenAI configurations?
  - When we say “Generative AI,” are we saying just GenAI solutions or possibly optimized prompt engineering, fine-tuning, combinations of GenAI with other forms of AI/ML, or other tools (simulation, verification, optimization, etc.)?
- RQ4: What experiments could demonstrate improvements empirically?
  - Formulate structured experiments and use cases



INCOSE's Competency Framework

Competency := observable, measurable set of skills, knowledge, abilities, behaviors, and other characteristics an individual needs to successfully perform work roles or occupational functions.

Integrating
- Project Management
- Finance
- Logistics
- Quality

Core
- Systems Thinking
- Lifecycles
- Capability Engineering
- General Engineering
- Critical Thinking
- Systems Modeling and Analysis

Professional
- Communications
- Ethics and Professionalism
- Technical Leadership
- Negotiation
- Team Dynamics
- Facilitation
- Emotional Intelligence
- Coaching and Mentoring

Management
- Planning
- Monitoring and Control
- Decision Management
- Concurrent Engineering
- Business and Enterprise Integration
- Acquisition and Supply
- Information Management
- Configuration management
- Risk and Opportunity Management

Technical
- Requirements Definition
- System Architecting
- Design for...
- Integration
- Interfaces
- Verification
- Validation
- Transition
- Operation and Support

To be truly useful, a GenAI assistant must possess the key competencies defined in the INCOSE framework for systems engineering

Example Competencies and Use Cases for Applying GenAI

Competency	INCOSE Definition	Exemplar Use Cases
Requirements Definition	To analyze the stakeholder needs and expectations to establish requirements for a system	• Extract candidate requirements from a Concept of Operations • Represent stakeholders • Extract tentative formal representations from natural language requirements
System Architecting	The definition of the system structure, interfaces and associated derived requirements to produce a solution that can be implemented	• Formulate many alternative structures and allocate requirements to components • Formalize informal architecture definitions
Design for…	Ensuring that the requirements of all lifecycle stages are addressed at the correct point in the system design	• Identify *ility tradeoffs • Formulate design and optimization problems
Interfaces	The identification, definition and control of interactions across system or system element boundaries	• Formulate potential contracts (vertical, horizontal) • Identify modularity, scalability, and interoperability issues

We have identified several potentially high-value use cases

Generative AI for Rapid SE

The Good

- Rapid content generation
- Data retrieval and analysis
- Converse in coherent and relevant natural language
- Write code
- Brainstorm “compelling” ideas

The Bad

- Fabrications
- Data bias
- Lack of explainability
- Lack of reasoning capabilities
- Lack of uncertainty expression
- Lack of consistent accuracy

The Need

- Trustworthy, verifiable, and interpretable capabilities that significantly improve the quality and speed of Systems Engineering practice

Can we boost GenAI’s utility and mitigate weaknesses?

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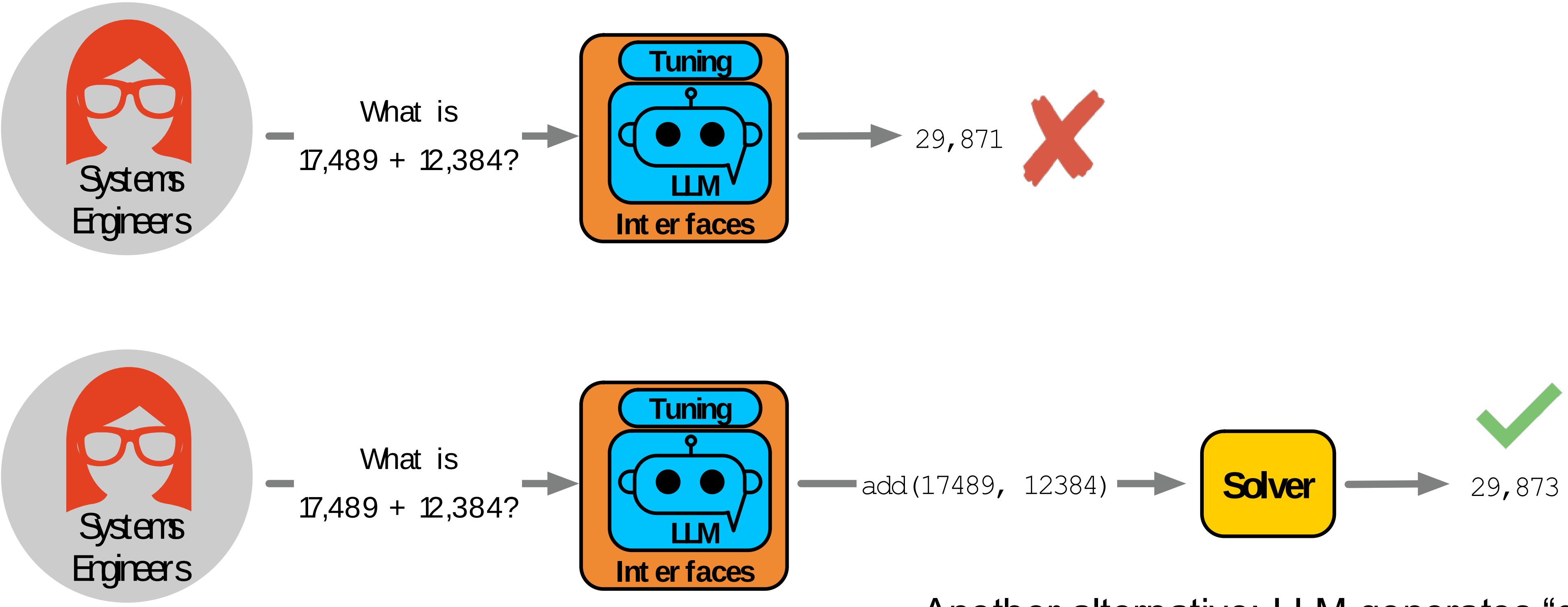
Basic Pattern

