International Council on Systems Engineering
A better world through a systems approach

Cost Impacts of Generative AI in Systems Engineering Processes

Ray Madachy, Barclay Brown, Ricardo Valerdi,
Gan Wang, Marilee Wheaton

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Panelists

Ray Madachy

Professor, Naval Postgraduate School

Barclay Brown

Senior Fellow for AI Research, Collins Aerospace

Ricardo Valerdi

Professor, University of Arizona

Gan Wang

Vice President of Systems Engineering Ecosystem, Dassault Systèmes

Marilee Wheaton

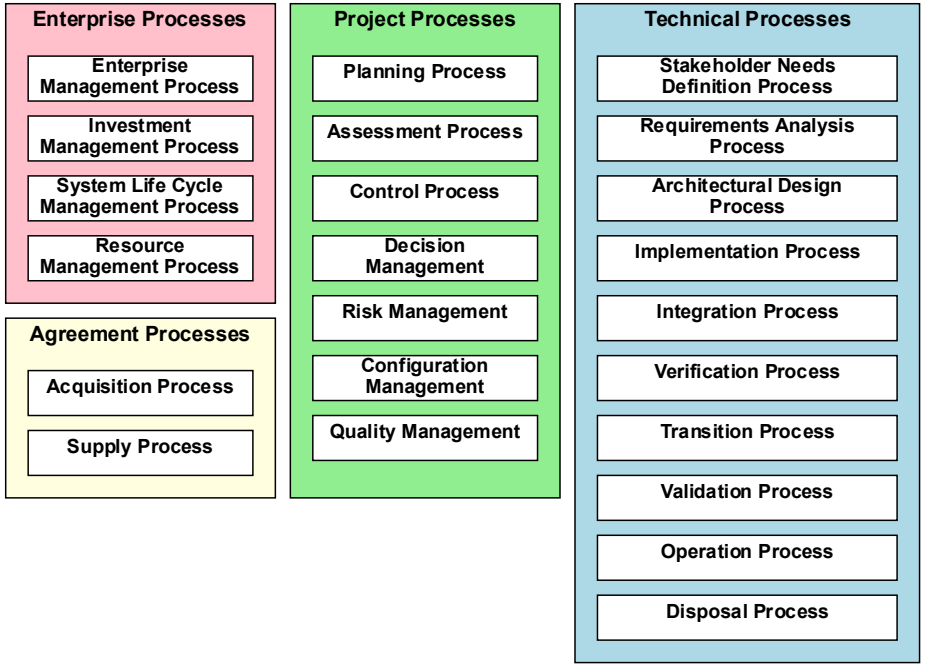
Systems Engineering Fellow, The Aerospace Corporation

Panel Context: Cost Impacts of Generative AI

- Disruptive transformation of systems engineering processes when using generative AI
- AI usage is introducing a major new source of cost variance
  - Empirical data indicates significant effort reductions
- Existing cost models insufficient for new SE processes
- Goal: better understand, model, and quantify AI-driven cost impacts
- Panel shares early research, practical approaches, open questions

Relevant Costs

- Labor cost of teams performing systems engineering processes.
- Cost of producing system requirements, system interfaces, critical algorithms, operational scenarios, and supporting artifacts.
- Process phases and activities aligned with the ISO/IEC/IEEE 15288 standard.



AI Usage Potential Cost Decreases

Activity	Benefits
Acquisition and Supply	Assist in drafting acquisition strategy, evaluating supplier proposal, and generating contract requirement traceability. Enable rapid review of past contract and risk clause.
Technical Management	Support planning by generating work breakdown structure, risk register, and configuration guideline. Monitor project data to alert deviation from performance target.
System Design	Recommend design pattern, generate architecture option summary, and propose interface concept. Generate models, and assist in trade analysis using prior design rationale.
Product Realization	Help create specification, checklist, and realization workflow. Monitor manufacturing readiness data or digital twin output for deviation.
Product Evaluation	Suggest test objective, derive evaluation plan, and summarize finding from past verification activity. Assist in validation scenario generation and mission alignment check.

AI Usage Potential Cost Increases

Activity	Downfalls
Acquisition and Supply	Relying on AI to evaluate supplier or contract artifact without expert review might overlook contextual risk or misinterpret requirement intent.
Technical Management	Overuse of AI for planning or risk identification might produce false confidence in completeness or cause oversight of emergent issue.
System Design	Accepting architecture suggestion without human vetting can lead to brittle or non-viable solution in complex or novel domain.
Product Realization	Using AI-generated specification or workflow blindly can introduce integration error or unverified assumption in production step.
Product Evaluation	AI-generated test or validation scenario might miss edge case or domain-specific constraint if not critically reviewed by engineer.

Investment Costs

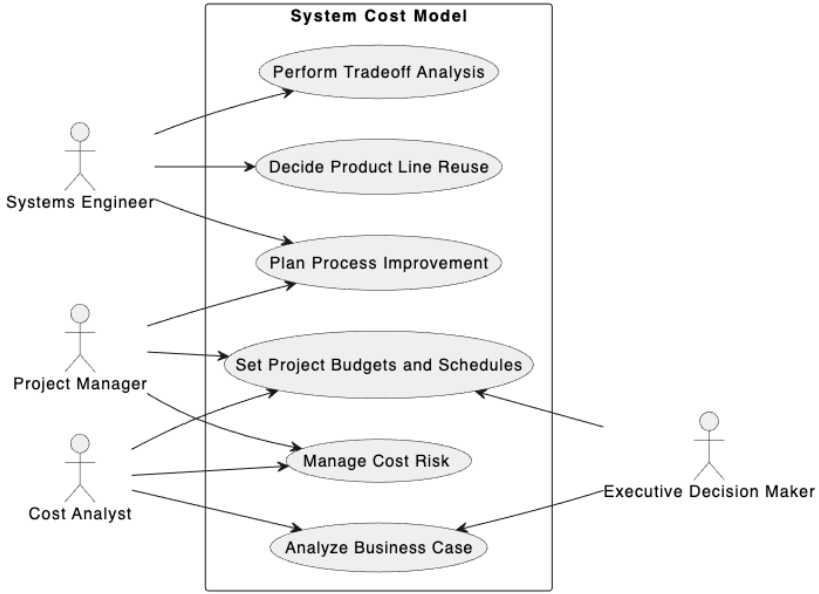
- **Hardware and Infrastructure** for technological resources required for AI adoption, ranging from basic infrastructure to highly scalable, robust systems.
- **Knowledge Integration and Data Management** supporting AI systems evolution from limited context awareness to fully indexed and dynamically managed knowledge bases.
- **LLM Customization and Fine-Tuning** for AI model customization, from using a generic model to extensive fine-tuning with specialized datasets.
- **LLM Retraining** for model updates, evolving from minimal retraining to real-time adaptive learning with Reinforcement Learning from Human Feedback (RLHF).
- **Personnel Training** is the progressive development of workforce competencies to improve AI-assisted engineering processes. Without adequate training, organizations risk misuse, over-reliance, or underutilization of AI tools, leading to inefficiencies or defective engineering outputs.

Open Research Questions

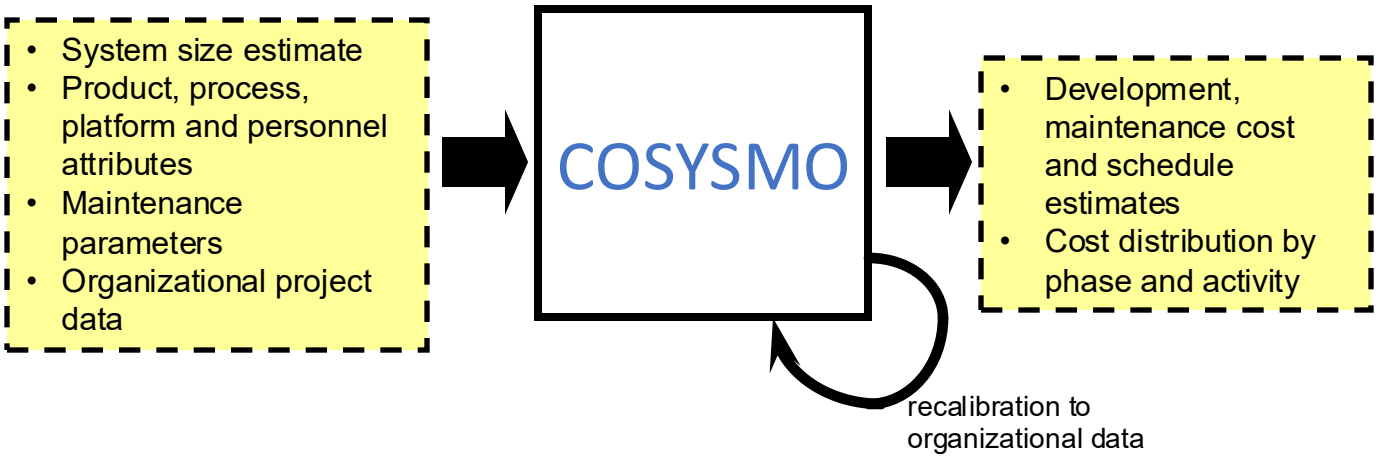
- When and where is AI assistance cost-effective in the SE lifecycle?
- How should updated cost models be structured and used?
- What skills and training are needed for effective AI adoption?
- What are the impacts of generative AI on product quality?
- How does AI-driven productivity scale from individuals to teams?