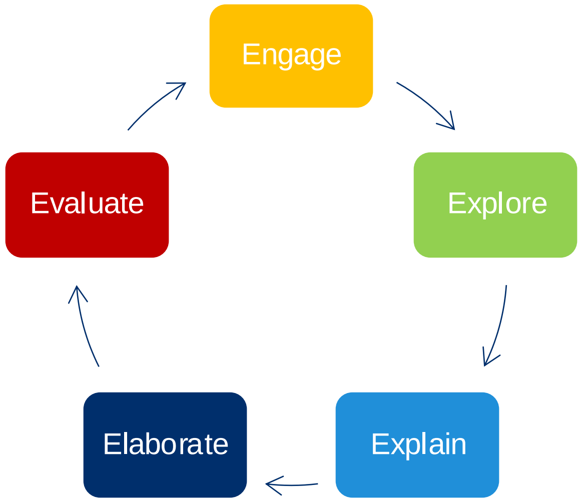


Another alternative: LLM generates “good guesses” that are sent to a checker/verifier

Outsource weaknesses of GenAI to trustworthy, verifiable and reliable tools/agents

Cognitive Agentic Systems Engineering

- LLMs do not negate the need for thoughtful, systematic, and iterative thinking, which is a core principal of systems engineers
- The usefulness of LLMs comes when integrated into a robust architecture that supports both cognitive and agentic thinking
- When we solve problems, we think of potential functional solutions and through research, reasoning, and iteration, arrive at good solutions
- We almost never solve complex systems engineering problems zero-shot off of our pre-trained memory. The majority of the time we are really iterating through the cognitive processes outlined in the 5E model [1].



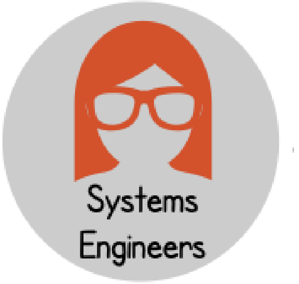
5E Model

Hypothesis: Can we transform “System 1” standalone GenAI models into “System 2” assistants using cognitive agentic methodologies?

[1] BSCS Science Learning. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness. BSCS.*

Cognitive Agentic Process for Existing Systems

Current System
- Digital Twins
- MBSE Artifacts



New Mission
- CONOPS
- Use Cases
- System Requirements & Constraints
- KPPs/TPMs

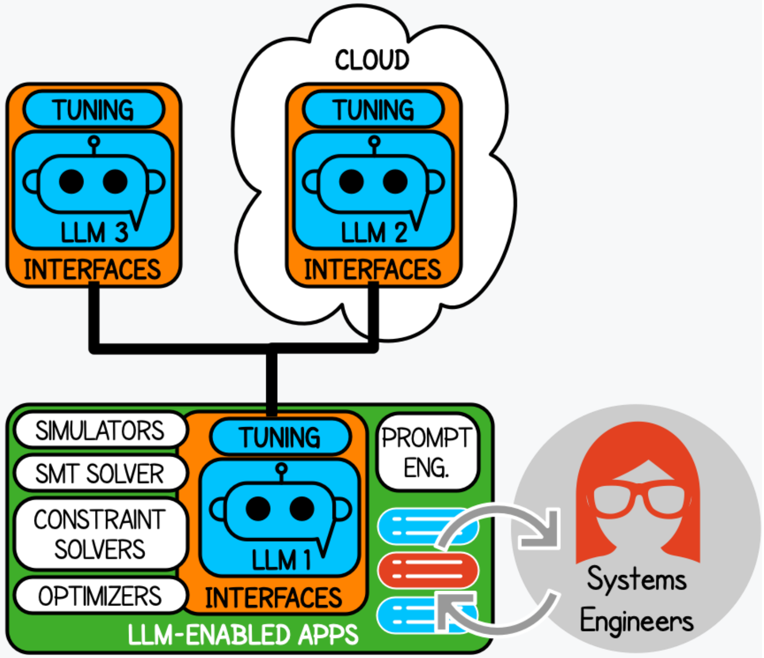
Cognitive Agentic Architecture
- Cognitive Orchestrator
- Thought…
- Thought…
- Thought…
- Concept Agent
- Development Agent
- Test Agent

<u>Trustworthy & Verifiable Tools</u>
Simulators (e.g., AFSIM), Planners (e.g., fast-downward over PDDL), Solvers (e.g., SMT, Constraint-based), Causal Models, etc.…

Output
- MBSE Artifacts
- Subsystem Impact
- Regression Testing
- Simulation Results

Conclusions

- AI4SE solutions must be trustworthy and verifiable
- Current standalone GenAI solutions lack these properties. Existing interfaces are “broken” and “deceptive”
- GenAI solutions seem promising when augmented with cognitive and agentic capabilities allowing them to ask questions, think over periods of time and reason over outputs from trustworthy and verifiable tools
- Defining metrics will be critical to ensure the AI is improving the quality and speed of the Systems Engineering practice in meaningful ways



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