Cost Modeling

Typical Systems Engineering Cost Model Use Cases



COSYSMO Black Box Model



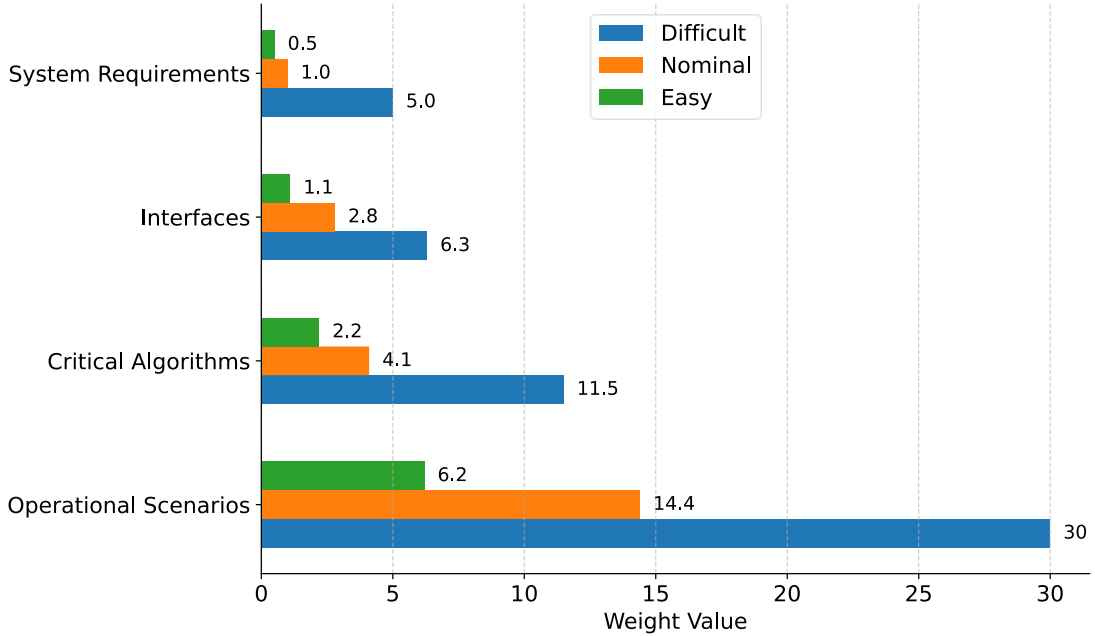
COSYSMO Effort Equation

$$Effort = A * Size^{B} * \prod_{i=1}^{N} EM_i$$

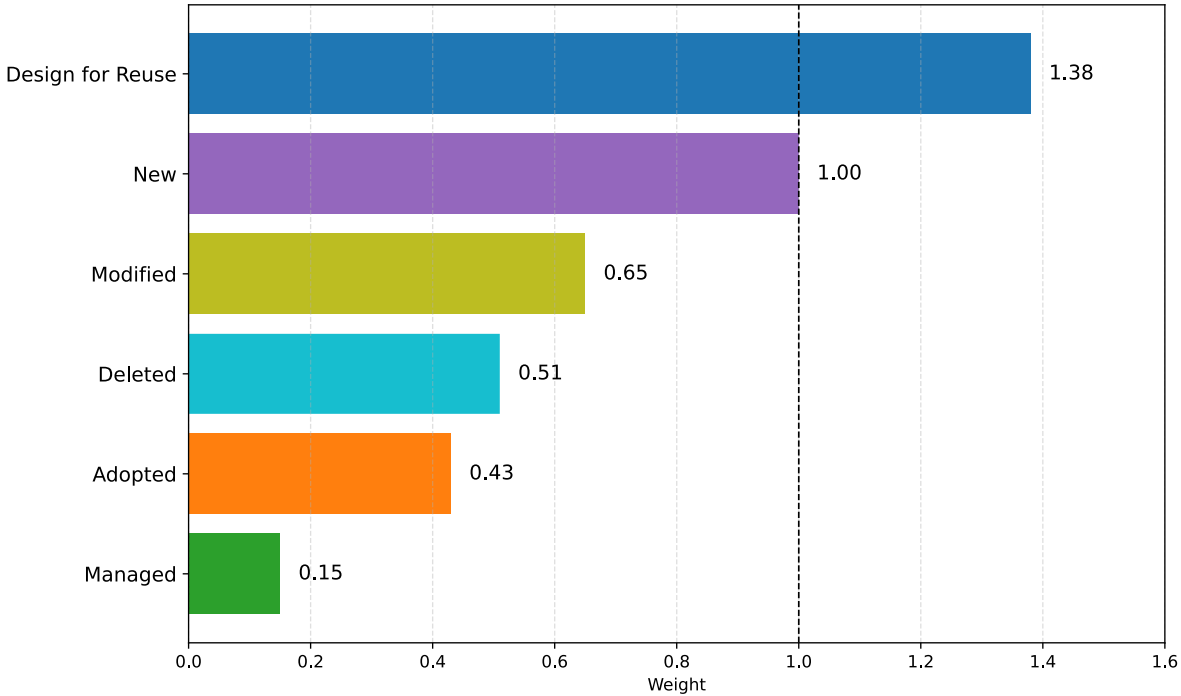
Where

- *Effort* is in Person-Months (PM)
- *A* is a constant derived from historical project data
- *Size* is a sum of weighted system requirements, interfaces, algorithms and scenarios
- *B* is an exponent for the diseconomy of scale
- EM_i is an effort multiplier for the i^{th} cost driver. The geometric product of *N* multipliers is an overall Effort Adjustment Factor (*EAF*) to the nominal effort.

Size Driver Weights



Size Driver Reuse Weights



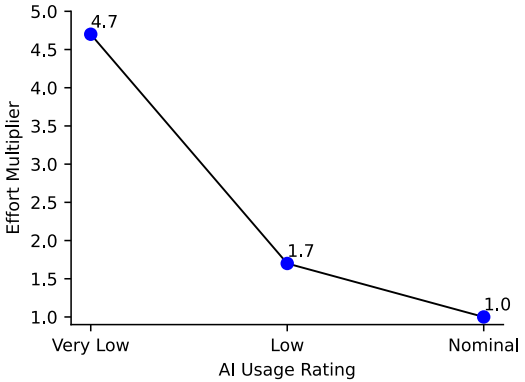
Cost Driver Rating Scales and Effort Multipliers

	Very Low	Low	Nominal	High	Very High	Extra High	EMR
Requirements Understanding	1.87	1.37	1.00	0.77	0.60		3.12
Architecture Understanding	1.64	1.28	1.00	0.81	0.65		2.52
Level of Service Requirements	0.62	0.79	1.00	1.36	1.85		2.98
Migration Complexity			1.00	1.25	1.55	1.93	1.93
Technology Risk	0.67	0.82	1.00	1.32	1.75		2.61
Documentation	0.78	0.88	1.00	1.13	1.28		1.64
# and diversity of installations/platforms			1.00	1.23	1.52	1.87	1.87
# of recursive levels in the design	0.76	0.87	1.00	1.21	1.47		1.93
Stakeholder team cohesion	1.50	1.22	1.00	0.81	0.65		2.31
Personnel/team capability	1.50	1.22	1.00	0.81	0.65		2.31
Personnel experience/continuity	1.48	1.22	1.00	0.82	0.67		2.21
Process capability	1.47	1.21	1.00	0.88	0.77	0.68	2.16
Multisite coordination	1.39	1.18	1.00	0.90	0.80	0.72	1.93
Tool support	1.39	1.18	1.00	0.85	0.72		1.93

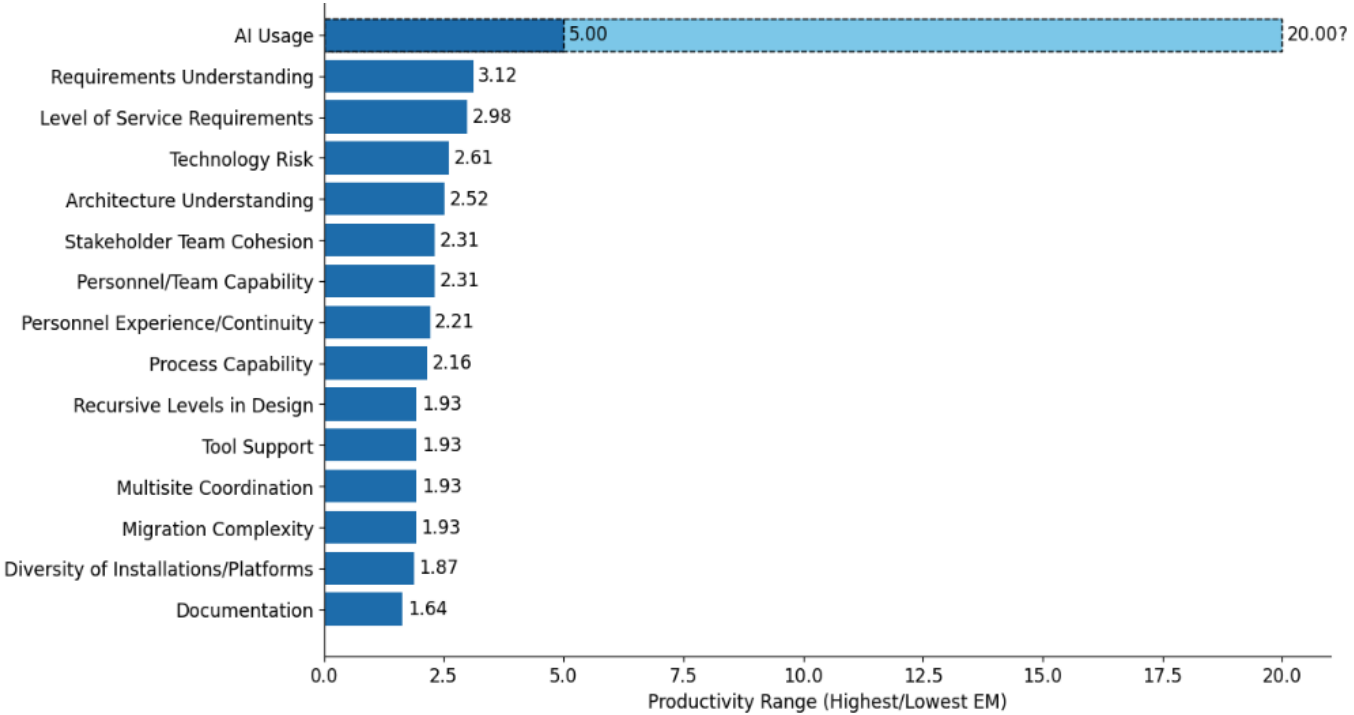
EMR = Effort Multiplier Ratio

AI Usage Project Cost Factor Ratings and Provisional Effort Multipliers

Very Low	Low	Nominal	High	Very High
Minimal to no AI assistance. Development relies on traditional methods and tools. AI tools may be present but are rarely, if ever, consulted.	Moderate AI usage, typically for summarization, basic information retrieval, and model templating. AI tools are not deeply integrated into the development workflow.	Regular use of AI tools for various tasks like MBSE help, design insights, or testing assistance. AI tools are a recognized part of the toolkit but aren't central to development	Frequent and strategic use of AI assistance. AI tools play a central role across the lifecycle from architecting, to design, implementation, and V&V.	AI tools are deeply ingrained in most activities. They are crucial for decision making, problem solving, and automating tasks. The development process is designed around maximizing AI tool benefits.



COSYSMO Cost Driver Productivity Ranges



Example Investment Analysis

- A systems engineering organization is currently at maturity Level 2 (Developing) and wants to advance to Level 3 (Competent). They develop 1500 Equivalent Nominal System Requirements per year on projects at $20,000/Person-Month.
- It is desired to estimate the annual cost savings after AI adoption and break-even point when the investment will pay for itself.
- Investment costs to achieve Level 3 per maturity level practices:

Expense	Cost
All systems engineers take generative AI training	$300K
High performance computers purchased for LLM training	$150K
LLM team will retrain organizational models	$180K
Total Investment	$630K

- After adoption, their project practices will improve from the AI Usage rating from Low to Nominal.
- When is the break-even point?

Investment Analysis Results

- **As-Is (*AI Usage* = Low)**
  $Effort = A * Size^B * EAF$ = .054 * $1500^{1.06}$ * 1.7 = 213.6 PM
  Annual Cost = $20,000/PM * 213.6 PM = $4.27M

- **To-Be (*AI Usage* = Nominal)**
  $Effort = A * Size^B * EAF$ = .054 * $1500^{1.06}$ * 1.0 = 125.6 PM
  Annual Cost = $20,000/PM * 125.6 PM = $2.51M

- From the above, the annual savings and break-even point can be calculated:

  Annual Savings = $4.27M - $2.51M = $1.76M
  Break Even = Investment / Annual Savings = $.63M / $1.76M = .36 years

- The investment will pay for itself in slightly over 4 months of adoption on systems engineering projects.
- Thus, it would be a worthwhile investment, and the ROI would be a substantial multiplier after a few years.

Barclay Brown Position

You can also use this for a title slide.

Generative AI for systems engineering

Requirements Engineering

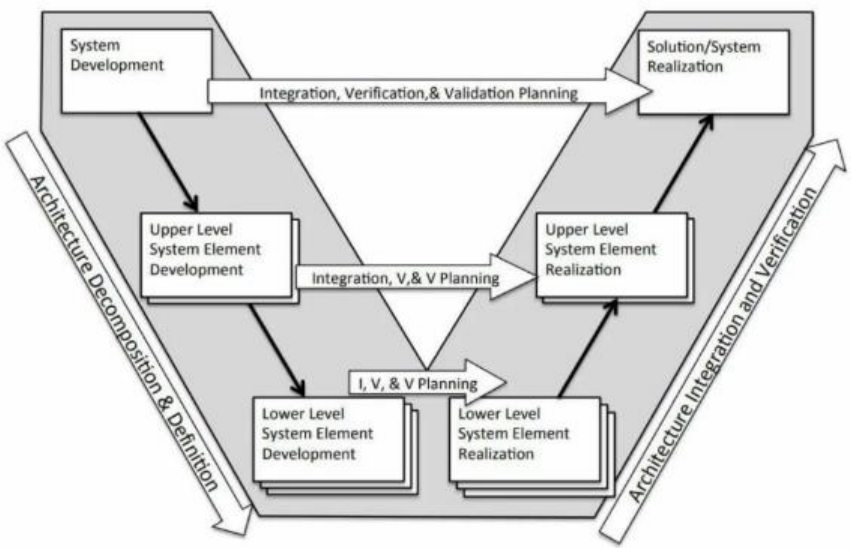
- Analyzing natural language requirements documents to identify inconsistencies, ambiguities, and missing information
- Generate different levels of specs and requirements to ensure to complete traceability

System Design and Modeling

- LLMs can help automatically generate system architecture diagrams and models based on textual descriptions.
- Identify potential design flaws and suggest improvements by analyzing existing designs and simulations.

Documentation Generation

- Create system documentation like presentations, user manuals, test plans, and interface control documents from existing data.
- Summarize complex technical information into concise reports.



Testing and Verification

- Generate test cases based on system requirements and models.
- Analyze large datasets from testing to identify patterns and potential issues

Knowledge Mgmt and Training

- Answer engineers' questions about systems, standards, and best practices by accessing and processing stored technical information
- Generate training materials based on other system documentation

Generative AI Applications using LLMs throughout the systems lifecycle

AI as a Team Member

Metaphor: Police Dog Handler

- Police Dogs:
  - Basic training typically spans 4 to 6 months.
- Handlers:
  - Handler courses generally last from 2 to 4 weeks, focusing on effective communication and operational techniques with their canine partners. Tactical Police K9 Training
- Metaphor
  - Gen AI has special skills
  - Experienced handler can get the most out of the special skills
- New paradigm: AI and handler join an engineering team with real work to do

Detection: Identify narcotics, explosives, firearms, and other contraband.
Tracking: Locate suspects or missing persons using scent trails.
Apprehension: Assist in detaining fleeing or aggressive suspects.
Search and Rescue: Find individuals in natural disasters or accident scenarios.
Evidence Recovery: Locate items at crime scenes, such as weapons or personal belongings.

Eventually we will all be handlers at some level, but there will always be expert handlers too

What makes us human?

What makes us human, sentient, beings?

Mental States

- Interest, desire, ambition, understanding, willingness
- All emotions
- Intention – the uber mental state

LLMs have none of this, and no capacity for them, though they can TALK like they do.

So what's a conversational AI? Maybe:

It's life, Jim, but not as we know it

A new kind of being:

- Neither human nor sentient
- No soul; no goals
- Vast knowledge and information
- Creativity of a sort
- Little (or no) judgment
- Great speed
- "Eager" to please
- Happy to re-do things many times

The BIG Paradox: 1

Creating the perfect assistant…

What would you include?

Would you make it sentient
(with rights, goals, desires, independent thoughts)

What should it know?

How should it behave?

The BIG Paradox: 2

Treating AIs like beings is the most productive way to relate to them

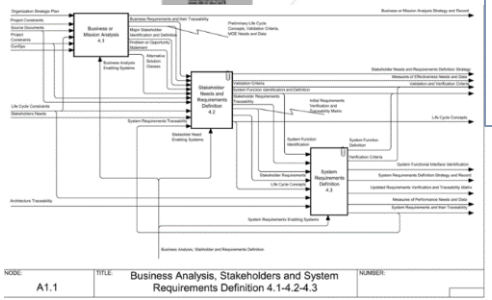
- They know all about human behavior so they respond better when addressed in that same way
- Have them act in any way that serves you
- They learned from humans so don't expect some kind of super-human wisdom

Systems Engineering: Managing Information

- "According to a McKinsey report, employees spend 1.8 hours every day—9.3 hours per week, on average—searching and gathering information. Put another way, businesses hire 5 employees but only 4 show up to work; the fifth is off searching for answers, but not contributing any value." Source: Time Searching for Information.

Employees spend more than 25% of their time searching for the information they need to do their jobs: Survey

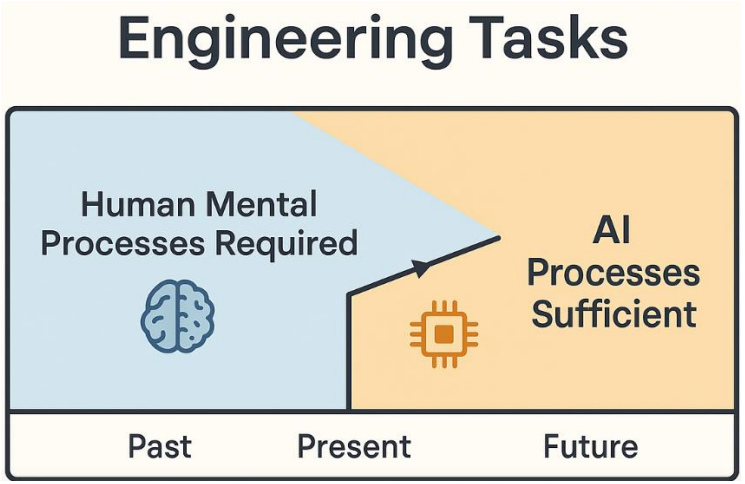
- IDC data shows that "the knowledge worker spends about 2.5 hours per day, or roughly 30% of the workday, searching for information….60% [of company executives] felt that time constraints and lack of understanding of how to find information were preventing their employees from finding the information they needed." Source: Information: The Lifeblood of the Enterprise.



Systems engineering floats on a sea of text and model-based information

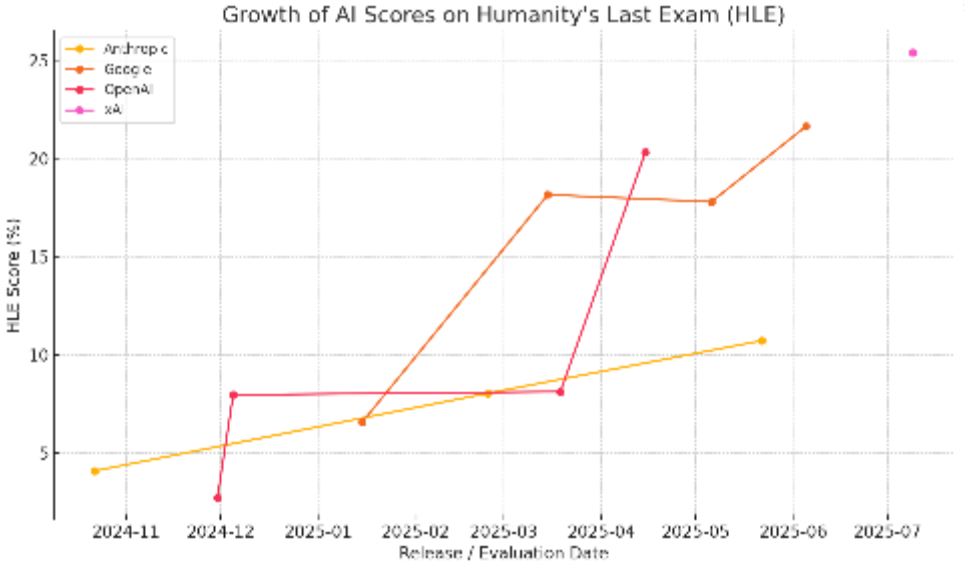
Impact on Decision Making

- AI can assist with rearranging, summarizing, correlating information
- Tracing, deriving artifacts well-supported by generative AI
- System-level decisions still primarily human-driven
- AI serves as an augmentation tool rather than full replacement for human decision making
- Effective use depends on understanding AI limitations and strengths, and its constantly growin abilities



Paradigm Shift Analogy

- Early spreadsheets underestimated—now ubiquitous
- Similar broad applicability expected for generative AI
- Impossible to list all potential SE use cases
- Human creativity + AI capability leads to new workflows
- Encourages more efficient and higher quality SE practices



GPT-o3 Prompt: *Find actual true data on the growth of AI scores on HLE and plot with separate lines for models by OpenAI, Anthropic Claude, Google Gemini, and XAI Grok*

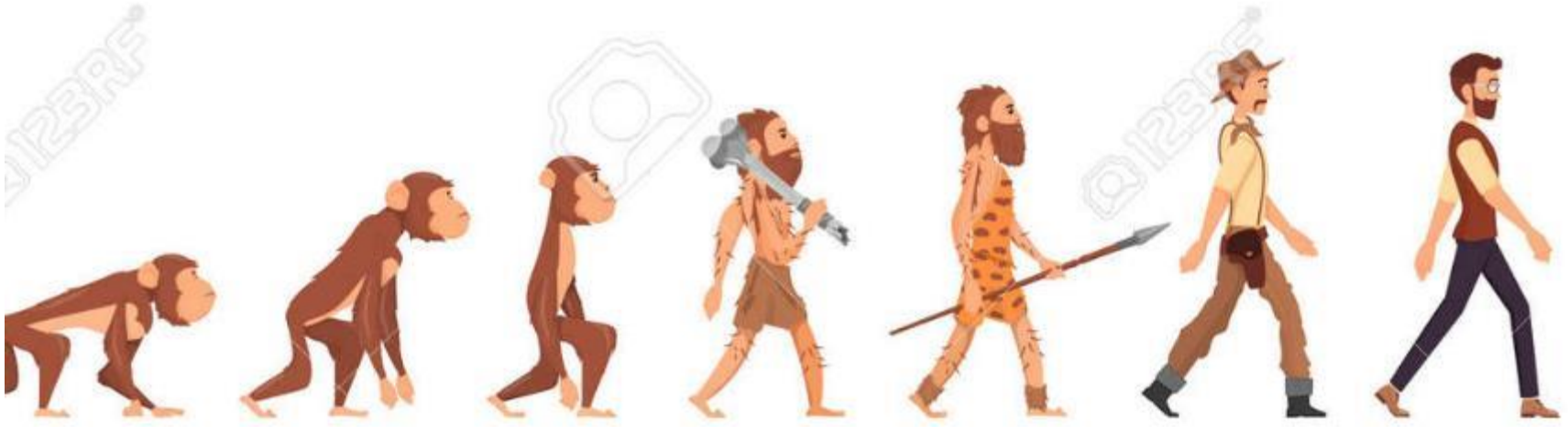
Thought for 6m 26s >

#	Category (≈ 10 buckets)	Count
1	Official developer / release notes	16
2	Tech blogs & commentary (Medium/Substack, independent dev blogs)	19
3	Community forums	11
4	Benchmark leaderboards & evaluation portals	8
5	Mainstream & tech news outlets	9
6	Industry analysis / consulting sites	9
7	Product docs & console pages	4
8	Academic journals & pre-prints	4
9	Social-media posts (short-form)	4
10	Video platforms / recorded demos	5

Ricardo Valerdi Position

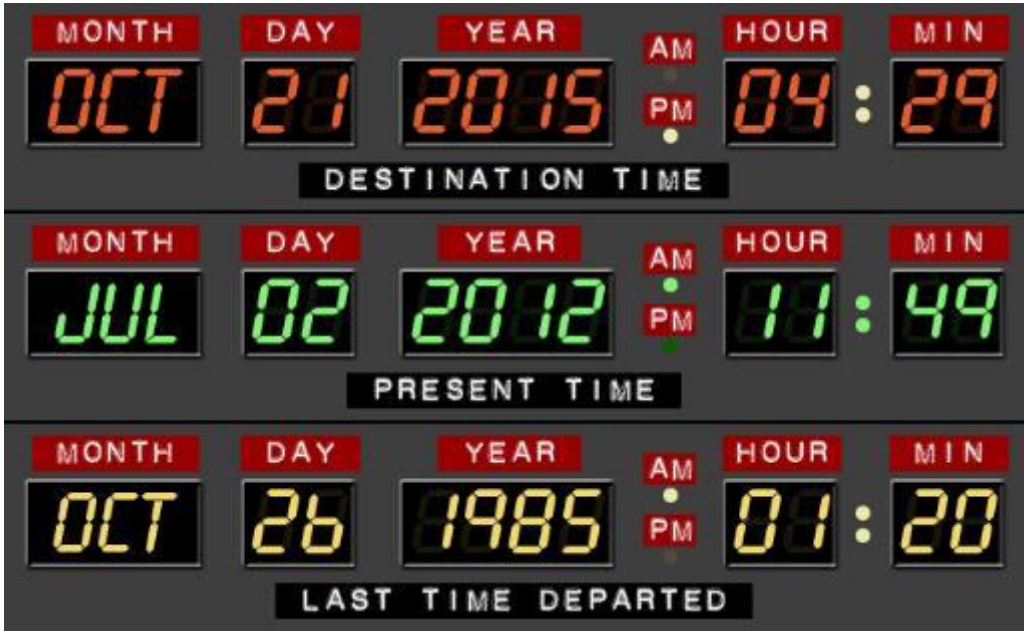
You can also use this for a title slide.

COSYSMO Model Evolution



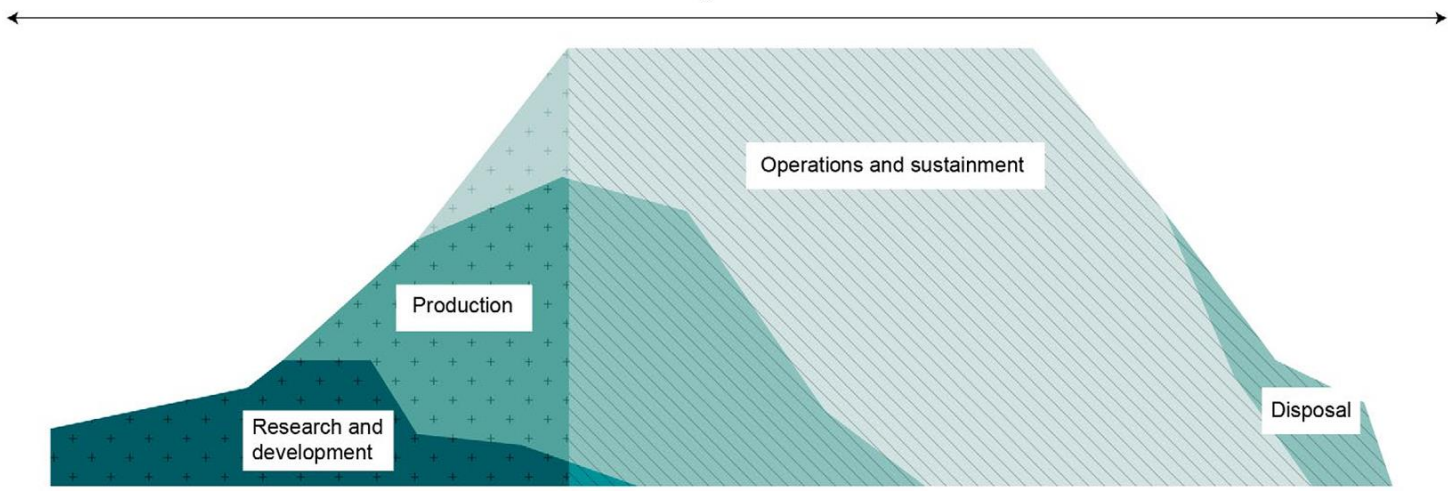
2005 (v1)	2010 (agile)	2015 (reuse)	2020 (MBSE)	2025 (AI)	2030	2035	2040

Can AI Help Look Into the Future?



Beyond Development Costs

Figure 2: Notional Life Cycle Cost Profile for an MDA-Developed System



Source: GAO analysis of Department of Defense and Missile Defense Agency (MDA) data. | GAO-22-104344

Updated COSYSMO Tool

Constructive Systems Engineering Cost Model (COSYSMO)

System Size

	Easy	Nominal	Difficult
System Requirements	11	23	3
System Interfaces	2	6	5
Critical Algorithms	5	5	2
Operational_Scenarios	3	4	2

Cost Factors

Requirements Understanding	High	Documentation	Nominal	AI Usage	High
Architecture Understanding	Low	Diversity of Installations/Platforms	Nominal	Personnel Experience/Continuity	Nominal
Level of Service Requirements	Nominal	Recursive Levels in Design	Nominal	Process Capability	Nominal
Migration Complexity	Very High	Stakeholder Team Cohesion	High	Multisite Coordination	Nominal
Technology Risk	Nominal	Personnel/Team Capability	Nominal	Tool Support	Nominal

Labor Rate

Cost per Person-Month (Dollars) 20000

Calculate

COSYSMO with AI

- COSYSMO with AI: https://softwarecost.org/tools/COSYSMO_AI/ (or lowercase)
- Basic COSYSMO: https://softwarecost.org/tools/COSYSMO/
- System cost model suite with COSYSMO, COCOMO (software engineering), and hardware production: https://softwarecost.org/tools/cost_model_suite/

Gan Wang Position

What is the AI coefficient?

Generative AI as a Game Changer

Two-Pronged Impact:

- Cost estimating and analysis is rooted in **statistical inferences** of historical **data**
  - GenAI / LLM offers unparalleled capacity for data analysis and pattern recognition
  - Potentials for more data, longer and wider history, more parameters, greater depth and finer grain
  - Ability to tackle greater complexity, effective learning, and incremental improvements
  - (Potentially) faster and better – overcoming lengthy, tedious, labor-intensive data collection and analysis

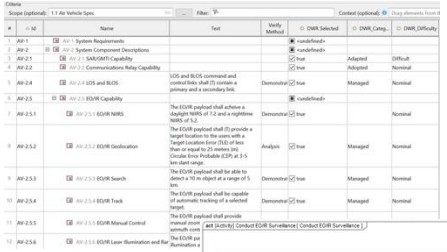
- Cost estimating and analysis is about **productivity**
  - Use of GenAI fundamentally changes productivity in system development life cycle
  - Existing cost models **no longer valid**!
  - **New parameters** must be considered and **cost models** developed

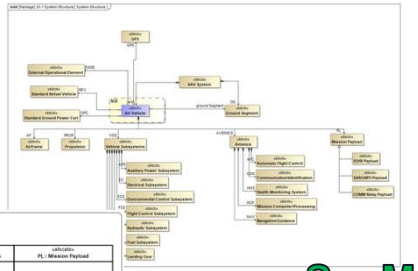
What is the AI coefficient?

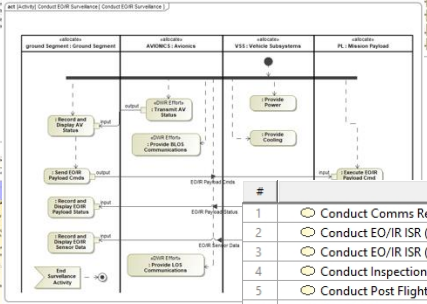
Cost Models: What is the AI coefficient?

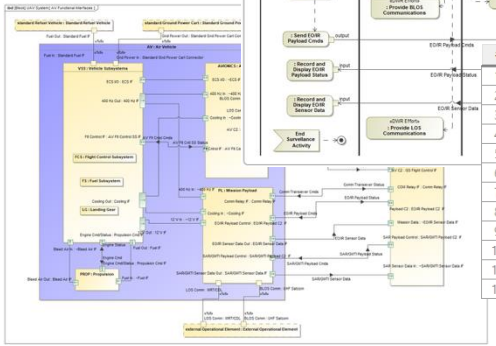
- What's the new cost estimating relationship?
  - Accounting for AI impacts
- New size and cost drivers?
  - Modified?
- More – and new – data, with greater granularity?
- New approach to estimating?

Latest Advancement: MBSE Integration









#	Name
1	Conduct Comms Relay
2	Conduct EO/IR ISR (Land)
3	Conduct EO/IR ISR (Maritime)
4	Conduct Inspection and ID of Target
5	Conduct Post Flight
6	Conduct Pre-Flight
7	Conduct SAR/GMTI ISR (Land)
8	Conduct SAR/GMTI ISR (Maritime)
9	Perform AOG Recovery
10	Perform Automated Launch, Flight and Recovery
11	Perform Manual Launch, Flight and Recovery
12	Transport, Assemble and Disassemble

SysML with Advanced Modeling Tools

COSYSMO

Parametric Cost Estimating

Wide Adoption of MBSE

Organizational Considerations

- Change are inevitable, challenges are numerous…
  - AI expertise, knowledge, and knowhow
  - AI-based CER
  - Data collection in the mist of productivity change
  - Security, and IP management

- How do we influence it?
  - The methods and processes
  - Culture and workforce mindset

Marilee Wheaton Position

You can also use this for a title slide.

Holistic View of AI in SE

- AI impacts go beyond technology alone
- Must consider full lifecycle SE integration
- AI seen as augmentation, not replacement
- Augmented Intelligence (AugI) perspective key
- Human-AI collaboration leads to better outcomes

AI-Augmented SE Practices

- Teams human strengths with AI capabilities
- Addresses limitations of both humans and AI
- Enhances productivity, creativity, and quality
- Requires process, infrastructure, and cultural alignment
- Focus on synergistic human-AI teaming

Implications for Cost Modeling

- Need to capture AI impacts in current cost models
- Consider AI influence across lifecycle phases
- AugI requires new metrics and modeling approaches
- Dynamic collaboration impacts cost estimation
- Continuous update of models essential

Future Directions

- Promote empirical data collection for AI impact
- Encourage cross-disciplinary collaboration
- Develop standards for AugI in SE
- Educate SE community on best practices
- Align cost modeling with evolving AI capabilities

Audience Questions